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Construction and Building Research

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Foreword

The 2nd International Conference on Construction and Building Research, held at the Polytechnic University of Valencia's Advanced School of Construction Engineering in November 2012, was set up under the auspices of the Conference of Directors of Building Surveying and Construction Engineering Schools as a tool for exchanging innovative scientific information and technology transfer.

Numerous areas of knowledge converge in the construction industry, necessitating the combination of numerous scientific and technological variables and a multidisciplinary approach to research in the field, and so a very broad perspective is required to establish ongoing relationships between contributions from different areas.

It is tremendously difficult to find any master formula for bringing different studies together and it can only be done in a context of collaboration and multidisciplinary enrichment.

Therefore, in order to publish and disseminate the results, the Organising and Editorial Committee for the 2nd International Conference on Construction and Building Research felt it was extremely important to select some of the studies presented that examine issues in materials and building systems; construction technology; energy and sustainability; construction management; heritage, refurbishment and conservation.

The appeal of this publication lies in the fact that it groups together, from an interdisciplinary perspective, various studies that generate knowledge, promote technological development and are committed to innovation which is fundamental for the industry's future.

I hope that this publication will prove highly useful for construction professionals, researchers, innovators and in short, for people interested in deeper exploration of issues in the complex world of building and construction.

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Director
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Contents

Part I
Building Construction Management

Carmen Llinares-Millán

Abstract The construction industry is currently undergoing a process of change to adapt to the new market situation. In this scenario of change, management processes must be improved to boost competitiveness. This present chapter examines studies on these processes from a variety of perspectives.

From a strategic approach, the chapter identifies success factors for architectural practices and differences between project management systems.

From a process-centred approach, it looks at management models able to improve quality, reduce production times and minimise costs with examples of their application to building processes, ceramic coatings construction and C&D waste.

Finally, the chapter presents a person-centred approach, with examples of studies focusing on the worker, job promotion systems, experiences in architects' careers and the qualities a project coach should have. Users are also analysed in order to integrate their needs in the design process.

Stop Designing Architecture, Design Your Practice!

J. Lago-Novás

Abstract Contemporary practice has proven that design quality is not sufficient for success. Throughout architecture's history, there has existed the naive perception that best designs came from artists whose practice remained untouched by the imperatives of business. Most architects are entrepreneurs and designers who face business responsibilities without the right training. Architects must learn how to analyze business ideas, identify opportunities and consider marketing strategies at different stages of the design process.

But architects have all been taught similarly; this is design based, with very little or non-existent business education. When architects start their practice, they start straight away designing architecture without being aware that what they are starting is a business and therefore their first design should be their own practice. Getting management skills will help them not only to manage their businesses by understanding all stakeholders, but will help architects to learn how to earn opportunities to design.

The results shown in this article, proves through a ranking system, that a successful practice is well balanced among design excellence and business management awareness.

Keywords Management • Practice • Success • Architecture • Business

1 Introduction

Most architects start their practices by winning a competition or a commission straight away and without a business plan. This situation makes that 80% of these practices close during the first 12 months. There is no other industry where the owner of the business starts it without having a business plan, without designing the business [1]. But there are various examples of successful practices that have proven that designing the practice as well as designing architecture is a successful business model without compromising any of both sides of the balance.

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There are measurable indicators of success that help to identify successful examples so that we can then analyse what these practices have in common so that we can define a design business model which is successful both for designing architecture and for designing the management processes of the practice.

1.1 Definition of success

In order to understand the analysis and classification of the data and ultimately understand the obtained conclusions, it is absolutely necessary to define what **success** in architectural practice means in this article: those practices that are able to generate and identify opportunities consistently to design architecture.

Without clients there is **no architecture**, and without excellent architectural design there is no possibility to attract the appropriate **clients**. Therefore, both are two faces of the same coin, both with the same importance; it's a true balance between talent and management.

1.2 Existing environment

The environment where architects operate has changed and we need to answer the challenges of this new environment in order to be successful. Change brings opportunities, and the practices that adapt best, will be the ones with more chances to be successful.

In the current economic environment, where the destruction of architecture companies are double of the ones in any other industry [2], is important to underline that there are architecture practices than not only are not going bankrupt, but they are even growing. They are growing thanks to the design of business and organizational models that have allowed them to grow in a sustainable way and be flexible enough to adapt to the changing and difficult scenario. Most of these practices are Anglo-Saxon, in particular, practices from the US, where design management processes where implemented years ago due to the fact that most of these practices started at the same time as the industrial revolution, and therefore they adopted those industrial production processes into the management processes of the architectural practice.

The lack of management education in the architecture schools makes it very difficult for architects to understand that success in architectural practice is a perfect balance between talent and professionalism, and sometimes one or other part of the balance is misunderstood and underestimated depending whom you speak with. These underestimations even make people to think that architects with lots of commissions compromise their architectonic quality or that architecture *artists* will inevitably go bankrupt due to their lack of business management awareness.

This lack of alignment between architectural quality and business management [3] makes that architectural practices with an amazing talent have to close due to economic circumstances; and practices with great amount of commissions, due to the lack of talent, create uninteresting architecture objects.

2 Indicators of Success

There are various indicators that determine the success of an architectural practice. It's important to remember that these indicators are according to the definition of success mentioned at the beginning of this work. Therefore these indicators value: public recognition, recognition within the architecture sector, financial results [4] and operational results, all at the same level and with the same weight.

The indicators are divided in three families according to the following description and named with R and a number that you can then trace in Table 1:

- **A: R&D:** These indicators examine the design quality, innovation and the admiration inside and outside of the architecture industry. The indicators are:
  - Most admired to work in. (R1).
  - Most admired inside the sector. (R2).
  - Most admired outside the sector.(R3).
  - Most innovative. (R4).

These results come from a poll that was made among 200 people over the web, during January and February 2012. 100 were architecture professionals and 100 were "outsiders".

- **B: Marketing and Communication:** These are selected according to the implementation and success of their communication [5] and design strategies within their business and design plans translated into measureable figures. The indicators are:
  - Number of search results in Google. (R5).
  - Number of visits into their corporate web page. (R6).
  - Ranking at the Google PageRank. (R7).
  - Number of followers in facebook. (R8).
  - Number of followers in LinkedIn. (R9).
  - Number of followers in Twitter. (R10).
  - Number of videos in YouTube. (R11).
  - Number of prints on and off-line. (R12).
  - Number of awards. (R13).
- **C: Finance and HR.:** These describe financial, operational and human resources aspects. The indicators are:
  - Number of built projects. (R14).
  - Number of employees. (R15)
  - Number of non-architects employees (diversity). (R16).
  - Number of countries where they work. (R17).

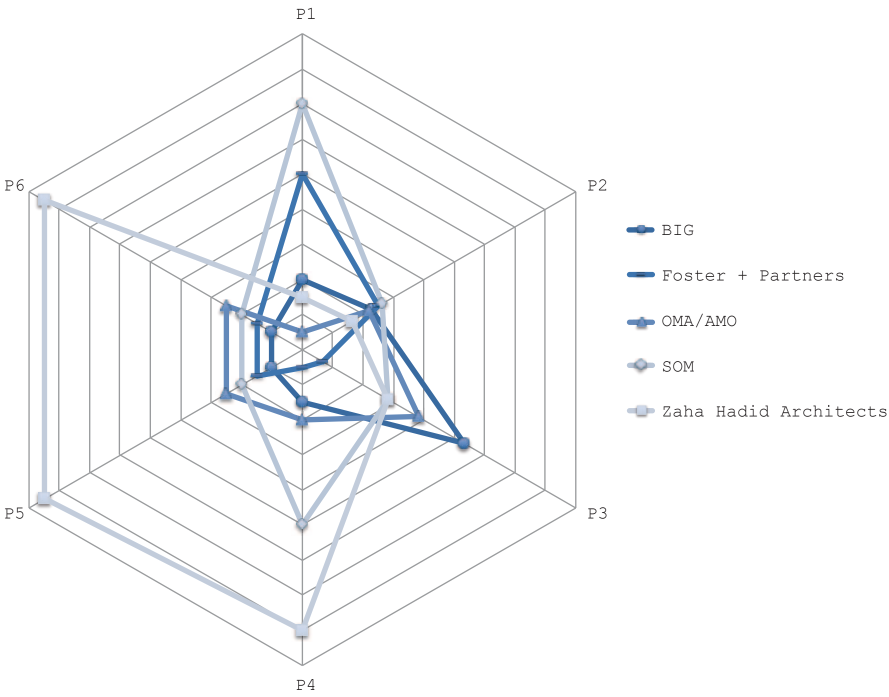

Fig. 1 Profiles according to indicators R1–R19

– Turnover. (R18).
– Profitability per employee: turnover/ number of employees. (R19).

Figure 1 shows the profile of five architecture practices according to the indicators mentioned above and divided according to: P1. Creativity. P2. Client focused. P3. Professionalism. P4. Collaborative. P5. Economically efficient. P6. Global

In Table 1 you can see the individual and global rankings of twenty top international practices according to the indicators of success described previously. R1 to R19 show each individual ranking from 1 to 20 among the offices that are shown in the first column. i. e. Aedas is ranked number 2 in R5, which is "Number of search results in Google". The last column "Ranking" represents the final ranking as an average of all other 19 rankings.

3 Conclusions

To be successful, practices have to be equally admired by their clients and within the sector. To manage to obtain this admiration, only practices that have designed their practices as well as their architecture manage to obtain both admirations. Like this,

Table 1 Individual and global rankings

	Estudio	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	Ranking
1	3DReid	20	20	20	12	18	19	18	18	13	13	18	18	12	17	14	13	20	9	9	20
2	ACXT	20	20	20	18	11	17	18	8	2	11	9	10	20	10	15	8	3	7	8	11
3	Aedas	20	20	20	15	2	11	1	6	3	6	3	17	15	15	1	1	2	3	16	7
4	Allies & Morrison	20	20	20	7	17	18	12	19	11	10	19	20	14	8	8	9	19	11	15	18
5	AS—Architecture Studio	20	20	20	9	19	9	12	20	20	20	20	15	18	20	11	14	7	11	11	19
6	BIG	4	8	11	4	6	6	1	3	8	1	7	3	11	13	7	18	18	9	2	5
7	Broadway Malyan	20	20	20	17	14	16	12	16	9	8	8	16	18	9	12	10	17	8	7	16
8	David Chipperfield Architects	1	6	20	6	12	13	1	4	12	20	15	7	7	5	5	16	9	11	10	8
9	Foster + Partners	10	1	1	10	4	5	1	13	4	2	6	1	1	2	6	3	4	1	3	1
10	Herzog & de Meuron	2	2	4	2	15	8	18	1	16	20	1	6	5	12	10	5	12	11	18	6
11	Jean Nouvel Ateliers	7	20	3	16	16	7	1	12	14	20	16	13	8	19	19	17	10	19	19	15
12	OMA/AMO	6	7	12	1	3	2	1	2	6	3	14	4	2	4	8	6	5	6	5	3
13	Populous Architects	20	20	20	19	20	20	1	15	10	5	17	18	15	7	3	15	6	5	1	12
14	Renzo Piano Building Workshop	8	4	20	13	10	4	1	14	20	9	10	14	6	18	20	12	14	20	20	13
15	RMJM	20	20	20	20	7	14	12	17	7	20	11	11	17	14	4	4	13	4	6	14
16	Rogers, Stirk & Harbour & Partners	11	5	10	8	13	10	12	9	15	12	13	12	9	3	17	11	15	11	14	9
17	Sauerbruch Hutton	20	20	20	11	9	12	12	11	20	20	12	8	10	11	13	20	16	18	13	17
18	Snohetta	5	20	20	5	8	15	1	10	17	7	5	9	12	16	16	18	10	17	12	10
19	SOM	9	3	13	14	5	3	1	5	1	20	2	2	4	1	2	2	1	2	4	2
20	Zaha Hadid Architects	3	9	2	3	1	1	1	7	5	4	4	5	3	6	18	7	8	16	17	4

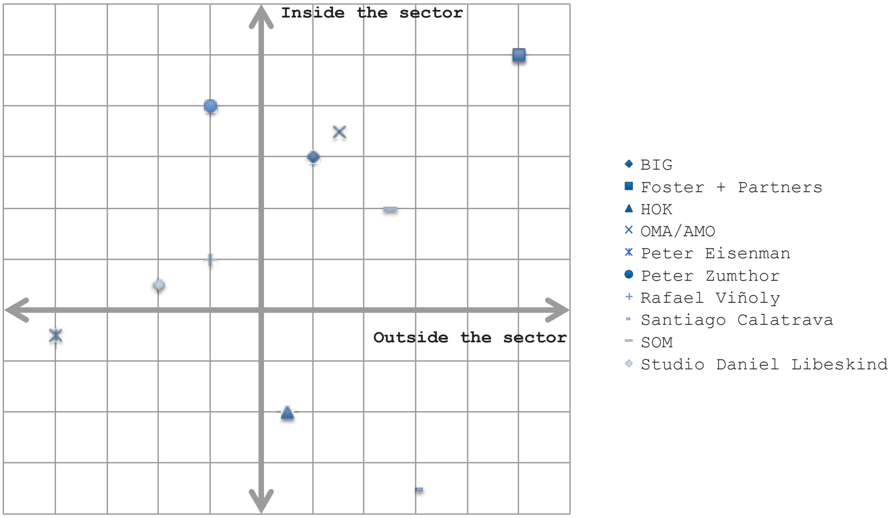

Fig. 2 Positioning-Admiration inside/outside sector

we can finally get, as you can see in Fig. 2, four different areas according to their profiles and how these practices consider as priority designing their practices as well as their architecture.

- **Top right quadrant:** admired inside and outside the architecture industry: most successful practices.
- **Bottom right quadrant:** admired outside the sector, has the risk to become unconsciously in a corporate architecture office, compromising their architectural quality.
- **Top left quadrant:** Admired mostly inside the sector, is a kind of profile that tends to disappear due to the fact that their peers are not their clients, and without clients is not a feasible company.
- **Bottom left quadrant:** not considered either inside or outside the sector: mediocrity or lack of adaptation will make them disappear.

To be successful and survive in such demanding environment, architectural practices have to be creative, client focused, professionals, collaborative, economically efficient and global [6].

Identifying and giving response to these new opportunities that arise, practices that have designed their practices have better chances to be able to do so than those just considering design as a word remained for *artists*.

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Strategies to Reduce Defects in Floor and Wall Tiles; Application of Continuous Improvement Processes

P. Del Solar and M. Del Río

Abstract Continuous improvement is a key element in any business strategy, and it is even required in enterprises with a management system in agreement with the UNE EN ISO 9001: 2008 standard. However, due to the characteristics of the construction sector, it is especially complex to put it into practice. This paper describes the work underway to try to reduce defects in construction ceramic coatings applying continuous improvement tools. Once data on the construction defects found in seven housing building works have been collected, priorities were established for the implementation of the improved project, based on statistical tools for continuous improvement. The process of analysis is explained in this paper, as well as the reasons to deepen the study focusing on the shortcomings of this working chapter, so as to establish strategies to reduce failures in it.

Keywords Continuous improvement • Quality • Management • Construction failures • Construction defects

1 Introduction and Aims

This paper presents a research Project carried out on the Continuous Improvement process within the Quality Management Systems applied to construction companies.

Practically all Management models (ISO 9001, SixSigma, Total Quality Management TQM, Análisis de Modos de Fallo y Efectos) [1] defend Continuous Improvement as one of the most important processes in quality assurance. Industrial sectors in general, as can be seen in the existing literature, started to integrate improvement projects some years after Deming claimed the statistical techniques applied to quality, in Japan, in 1948. Today, the "Deming-Sheward circle" is widely known: Plan-Do-Check-Act.

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However, due to the singularities of the construction sector, and the continuous use of prototypes reproduction, implementing improvement processes and measuring the results is not easy, as it would have been in an assembly line.

Nevertheless, despite difficulties, the only way to improve is to know our mistakes before implementing actions to prevent repetition. To this end, we are working on the analysis of construction failures and designing a methodology to implement improvement plans and assessing their performance.

The aims of this paper, which gathers the progress of the on-going research work, are the following:

- Briefly explain the statistical quality tools applied in the study.
- Present the classification work of incidences detected in seven construction works.
- Establish priorities to enable setting strategies of the potential improvement projects.

2 Research Methodology

2.1 Background of Continuous Improvement

Today we have assumed *"continuous improvement and innovation as imperative to compete in the short-term and to survive in the long term in a globalized economy environment"* (our translation) [2]. Every author, management model or excellence model in management defends this premise. Although a long way has been followed—since the masters began to spread these ideas -we still have a long way to go in the construction sector. Our country, Spain, is particularly delayed when compared to United States or England, for example.

Juran [3] and Ishikawa [4, 5] have done a great job advocating and disseminating the benefits resulting from the implementation of the Continuous Improvement as an essential process to evolve from the "quality assurance" to the "Total quality" and "Quality Control" [2, 4].

In 1962, Ishikawa began to introduce Total Quality in Japan through the Quality Circles, affirming that, *"using total quality control with the participation of all the employees, including the President, any company can create better products (or services) at lower cost, as well as increasing sales, improving the utilities and turning the company into a top organization"* [4]. The concept of "total quality control" was devised by Armand V. Feigenbaum in the 1950s [4], but he argued that the TQC should be in the hands of specialists, as opposed to Ishikawa's approach, whose idea has reached our days.

In Spain however, within the construction companies, the quality assurance systems did not begin to be implemented until the 1990s, based on the ISO 9001 standard and today, Total Quality has not yet been integrated.

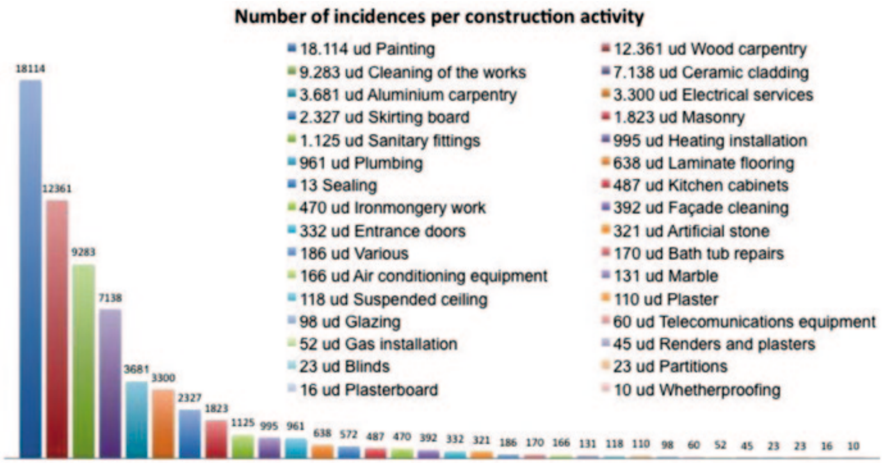

Fig. 1 Stratification historiogram of the number of defects per construction activity

The latest version of the ISO 9001: 2008 standard stresses the importance of the continuous improvement process and defends the principles of Total Quality: i. e. focus on the customer, address responsibility, company involvement at all levels, etc.

Our research project aims to establish a methodology, which will enable the implementation of improvement projects in a simple way in construction companies.

2.2 Improvement Project Applied to Diminishing Construction Defects

As Ishikawa states: *"The seven tools of quality control, when used skilfully, allow to solve 95 % of the problems of the different jobs. Intermediate and advanced statistical tools are only needed in 5 % of cases."* [5]. These seven tools are:

- Pareto chart
- Cause and effect diagram (or Ishikawa diagram or herringbone).
- Stratification
- Verification or check sheet
- Histogram
- Scatter diagram
- Control graphs and charts.

In the first phase of our study, we have worked with the "Check sheet", taking data from five housing construction works, and collecting a total of 65.528 incidences. These incidences have been classified in different categories regarding the "Stratification" tool. [6]. All these data was obtained thanks to the collaboration of ARPADA construction company, whom we want to express our gratitude (Fig. 1).

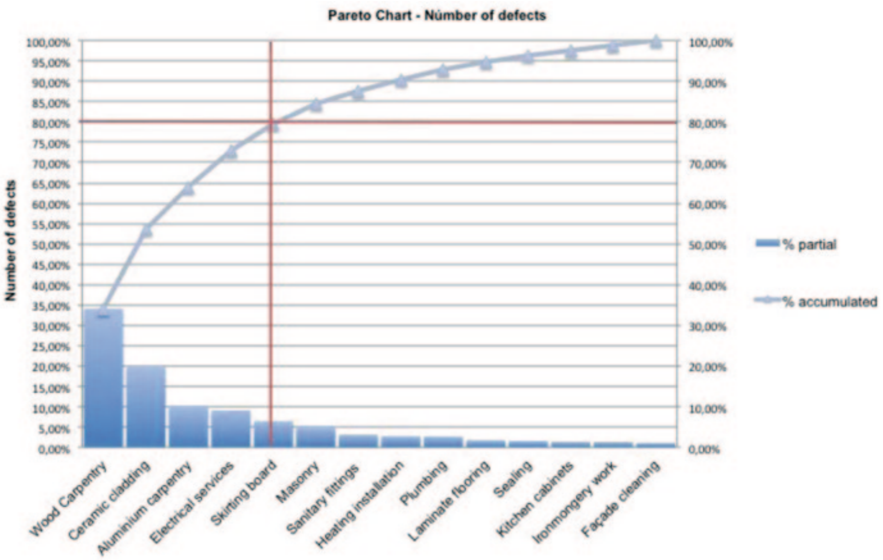

Fig. 2 Pareto Chart—Improvement projects prioritizing

Due to the low impact on repair cost of the construction activities with more incidences: painting and cleaning works, we decided to separate data and focus on trades with the greatest impact and representing more than 1 % of the total. With this data a "Pareto chart" is represented providing information to *"determine the frequency or the relative importance of various problems or causes" and helps to "concentrate on vital issues sorting them in terms of importance"* (our translation) [7; Fig 2].

As can be seen, 80 % of the defects are concentrated in 5 construction activities:

- Wooden carpentry
- Ceramic tile cladding
- Aluminium carpentry
- Electrical installation
- Skirting board

2.3 Prioritizing to Establish Strategies

At this point we have to decide in which trade we are going to focus our efforts to try to implement action and control protocols in order to achieve a significant reduction in the defects produced. *"Often the first two or three types of defects comprise at least seventy or eighty per cent of the total." "Is clear that if we eliminate these specific defects, we will have eliminated most of the defects and the fraction of faulty units will decrease dramatically,"* (our translation) [5].

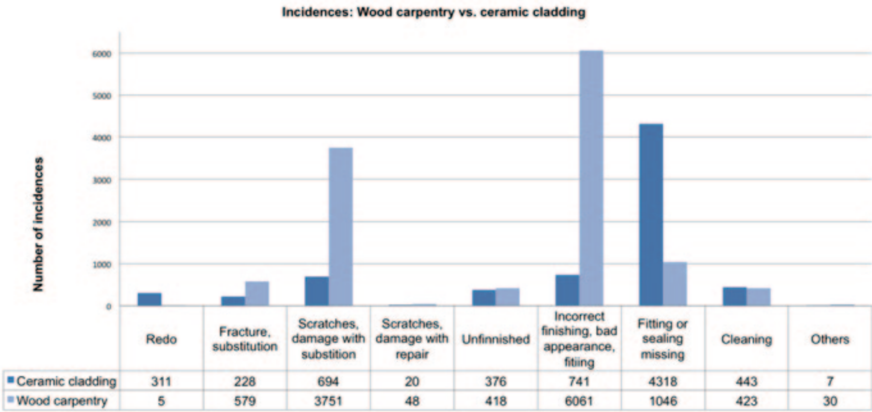

Fig. 3 Incidences in wooden carpentry and ceramic tile cladding

In this case, before focusing on specific defects, particular construction activities will be the center of interest. Our Pareto chart shows that the two construction activities with the greatest concentration of incidents are wooden carpentry and ceramic tile cladding.

Defects in these two groups were analyzed according to the other classification categories: action type for repair; repair cost seriousness; impact seriousness in the corporate image; and cause producing the incidence.

The following table compares the effects of these two trades according to the type of action (Fig. 3):

In this figure, a substantial difference can be seen in three groups:

- Scratches or damage requiring replacement or repair.
- Poor finishing, bad appearance or lack of fitting. The element, or piece is finished but in an incorrect way or it looks bad.
- Sealing of an element is faulty or poorly executed. It requires this operation for working successfully.

Analyzing the various groups, the following conclusions can be drawn:

- In the first group, although the number of incidents is far greater in wood carpentry trade, replacing a step or cabinet door is usually a fast and clean operation, but substituting a wall or a floor, fully or partially, has a substantial impact on the work and, it can generally influence other trades or construction activities. This means that the priority should be to work on defects in ceramic tiling.
- Something similar happens in the second group. Mainly, an aesthetic flaw does not technically require replacement or reprocessing as it falls within the permitted tolerances. It is however, a potential claim the property users might do, and occasionally, it might result in the need to redo the defective area. In this case, as well as in the previous case, the impact of cost and time in the ceramic tiling activity is greater than in that of wood carpentry.

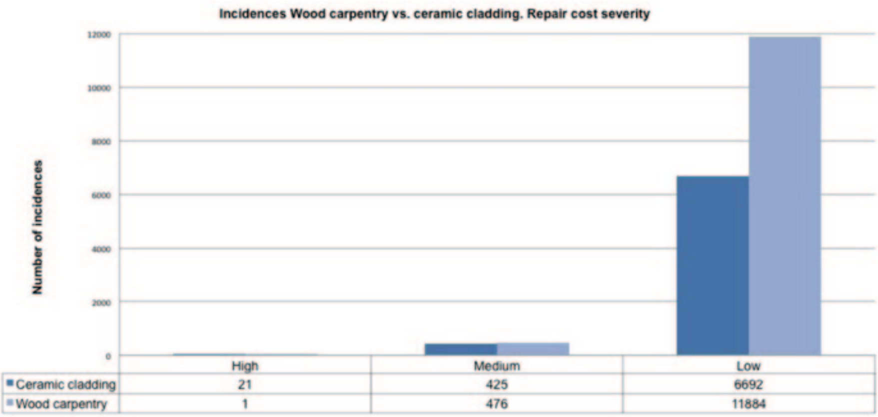

Fig. 4 Incidences in wood carpentry and ceramic coatings classified by repair cost severity

- The third group includes minor repairs, which can easily be fixed in both cases. Occurrences are more frequent in ceramic tiling.

In addition, the incidence between both construction activities classified in the other three categories are compared: seriousness due to cost of repair; impact seriousness on corporate image; and cause that produces the incidence.

The most important conclusion in these cases indicates that 96.14 % of the incidents of the woodwork belong to the group of low-cost repairs, confirming the conclusions drawn in the comparison previously commented (Fig. 4).

3 Future Research Lines

In accordance with the study so far—summed up in the previous sections—the research will be followed working on the improvement project of the defects found in the ceramic claddings. The steps to be fulfilled are:

- Study of the incidences in the ceramic cladding group.
- Defects stratification by types.
- Histogram and Pareto chart to establish action priorities within the defects of this activity.
- Proposal of Protocols and Verification/checking sheets to take into account in the construction phase by the workers and the subcontractors performing these jobs.
- Collect data in new construction works to determine the degree of improvement obtained.

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Success Strategies for On-Site Waste Management in Spanish Construction Sites

P. Villoria Sáez, M. del Río Merino and A. San-Antonio González

Abstract There is a wide range of measures that can be implemented in the building construction sites and not all of them are equally effective in reducing construction and demolition (C&D) waste generation or improving its management.

Therefore, this research carries out a survey conducted among the construction stakeholders in order to evaluate the use and effectiveness of 13 measures aiming to promote the minimization and correct management of C&D waste. In addition, this study identifies the most suitable types of building constructions to implement these measures and the advantages and drawbacks of their performance in a building construction project.

Results of this study show that among the highly effective measures are the contract of suppliers managing the waste, the distribution of small containers in the working areas and the periodic checks, although only 50 % of respondents usually implement this measure in their works.

Keywords Construction and demolition waste • Waste management • Success strategies • Construction agents • Building construction

1 Introduction

The large-scale construction activities occurred in certain countries of the European Union (EU) have produced a vast amount of construction and demolition (C&D) waste inappropriately managed, as only 50 % of it is actually recycled, not reaching the quantitative target established for 2020 [1–3]. In an attempt to correct the serious consequences, several countries are developing specific legal frames for C&D waste management, to encourage prevention, reuse and recycling.

For the particular case of Spain, the Royal Decree (RD) 105/2008 [4] proposes the inclusion and development of a Waste Management Plan (WMP) for each construction project. This document should necessarily include a description of the best practice measures of reuse, valorisation or final disposal of the waste and the

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descriptions regarding storage, handling or any other managing operation of the C&D waste to be carried out on the working site.

Although all these measures have been implemented by EU countries, according to de Guzmán Báez et al. study, professionals are still reluctant to implement best practices [5]. There is a wide range of practices that can be implemented, but not all of them are equally effective in reducing C&D waste generation or improving its management. Therefore, the agents involved in taking a decision on the C&D waste management might have difficulties in opting for the more effective ones. For this reason, assessing such practices would help agents in making more effective management decisions.

Moreover, this situation has not only worried EU governments, but it has been of great interest for researchers in the field. According to [6] special attention to C&D waste management has been developed in recent years. Indeed, specific research within the construction sector has focused in optimizing waste management including quantifying methods of C&D waste generation, as Lu and Yuan claim [7]. Among these studies Solís-Guzmán et al. [8], Llatas [9] and Villoria Saez et al. [10] can be highlighted. Furthermore, specific works on best practices in C&D waste management have also been of interest to many authors [11–13]. Other researchers have focused their analysis on causes influencing C&D waste management on site [14, 15]. Both studies have identified several critical success factors for the C&D waste management; i.e. the limited number of areas in which results—if satisfactory—will ensure successful competitive performance.

Although research on C&D waste management in Asia has been widely conducted, little attention has been paid to best practices of C&D waste management in other geographic areas such as in the EU. The knowledge of C&D waste management developed in one geographical area is not easily adapted and applied to other areas without considering their contextual differences [16]. Therefore, the main goal of this paper has hence been to identify the most commonly used waste management strategies and to assess their efficiency and viability, determining advantages and drawbacks. To this end, a questionnaire has been performed to the stakeholders intervening in the construction process.

2 Methodology

The research methodology presented here is used to identify the effectiveness of C&D waste management strategies [17]. Therefore, the steps used for identification of the success measures are: identifying a full set of selected strategies; conducting a survey to investigate each strategy importance; calculating each index value based on the survey data; and analyze the data obtained.

From the body of literature covering C&D waste management [18, 19], a total of 13 strategies for successful on-site C&D waste management were identified:

1. Contract providers to manage waste products [12].
2. Planning the number and size of containers needed for each activity [20].

3. Register the quantities and characteristics of the waste that comes from the construction work and control it [21].
4. Carry out periodic checks on the use of containers of C&D waste [21, 22].
5. Follow the plans of the project to prevent carrying out unexpected chases or holes [16].
6. Perform an on-site segregation of each waste category [12, 20, 21].
7. Respect the instructions of the manufacturer in the collection of material [21, 23].
8. Give talks for operators in the field of waste management [12, 16].
9. Distribute small containers in the working areas to facilitate the segregation of the different types of waste [21].
10. Reduce excess of ordered material to avoid fracture of it [20, 21].
11. Buy materials avoiding unnecessary packaging [20].
12. Planning coordination and review meetings about C&D waste [22].
13. Use shredder machines or compactors in the worksite for the C&D waste [15].

Moreover, an online questionnaire has been conducted to collect opinions of these best practices. In this sense, respondents were invited to evaluate the previous 13 strategies selected, in terms of their effect and viability. The level of importance was measured on a 5-point scale, where 5 denoted very efficient and 1 insignificant.

The questionnaire was conducted from January to February 2012 and consisted of a total of 82 questionnaires distributed by e-mail to the construction agents in Spain, who were randomly selected from the target population of contractors. During the survey, the following strategies were taken to ensure a high response rate: e-mailing and phoning each construction agent prior to the distribution of the surveys asking for their acceptance in participating and sending reminders every two weeks. A total of 58 valid responses have been obtained, reflecting a response rate of 70.73 %.

Finally, to evaluate the relative effectiveness or importance of the measures analyzed, an index value for each strategy has been calculated using Eq. 1.

$$I_x = \frac{\sum_{y=1}^{5} N_{xy} V_y}{\sum_{y=1}^{5} N_{xy}} \quad (x = 1, 2, \ldots\ldots n;\ y = 1, 2, 3, 4, 5) \tag{1}$$

where:

I_x is the index value of the strategy effectiveness.
V_y is the mean value appointed by the agents of each strategy ($S_1 = 1, \ldots, S_5 = 5$).
N_{xy} is the number of agents that chose the y^{th} value (V_y) for the x^{th} strategy.

Equation 1 has been widely adopted to identify the relative importance of factors/variables by calculating their importance index values and it has been used to calculate the index value of each strategy in this paper [12, 15, 24]. The strategy measures selected were then ranked according to their index value score. This analysis has led to part of the conclusions which have given rise to the conclusions of this paper.

Table 1 Percentage of stakeholders which usually implement the strategies studied

On site strategies[a]	%
1. Contract suppliers which manage their products waste	64
2. Planning the number and size of containers needed for each activity	57
3. Register the quantities of C&D waste and control them	50
4. Carry out periodic checks on C&D waste containers	50
5. Follow the plans of the project to prevent carrying out unexpected changes	46
6. Perform an on-site segregation of each waste category	43
7. Respect the instructions of the manufacturer in the collection of material	39
8. Give talks for operators in the field of waste management	36
9. Distribute small containers in the working areas	36
10. Reduce excess of ordered material to avoid fracture of it	32
11. Buy materials avoiding unnecessary packaging (bulk)	29
12. Planning coordination and review meetings about C&D waste	29
13. Use shredder machines in the worksite for the C&D waste	18

[a] Respondents can select more than one strategy, and therefore, percentages can exceed 100 %

3 Results and Discussion

Identifying all the measures determined by the agents in the WMP it is not only essential, but also, it is important indicating the degree of effectiveness and feasibility of them. Table 1 show the results of the common on site strategies according to the surveyed stakeholders, which refers mainly to recruiting suppliers to manage waste products (64 %) and to plan the number of containers and size needed for each activity (57 %).

From the results, it is necessary to remark that only 50 % of respondents claim to have carried out checks on the use of C&D waste containers or registering and controlling the quantities of waste leaving the work site. In addition, all agents surveyed were asked to value the strategy from 1 to 5. Table 2 shows the ranking of the assessment performed by the surveyed agents and the index value obtained for each strategy valued using Eq. 1.

In general, respondents highlighted, with I_x greater than 4.0, the contracting of suppliers to manage their products waste. This means that it tends to be a high effective measure. In addition, strategies such as: on site segregation of each waste category, the distribution of small containers in working areas, periodic checks and planning the number of containers required, are valued as medium-high effective measures ($I_x \geq 3.0$).

In particular, the distribution of small containers in the working areas is a well valued measure; however, only 36 % of respondents implemented this measure in their works habitually (Table 1).

Furthermore, among the results, the stakeholders positively valued—I_x greater than 3.0—periodic controls of waste containers and of the generated C&D waste quantities, although only 50 % of those surveyed usually perform these checks (Table 1).

Table 2 Index value calculation for each on-site strategy analyzed

On-site strategy	Assessment (Me)	I_x	Ranking
1. Contract suppliers which manage their products waste	4.00	4.138	1
6. Perform an on-site segregation of each waste category	4.00	3.638	2
9. Distribute small containers in the working areas	4.00	3.466	3
4. Carry out periodic checks on C&D waste containers	3.50	3.414	4
11. Buy materials avoiding unnecessary packaging (bulk)	3.00	3.397	5
2. Planning the number and size of containers needed for each activity	4.00	3.397	6
3. Register the quantities of C&D waste and control them	3.50	3.276	7
12. Planning coordination and review meetings about C&D waste	3.00	3.190	8
8. Give talks for operators in the field of waste management	3.00	3.121	9
7. Respect the instructions of the manufacturer in the collection of material	3.00	3.103	10
13. Use shredder machines in the worksite for the C&D waste	3.00	3.103	11
5. Follow the plans of the project to prevent carrying out unexpected changes	2.75	2.759	12
10. Reduce excess of ordered material to avoid fracture of it	3.00	2.741	13

Moreover, the agents were invited to point out the possible advantages of implementing on site strategies. Surveyed stakeholders showed that the main advantages are: improving the image of the company committed with the environment and enhancing the on-site C&D waste management, the saving of raw materials and raising staff awareness. In addition, respondents determined that the application of these strategies contributes to some extent, to reduce the economic cost, to obtain greater advantages in bids and reduce legal sanctions. On the other hand, when they were asked to provide their opinion on the major drawbacks all the answers obtained could be classified into the following factors:

- Economic: The extra costs for a greater vigilance and control for its implementation due to lack of awareness of agents that intervene in the process. Ultimately, the need of a person just dedicated to it.
- Time: More time devoted to sorting out waste, which conditions the work plan schedule.
- On site space: Lack of space to locate the different types and varieties of containers.
- Increase of red tape.

4 Conclusions

The assessment performed in this paper implies a detailed knowledge of the effectiveness and viability of each of the strategy studied. Through a series of analytical processes, this research identified 3 effective on site strategies: (1) Contracting suppliers to manage their waste, (2) on-site sorting out waste categories, (3) distributing small containers in the working areas. Indeed, the distribution of small containers in the work areas is the third best valued measure ($I_x = 3.466$), while only 36 % of respondents implemented this measure commonly in their works.

The success strategy assessment developed in this paper, highlighting their effectiveness as well as their advantages and drawbacks, can help construction stakeholders to make a decision between the wide range of possible C&D waste measures, ensuring a sustainable waste management procedure throughout the construction process and promoting zero waste generation buildings.

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Building Engineers' Promotion and Its Effect on Job Satisfaction. A Qualitative Study of Site Managers in Castilla-la Mancha

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Abstract Job promotion is an important issue for employees' professional development. Our research aims to explore promotion systems for building engineers used by construction companies in Castilla-La Mancha Autonomous Community. We also aim at analyzing the influence of promotion on job satisfaction. This paper draws on qualitative data comprising 34 semi-structured interviews with building engineers working as site managers for construction companies. Findings reveal that promotion is related, among other factors, to company size, site volume, qualifications, seniority or results. Additionally, when promotion initiatives exist their influence on job satisfaction is either positive or neutral, while when they don't exist the effect is negative.

Keywords Job satisfaction • Promotion • Human resource management • Qualitative research

1 Introduction

Specialized literature reveals that human resources represent the most important and variable factor of the production process, besides being a vital and strategic element for any organization whose target is to improve its productivity and competitiveness [1]. Thus, the implementation of policies and practices related to human resources, such as those regarding selection, recruitment procedures, training, incentives and assessment, is closely related to the overall performance of the company, which implies that human resources become a beneficial source of competitiveness [2].

Career development is an important activity for recruiting and for keeping qualified and committed employees, as well as for preventing them from burning out. On the other hand, career development is a constant, organized and formalized effort that considers people as a resource of vital importance for organizations [3].

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The complexity of today's construction project environments has also created an even greater need to make sure that construction companies have effective career development programmes to fill project management roles with the 'right' people for successful delivery [4].

For many employees, reaching a certain position or rank inside the organization is important [5]. In fact, some companies have a well specified hierarchy and career advance takes place through promotion, reaching higher level positions [6]. Being a reward that implies making progress in the organization together with more responsibilities, promotion can also be used to motivate employees. Actually, most workers think that employment conditions such as salaries, benefits and the working environment are very important aspects of their work [5].

A promotion can be an ideal company response to the productive learning experience of employees in their job. The more seniority in a certain job, the more specific knowledge the worker gains, involving major costs for the company in case it decides to look for another external worker with the same performance of an internal employee. Along their professional career, people acquire skills and gain experience in jobs that are transferable to higher level positions. When workers make an effort, not for maximizing their present wage, but it influences respect for their talent, then promotion must be used for motivating the worker, especially in those companies where training is costly [6].

This paper aims to explore promotion strategies that construction companies implement with building engineers working as site managers, and to analyze the effect that this promotion has on their job satisfaction. The research has been carried out in the Autonomous Community of Castilla-La Mancha, using a qualitative methodology with semi-structured interviews that took place between July, 2010 and May, 2011.

2 Variables of Study

2.1 Job Satisfaction

The study of job satisfaction has been approached from manifold viewpoints, which have enriched its definition with different nuances. Thus, some authors state that there is not a universal and agreed-upon definition as such for the term [7, 8]. Here we will use the definition provided by Spector [9], according to which job satisfaction is how people feel at work, including a variety of aspects related to it. It can be understood as an extension of what people like (satisfaction) or dislike (dissatisfaction) about their job. Job satisfaction can be approached either as a general and global feeling about work in general, or as a group of attitudes related to different and specific labour issues.

Although there are some factors affecting job satisfaction [10], which implies that it can be examined from different viewpoints by using different categories or concepts [11], in this research only promotion activities developed by construction companies will be considered.

Workers who have a high degree of satisfaction with their job prefer their current working place, implying there is a low ratio of turnover among the most satisfied workers. In absence of other variables, job satisfaction provides a useful measure to know the importance people attach to their job.

2.2 Promotion

Promotions are an important aspect of a worker's career and life, affecting other facets of the work experience [12]. Moreover, promotion is a factor related to the worker's labour mobility, involving a change of position inside the organization that usually entails a wage increase [13]. Or it can also have an effect in other aspects of the job such as training involved or the increase in responsibilities [5].

Pergamit and Veum [5] found that some job changes inside companies are defined as promotion, without implying any change of occupation or position. In fact, the majority of events that workers named as "promotion" did not involve a change in duties or consisted in getting a higher degree of their current position.

As regards its influence on job satisfaction, some researches have found that employees who have had some promotion declare that it affects positively [5, 6], as those who have expectations of being promoted within the next two years [12]. In addition, promotion can be a tool used by companies for increasing the commitment of their best workers [5] and for reducing turnover [12].

3 Research Approach

With the help of the "Colegio Oficial de Aparejadores, Arquitectos Técnicos e Ingenieros de la Edificación" (Building engineers' professional body) in the city of Cuenca, a request for participation in the study, including the objective of the research, was sent via e-mail. It was addressed to licensed building engineers working as site managers in construction companies. Only four of them answered directly that first e-mail; the rest of the interviews had to be arranged by asking these first four participants, or even our own colleagues, the telephone numbers of engineers they knew working as construction site managers. In this way, we applied the snow-ball technique until a 34 individuals sample was reached. Participation of professionals was facilitated by arranging interviews according to personal time-place convenience. Interviews, with an average duration of 60 min, were carried out in the following places: researchers' office in the Polytechnic School (38 %), offices/building site huts in place of work (38 %), and cafeterias (24 %). The provinces where participants were working at the time were Cuenca (53 %), Albacete (26 %), Ciudad Real (12 %), Toledo (6 %), and Guadalajara (3 %). For identification throughout transcriptions, participants are assigned a number.

The sample consisted of 27 males and 7 females, within a 23–63 age span. 15 % of respondents were under 29 years of age, 23 % between 30 and 33, 47 % between

34 and 37, 12 % between 38 and 40 and 3 % were over 60. In relation to family status, 65 % were married, 3 % had a partner, and the 32 % of the rest were single. 27 % of the married participants had no children, while 46 % had two children, and 27 % just one. All of them had a degree in Building Engineering. As regards their occupation 9 % were working as liberal professionals in construction project management teams, 6 % had their own construction company, and 85 % were working as site/construction project managers or as team directors. In relation to company size, 10 % of participants worked at micro companies (less than 10 workers), 39 % at small (less than 50 workers), 41 % were medium (less than 251 workers) and for the remaining 10 %, the number of workers ranged between 250 and 1,000.

Interviews were recorded for later transcription, on which the final document writing would be based. For the analysis of this document the ATLAS-ti software programme was used. This allowed identification of citations and codes through which information could be found and compared. The analysis of answers has let us identify common patterns, but we have also tried to provide descriptive information of how questions were perceived by each participant [14]. Since we followed Glaser's methodology, no preconceived assumptions were established at the beginning of the research. Thus, inductive analysis was applied to the survey contents [15].

The exploratory analysis derived from this methodology allowed the finding of regularities, which in turn allowed the generation of codes and categories. Relations between data and categories have been established by means of an interpretative analysis, trying to describe the phenomena studied, with the aim of developing a theoretical model [16].

4 Results

Interviewees were asked which promotion system or strategy was used by their company. Three of them reported not to knowing whether there was any type of promotion, thirteen declared there was no type of promotion and the rest, a bit more than half, gave an affirmative answer.

In the cases where there was no promotion, company size could be a variable justifying this lack. In total there were 3 micro-companies (< 10 employees), 8 small enterprises (< 50 employees) and 2 medium companies (< 250 employees), according to the definition established by the European Commission [17].

Participants justified this lack of promotion declaring it was due either to the size of the company or because building engineers started to work directly at their maximum rank and there were no possibilities of advancing in career.

Six types of promotion strategies have been identified: linked to results on construction site works; to seniority and to company experience; to the number of construction projects developed by the company; to superior's promotion; to colleagues leaving the company and lastly, promotion by means of economic incentives.

The economic downturn has influenced promotion initiatives implemented by construction companies. When the number of construction projects was high, before the real estate bubble exploded, building engineers' promotion was more related to their seniority or their working experience in the company. But nowadays, in full economic downturn and with a very small number of construction projects to be built, the possibilities of promotion or even continuance in the company are directly linked to the results obtained by the building engineer.

> *Not seniority, eh, not experience either. Results and day by day!!. Before, with more experience or with more time in the company, ..., But nowadays colleagues are not doing well or their boss doesn't think they are doing well or simply other aspects and they are dismissed,…., Today it happens to a colleague, tomorrow it could happen to me. One can see what happens around, not only in this company, I say it because I have many other colleagues in other companies* (Nº. 25).

Participants report the progression of positions that a building engineer can cover along his/her professional development, from minor to major category is the following: foreman, assistant site manager, site manager, group manager, technical director and zone director. Almost all interviewees had started their career as assistant site manager or as site manager. According to them, these first positions had lasted from several months to three years. While the first three positions are very related to construction works and the site, the rest are more related to company management.

Whereas the job of minor category they could carry out was not clearly defined, all participants knew that with their degree, they had a ceiling in their possible development within the company. In fact, in the case of SMEs and big companies, interviewees declared that the maximum they could aspire to become was group manager.

There is a small group of building engineers who directly associate economic incentives such as pay raise or productivity bonus related with profits, as a promotion. This system of economic promotion has also been acknowledged in previous research [5].

> *When I started working yes, promotion…, promotion involved the economic review* (Nº. 22).

As regards the question of how promotion possibilities influenced job satisfaction, we have not been able to find a conclusive response, since only two thirds of participants reported any type of effect.

On the one hand, when the company did not have a promotion system, the effect could be either negative, null or it had a contradictory effect on job satisfaction. On the other hand, when promotion did exist, the effect on job satisfaction could be positive, negative or not influence at all. In total, only a third of participants declared that promotion was positively affecting their job satisfaction, the remaining third was distributed between null, negative or contradictory effect.

Under the category of null effect, answers in which the lack of promotion was not affecting job satisfaction of participants have been included. Reasons for this were resignation or acceptance of the reality by the lack of possibility to ascend due to the economic situation or company size. Others did not know if it was affecting them or not because they had never been promoted or changed category.

> *Well, one knows the role that has in the company,…, you assume it, then it doesn't influence, no, it doesn't affect* (Nº. 10).

Now I have reached the ceiling. The one above me is the owner of the company. This means I cannot take the owner's position (Nº. 15).

When the promotion system was based on the results obtained in the construction site, if the company assigned a project with big initial economic losses to the building engineer, that were practically impossible to recover during execution, the existence of possibilities of promotion negatively influenced their job satisfaction. When comparing with other colleagues, the building engineer feels that the conditions for being promoted are not fair:

Of course, the truth is that it affected because…, well, you knew you had a step, you had to climb more steps than other colleagues to get to the same place (Nº. 20).

The positive effect on job satisfaction can be related to the following type of promotions: an economic incentive, a rise of category, or to have assigned higher budget building projects, with more responsibility or singularity.

Yes, when the promotion initiative is meant to improve your situation inside the company, with a raise of category or of salary, it is a recognition and then it affects your satisfaction, of course. To be praised for the work you do, especially when you don't ask for it, affects you very positively (Nº. 32).

5 Conclusions

Despite the limited size of the sample and the qualitative approach applied to the research, it can be assumed that promotion isn't a practice commonly used in small/medium-sized construction companies in the Autonomous Community of Castilla-La Mancha.

The existence of promotion initatives is related to factors like company size, the number of works and, therefore, the economic situation of the construction industry, the degree of the professionals, seniority and the obtained results.

Only three fourths of the participants reported some type of effect of promotion on their job satisfaction, not finding a conclusive response.

When there are no promotion initiatives, the effect on job satisfaction is usually negative. If any promotion system exists, the effect can be either positive or neutral.

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Management of the Building Process in Temporary Constructions: Case Study of the Unicaja Exhibition Pavilion

Carlos Rubio-Bellido, Miguel León-Muñoz and Jesús Alberto Pulido-Arcas

Abstract Temporary constructions demand further research in the management of their building process, as standard procedures are not able to give an adequate response to their special characteristics, in terms of their short completion schedule, their highly specialized construction systems and the obtaining of both building permits and public activity licenses. The authors present their on-going research in this field through the superb example of a 700 m^2 temporary exhibition pavilion commissioned by the Spanish Savings Bank UNICAJA. Having been installed in representative locations in 6 Andalusian cities, this structure welcomed more than 150,000 attendees during 8 months, from 2010 to 2011. Through the continuous work as part of a multidisciplinary team, the leading role of building engineers and architects, as effective managers of these sorts of commissions, has been proved. Innovative management schemes are hereby presented, with which the authors strive to pave the way for appropriate management procedures for these types of constructions.

Keywords Ephemeral architecture • Construction management • Coordination of multidisciplinary teams • Temporary constructions

1 Introduction

Integrated management of the building process is a field of work of renewed importance in the last years. Within our field of work, temporary constructions represent a little explored area. Their management process is substantially different from that for a permanent building. Specific construction techniques, obtaining permits and licences, coordination of all the professionals and planning schedules, require very specific working techniques. This research, based on a case-study that has been put

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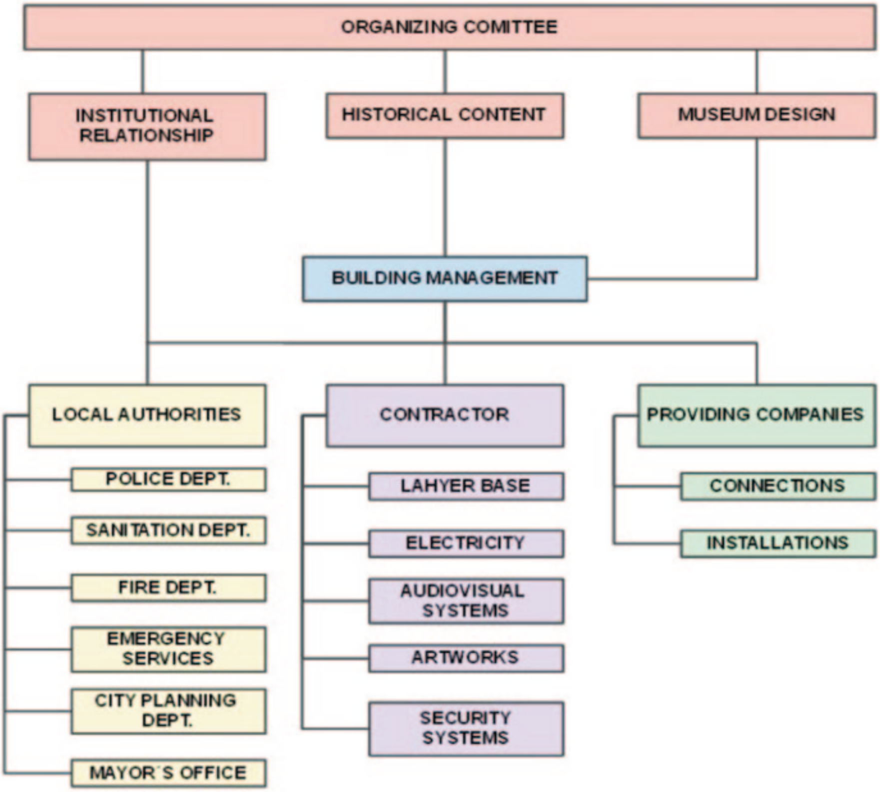

Fig. 1 Workteam

into practise, explores new schemes of work for the management of the building process, and it is proposed as a model that can be extrapolated to a high proportion of temporary architectures.

2 Case Study and Multidisciplinary Workteam

Based in a methodology developed by the authors, the results of research into a real case study are presented: The travelling temporary exhibition pavilion for the commemoration of the 125th anniversary of Unicaja. To manage its operation, an interdisciplinary committee was formed, composed of visual communicators, architects, building engineers, publicists, museology specialists, graphic designers, historians, image advisors, cultural managers and representatives of Unicaja[1].

The role of the technicians in the intermediate levelof decision making, as can be seen in Fig. 1, became clear, channelling the dialogue between the organising committee and the specialist service providers.

3 Methodology

3.1 Field Work and Selection of Project Locations

Whereas in a permanent building the site is a parameter that is already decided, in temporary constructions it has to be chosen, according to several criteria. The most restrictive is the topography of the site, as public spaces always have a gradient ranging from 3 to 10%, which implies further adaptation of the structure. Last but not least, necessary supplies -water, sewing system and electricity-, coming from supply network infrastructure, are not always available; the last one represents a particular problem, as the network is not always able to supply the required power.

3.2 Legislative Framework

Building management is directly influenced by the legislative framework, as it defines the duties and responsibilities of each professional. In Spain the two main legal enactments related to this field, both the Building Technical Code (CTE) [2] and the Enactment of the Building Management (LOE), exclude temporary constructions from its field of application. Our research, consequently, set a starting point in trying to build a framework where these constructions could be included; technical standards for our country and the neighbouring ones were compared, using the comparative methodology. Here the most remarkable results are highlighted.

Firstly, we can quote the only Spanish technical regulation UNE-EN 13782:2007 [3], referring to loads in temporary structures; but, due to a legal vacuum, it is not mandatory to fulfil its requirements. Another law not related to building industry, is the "public entertainment events" enactment. A diffuse and vague framework, which mixes national, regional and local regulations, exists for the installations and supplies.

France enacted its first technical code covering temporary constructions in 1985 [4], which was also amended in 2010 [5]: The CTS (Chapiteaux, Tentes et Structures) covers all sorts of them, establishing a classification in terms of maximum occupancy, duration of the activity held within it and the number of floors. Technical requirement comprises all parts of the building. A detailed procedure for obtaining opening permits and technical approval is also given, avoiding controversies among different local regulations as those ones in Spain. A single certificate that covers all aspects has validity thorough all the country.

Germany has also a long tradition of temporary constructions, ranging from 1950. From its legislative framework, we selected the state of the art technical code, the DIN 1055 [6]and DIN 1412 standards, which provides accurate hypothesis for structure calculations. This code is widely recognised as the standard for temporary structures, and providers amongst Europe certify the quality of their products by means of DIN 1055 and 1412.

3.3 Construction Systems

In permanent constructions, the eligibility criteria for constructions systems has been widely investigated, according to compliance with construction laws, price and feasibility, mainly. In temporary constructions, however, these criteria are different. Our methodology for choosing these systems has been settled based on the following criteria. The budget for the different materials is based on the cost of the material itself, the labour force (mounting and dismantling) and the transport; these last two combined often surpass the first one. The budget is also established after an economic study, which contemplates two possibilities: purchasing or renting the materials. Feasibility of every material is also strongly related to its maintenance cost, as, due to the numerous assemblies and disassembles; some have to be replaced, representing additional costs.

3.4 Implementation Schedules

As well as assuming the responsibilities for building management tasks in the very strict sense, the architects and the building engineers are responsible for other duties that, rather considered as additional, are essential in order to achieve success in the building management of these types of constructions. The occupation of the public space in central busy areas of the city requires detailed traffic plans for the circulation of heavy vehicles; moreover, the environmental impact of the activity requires specific studies to assure that the area is not affected by excessive noise or pollution. A detailed implementation schedule has to be designed for every location, combining a general approach that embraces all these tasks and bearing in mind, at the same time that local regulation differs considerably among the cities where the exhibition is going to be settled in.

4 Results and Discussion

4.1 Final Project and Locations

For each location technical advisory was given in form of technical reports for each location, delivered to the committee 8 weeks prior to the first installation; they combined technical facts presented in methodology and the desire of Unicaja to open the exhibition in representative locations in each city, where affluence of visitors was guaranteed.

Based on the former reports, the committee decided to finance the installation of two temporary pavilionsin the historic centres of 6 Andalusian cities: One of 500 m^2, which would house 5 thematic modules. The second, semi-open, would be a multipurpose sports track.

Fig. 2 Exhibitions opened to the public in different locations

4.2 Implementation of the Legislative Framework

The technical management decided to set the Spanish CTE as the required standard, which was certified by CE label for all products and systems, as well as UNE and Din standards. Besides, this standard was improved in specific areas. The integrity and stability of the structure and the skin of the building was guaranteed by French Standard CTS, as there were no temporary structures available that met German standard.

In each city, a technical project was carried out. In addition to this, several documents as public activity license, reports to the fire department and certificates of integrity of the structure, were delivered in order to complete a legal framework (Fig. 2).

4.3 Suitable Construction Systems

To adapt to the variable topography of diverse locations it was finally decided to opt for a floating floor system on adjustable pivots braced by means of ST-37-2 steel profiles. Since drilling the public thoroughfare was not viable, the foundations were made with a system of dead weights. A flooring of DM fireproof panels was laid over this system and hid the installations. The supporting structure on this base consisted of a system of T6 type aluminium pillars, beams and purlins measuring 210 × 110 mm for the pillars, 120 × 80 mm for the beams and 70 × 70 mm for the roof purlins.

The envelope (facade and roof) combined the principles of lightness and stability against exterior forces. The facades consisted of a double layer which combined an exterior layer of 40 mm thick cellular polycarbonate and an interior layer of taut

Fig. 3 Detail photo of the basement, exterior facade, roof and interior finishing

Fig. 4. Exhibition pavilion during the night. Interior view (artworks exhibition area)

PES polyester fabric with a double sided PVC covering; a 20 cm thick air-chamber was arranged between these layers to cushion thermal oscillation. The roof consisted of a system of taut PES polyester canvas covered with PVC on both sides, with an added mineral fireproofing treatment (Fig. 3).

The level of finish had to be of a very high standard, besides being combined with a profusion of audio-visual and interactive systems. The exhibition housed artistic elements belonging to Unicaja, such as original works of Antonio Machado, exhibited in a controlled atmosphere, and original paintings by Pablo Picasso (Fig. 4).

4.4 Schedules and Maintenance

In each one of the cities, an exhibition space composed of two modules had to be mounted, with a total volume of 3500 m^3, in 11 days, employing an average of 25 workers. The implementation schedules were very tight and non-negotiable, as the inauguration in each place involved the presence of the local authorities and chairpersons of the different committees from the promotional organisation, who would be appearing at previously arranged press conferences.

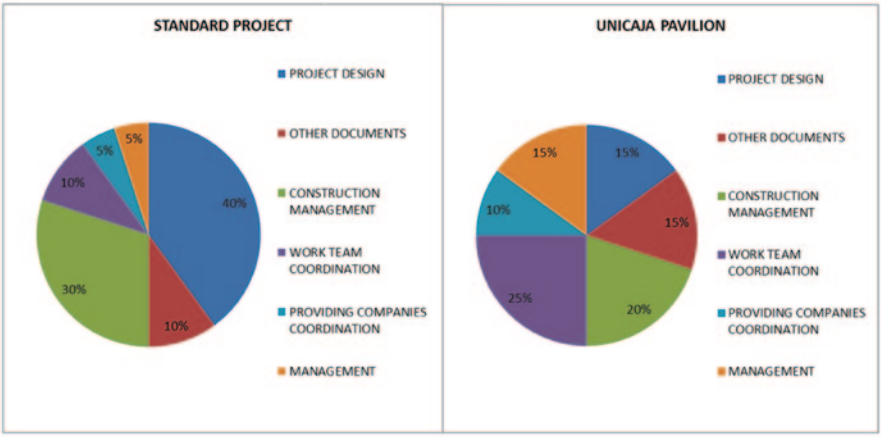

Fig. 5 Time management

Finally, during the 24 days in which the exhibition remained open in each location, the technical team was in charge of coordinating the possible maintenance tasks for the pavilions, and during dismantling a new disassembly coordination plan had to be undertaken, resulting in the management of two operations in one.

We also carried out a monitoring report in order to repairing or replacing elements before each disassembly assembly process and maintenance operations throughout the exposure life been guaranteed performance, quality and safety (Fig. 5).

5 Conclusions

From the experience presented here, we can conclude that a state-of-the-art does not exist in the field of temporary constructions. Therefore, it is necessary to establish suitable schemes of work for types of commissions, adapted to the specificity of these buildings.

Time management has to consider tasks such as additional permits of capital importance, as a delay in the opening in one location implies the delay of the whole itinerary.

Budget control has to consider always two options for material: renting or purchasing. Indirect costs imply assembling and disassembling, as well and transport costs, so that, from our experience, they can represent up to 80 % of the cost for the material itself.

The maintenance or replacement must be always under the technical management field of competence, as they can represent important deviation in budget execution.

A detailed study for each location of the event must be made before conceiving any idea of the temporary building, as the local regulations for each city differ widely; a prototype that adapts to every location is the ideal for this task.

In relation to the legislative framework, the main conclusion is that a technical standard for temporary constructions must be set in Spain, covering three main aspects: Structural integrity, fire protection and public security measures. Local regulations should be harmonised in basic aspects to avoid gaps in many security aspects.

Our professional environment (institute of building engineers and architects, civil liability cover…) must adapt to these new field of work, as we have found many difficulties when trying to "classify" this kind of commissions.

Finally, and as a final conclusion derived from this professional experience, we can affirm that, although this field represents a challenge for our profession due to misconceptions assumed by many, our professional validity as technicians capable of coordinating large multidisciplinary teams for temporary constructions has been amply demonstrated, as the success of this Exhibition has proved.

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The Project Coach: The New Role of the Project Manager for the Future Due to the News Tools Like Building Information Modelling, Integrated Project Delivery, Last Planner and Others

Marc Bach

Abstract Design-Bid-Building is the traditional approach to manage a project, but in the last decade we can find other kinds of contracts in many buildings, like Project and Design and more recently Integrated Project Delivery. The contractor appears from the beginning in both.

The recent failures in lean companies like Toyota, GM or Delphi, have aroused a new approach to the lean transformations. There are several books and articles about the important role of the Manufacturing Engineer or Operations Manager as a teacher and leader, similar to a coach's perspective. We could have the same problem in the construction field if we don't give the correct training to our project managers or site managers.

BIM, IPD and Last Planner require real collaboration and win-win attitudes. New skills like team working, empathy, mindfulness and resilience are more necessary. The proposed article will describe the qualities of "The Project Coach" and how to get these skills.

Keywords Collaboration • Project coach • Competencies

1 New Paradigm in the Construction Projects

The current economical crisis requires not only finish the projects without increasing costs, but also reduce the initial project budget. We need to put more effort into planning and risk management than recent years. We only have one way: including the contractor in the design phase and more resources in planning and scheduling. Generally speaking, we need more coordination among the whole stakeholders for all these factors.

Around the world people want efficiency and effectiveness in all industries and fields: banking, politics, manufacturing, healthcare, service, etc…. We can find

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examples in every sector that collaboration and win-win strategies are the key to get success to short and long term. Construction Projects (Civil and Residential) are complex systems and they're not easy to manage. According to Nobel Prize in Economy, J.f. Nash, a system goes to efficiency when all the subsystems seek not only their profits, but the benefits of the global system too.

In 2010, the Associated General Contractor of America (AGC), Business Success for Construction Project Owners (COAA), The American Institute of Architects (AIA), Leadership in Educational Facilities (APPA) and the National Association of State Facilities Administrators (NASFA) made a document promoting the IPD in the American Construction Industry called "Integrated Project Delivery for Public and Private Owners". IPD is now a reality in the construction field.

Thanks to Integrated Project Delivery Contracts and tools like Last Planner, BIM and the use of Tic's; we can bet by a project run with a win-win philosophy. The roles are new and different from the last century.

The project manager and site manager will become leaders instead of managers. But thanks to neurosciences everybody can become a leader. This article tries to convince that the new project manager will be more similar to a coach than a manager and how to achieve it.

2 Where Are We?

The Japanese culture of manufacturing is an example for many corporations around the world for efficiency and quality products. It´s called "munozukory" [1]. The key is that the relation between suppliers and manufacturers or managers and workers is based on TRUST and not so much in contracts. This is the first ingredient.

In 1982 Flores defined "the work of business is making and keeping commitments". We have another issue: COMMITMENT. The success of Last Planner System is based on this according to the works of Howell and Macomber [2].

Third aspect: VALUE. Stephen Covey in The 8 habit book listed four qualities for a leader: discipline, consciousness, passion and vision. Next, he describes characteristics for a corporation or a project and instead of vision; he talks about shared values [3]. We can find a similar approach in lean philosophy: create value and eliminate waste. In short, we have to know from the beginning the values of the different project stakeholders and put them together.

We'll have all the ingredients if we add COMMUNICATION. The article "Leadership and project management: time for a shift from Fayol to Flores" from several authors, goes in the same direction [4].

In conclusion, If we put contractors, architects, owners and maybe subcontractors at the beginning sharing benefits and risks… what happens to the Project Manager? In my opinion he has two options: to become an owner's representative or to become a project facilitator. The role of the second option is more similar to the role of a coach with teams. It's called "Team Coaching" [5] and is based in Systemic Coaching. This coach helps the project members to be more efficient, to pursue the common goals, improve meetings, teaching last planner and others tools to create a good environment in IPD Contracts. How? Observing and asking the right questions. For this reason, I called it “The Project Coach”.

A life coach is a person that goes with you in your challenges. An executive coach is the same, but for managers and their responsibilities inside their jobs. If we want to consider an IPD contract (win-win approach sharing benefits and risks) and the definition of coaching; the Project Coach is more similar to a life coach but for a group.

There is also a scientific reason about the necessity of a “Project Coach”. If we want to be effective and efficient in our challenges, according to neurosciences we have to practice “mindfulness”, called as well the “Director” [6]. In consequence, if we consider a project as a complex system made up for human beings, we need a director whose focus will be the effectiveness and efficiency of the project.

The challenge of the Project Coach is to help to minimize waste, get the target cost design and align the different values during the life of the project. He has to teach the tools that will serve to create trust and commitment among managers, architects, engineers, foremen, subcontractors, superintendents and laborers; that is to say, get the goals with efficiency and satisfaction for all parties. We can consider the Project Coach as a facilitator for the Collective Intelligence considering another topic of researching.

Summarizing, the same role that the life coach plays for the targets of his customers is the role that the Project Coach does with IPD contracts.

3 How to Get It?

This type of approach is not new in the lean construction literature. Ignacio Pavez wrote a Thesis in 2007 about the competencies of the construction manager to use lean construction tools (with relevant data) and a way to implement it [7]. Another example is the chapter 17 of the book “Project Management CIRCA 2025” published by The Project Management Institute. It’s defined competency as a capability or ability and we need to regard two actions: intent and behavior. [8]

The competencies of a construction manager are described in the study of Pavez, similar to a manager of another industry. In the other article, it’s described the competencies of the Project Manager like an owner’s representative, leader and coordinator of the project. It’s considered in this paper the role of the Project Coach defined previously and his competencies.

The Project Coach will help to work together with less effort. It’s like a stick that they use when they need it. Observing and asking the group, they will sense their virtues and their bottlenecks. If we take into account the Intentional Change Theory of Dr. Boyatzis [9], we can consider the Project Coach as a Positive Emotional Attractor for the Project. He has to create optimism, hope, confidence and resilience throughout the project.

Hence the knowledge of the Project Coach has to be huge: experience in construction, understanding how the human brain works to become more efficient (today with the recent discoveries of the neurology you can), lean construction tools and the techniques of a coach.

What type of competencies does the Project Coach need?

- Mindfulness
- Observing
- Assertiveness
- Rational and emotional empathy
- Communication skills
- Hope
- Creativity
- Discipline
- Developing others
- Efficiency Orientation
- Root Cause
- Conflict Management
- Prevent problems

We can define them as cognitive, emotional and spiritual competencies and furthermore they are different from a project manager or a construction manager. Competencies like mindfulness, observing (both are related), hope and developing others are typical from the spirituals guides: Jesus, Buda, Lao Tse, Ibn Arabi and many more.

Bhikkhu Bodhi, a monk of the Theravada tradition, further explains the concept of mindfulness as follows: "The mind is deliberately kept at the level of bare attention, a detached observation of what is happening within us and around us in the present moment. In the practice of right mindfulness the mind is trained to remain in the present, open, quiet, and alert, contemplating the present event. All judgments and interpretations have to be suspended, or if they occur, just registered and dropped" (source: Wikipedia). The right answers will come up in this state.

For John Teasdale, a mindfulness researcher, mindfulness is a habit and we can measure this skill with the test Mindful Awareness Attention Scale (MAAS), developed by Kirk Brown, American scientific [10].

In the cognitive tasks (analyze, planning, root cause, etc…) mainly works the prefrontal cortex, different to an emotional activity more related with the limbic system. But it's a simplification of the brain, in general all the parts are connected.

There are several tools to measure the emotional competencies: the Emotional Social Competency Inventory (ESCI-U), the Critical Incident Interview (CII), 360º feedback and more (MSCIT, QDE-A, TCI-R…). CII is useful for empathy, teamwork, influence, conflict management, developing others and achievement orientation. You can measure the cognitive intelligence scanning the brain too.

Bartzokis is a neurologist that researches the myelin and he called the process of learning myelination [11]. If we want to get a competency we need emotion (passion), frequency and necessity. Then, the way to acquire these competencies of the project coach is practicing the new neuronal connections.

These competencies are indeed similar to a team coach in the manufacturing sector. A industrial company that uses business process management is also an approach close to project management philosophy. Then, the skills of an operations consultant can be similar to a project coach if you regard instead of the multi-party agreement (an IPD with industrials and subcontractors) the operations manager, logistics manager, commercial manager, demand planner, manufacturing engineers, etc. This is the style of Toyota in his plants around the world that you can find in some books in this century, but the beginning of this new tendency was the research of Steven Spears in 2000 for his Phd in Harvard Business School [12].

4 Conclusion

If we want real team working in our projects and win-win approaches we have to develop ways to create trust, commitment, shared values and respect for people. This last point is the basis of Jidoka in the Toyota Production System, many times forgotten in lean manufacturing.

We cannot forget the connections between neuroscience and the leadership that helps to know how our brain works and discover that behaviorism is an old model to explain who we are and how we move.

The Project Coach, the IPD Contracts, the use of Last Planner System and BIM can help us to create trust, commitment and transparency in complex projects.

The next step of this article is to find projects to collect data and confirm the success of this new role in the projects. In the recent years, we can find some similar roles to the Project Coach like Director of Learning or Lean Project, but this article tries to define it and show his importance with win-win approaches.

The map is not the territory and the Project Coach will help to create a new vision of any Project. The complex systems have to align the multiple and different interests and struggle to get them. If we belong to a contractor and we bet for this approach the way is hard and long, but after repeating and repeating and with a good strategy, we'll get a networking of architects, suppliers, customers, engineers and workers with competencies to get success in any project.

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Applying EVM and Es Metrics to Analyze and Forecast Schedule Performance in the Spanish Context of the Building Sector

M. A. Guerrero, M. M. Carbonell and A. Montoyo

Abstract Most building projects finish their execution exceeding the contractually established completion date. Although Earned Value Management (EVM) is a technique widely developed in many countries to control the project schedule, in Spain it is not used in the construction industry. Furthermore, EVM has an extension called Earned Schedule that allow for more reliable control of the deviations occurring over the planned duration. This paper examines an application model of the EVM metrics recently proposed to be used in the Spanish context of the construction industry, but focusing only on time control. In order to verify the metrics obtained with this model, three prediction methods well established in the literature are applied on real data of six building projects, establishing critical thresholds to assess the practical validity of the predictions. Although the data set is relatively small, the developed analysis produces encouraging results that may serve as a starting point for further studies.

Keywords Earned value • Earned schedule • Forecasting • Building projects • Construction

1 Introduction

Earned Value Management (EVM) is a tool of project management that enables performance assessment of project execution, integrating the joint management of scope, time and cost. It allows identifying deviations in the execution and makes predictions about project final results considering the data collected until the control date and several performance assumptions. It is used in the construction industry from other countries and it has been the subject of several studies in this sector. However, the EVM methodology is not used in Spain in the construction sector because, first, large Spanish construction companies have their own management systems

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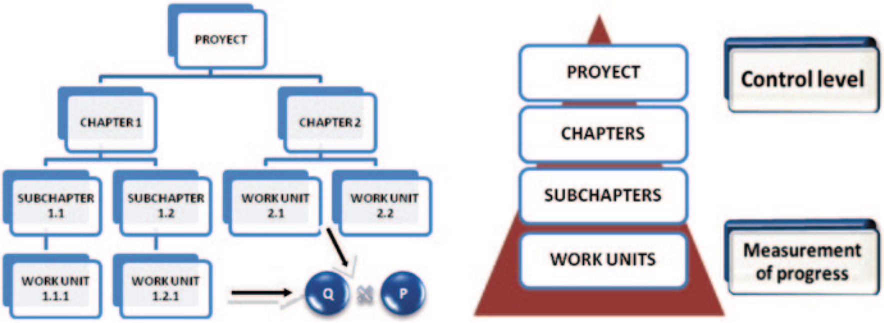

Fig. 1 WBS of the project budget

clearly focused on cost control, leaving time control in the background, and secondly, more importantly, many professionals of this sector do not know its existence [1].

The study developed aims to assess the practical validity of a simplified model recently introduced to apply the EVM methodology in the Spanish context of the construction industry. The research focuses only on time control, leaving aside the cost control. For this purpose, several EVM prediction methods, that enable estimating the final duration of a project, are applied using the revised model on a set data from building real projects. Both basic principles and practical use of the EVM methodology have been widely described in many sources of the literature (see e. g. [2]) and in this article it is assumed its understanding by the reader.

2 Model to Apply the EVM Metrics

2.1 Definition

In construction sites performed in Spain, the project budget (Budget at Completion, BAC) is decomposed by a Work Breakdown Structure (WBS) based on Chapters, Subchapters and Work Units (WU), according to the diagrams shown in Fig. 1. With this premise, Valderrama and Guadalupe [1] have presented two models to apply the EVM methodology, oriented towards the Spanish construction industry: *Simplified Model* for the Project Manager, representing the owner's perspective; and *Complete Model*, oriented towards the construction company. These models use two essential variables for each WU on which the budget of a project is divided: Quantity (Q) and Price (P).

This paper focuses on the simplified model, which is based on the traditional procurement method used in the Spanish construction industry, where partial payments to the constructor are carried out monthly by work certifications. The model uses as Earned Value (EV) the certificate amount, considering only the portion of work included in the planned budget of the project. Table 1 shows the equations involved in this model at project level and its correspondence with the key metrics of the EVM methodology.

Table 1 Simplified model

EVM metrics	Simplified model equations
PV (Planned Value)	$= \sum_{i=1}^{n} Q_{Pi} \cdot P_i$ (1)
AC (Actual cost)	$= \sum_{i=1}^{j} Q_{C1i} \cdot P_i$ (2)
EV (Earned value)	$= \sum_{i=1}^{j} Q_{C2i} \cdot P_i$ (3)
BAC (Budget at completion)	$= \sum_{i=1}^{N} Q_{Pi} \cdot P_i$ (4)

Where

- n is the number of WUs with planned quantities until the control date.
- j is the number of WUs in execution or completed until the control date.
- N is the total number of WUs.
- P is the price specified in the project for each WU.
- Q_P is the planned quantity for a WU until the control date.
- Q_{C1} is the total certified quantity for a WU until the control date.
- Q_{C2} is the certified quantity for only the work planned of a WU until the control date.

3 Considerations on the Application

Although Valderrama and Guadalupe [1] indicate that in the simplified model it is not required to have planning, this study considers essential the existence of a schedule made by the contractor before starting work. However, in most projects, planning undertaken by contractors do not reflect the temporal distribution of cost for each of the scheduled activities, and these do not follow a clear pattern of correspondence with the WUs of the project. This makes impossible a scheduling analysis at levels below the project level. For this reason it was chosen project level control for the experimentation proposed in the research (see Fig. 1).

It must also be considered that, in a procurement system with open measurement, as projects developed by public administration in Spain (the law allows variations up to 10 % of contract value) when the EV metric is matched with the certified amount it is assumed the possibility of committing errors of earned value measurement, even discounting the overrun certificates until the control date. In this con-

Table 2 Real project data

Project	Budget (In thousands of Euros)	Planned duration (months)	Actual duration (months)	Deviation (months)	Deviation (%)
1	2,845.29 k€	18.0	21.0	3.0	16.7
2	1,350.39 k€	12.0	16.0	4.0	33.3
3	2,305.65 k€	18.0	17.0	−1.0	−5.6
4	2,739.72 k€	15.0	19.0	4.0	26.7
5	779.52 k€	12.0	10.0	−2.0	−16.7
6	1,650.65 k€	15.0	16.0	1.0	6.7
Average	1,945.20 k€	15.0	16.5	1.5	10.2

text, an EV measurement error is made when a WU finishes with less quantity than it is expected, since it should be accredited 100 % of planned value at the time this happens. Similarly, when a WU exceeds its planned quantity does not mean that it is complete and 100 % of planned value can be accredited, but it should be known the new quantity and calculate the percent completed with regard to it. The above errors may be admissible provided that they do not involve a change of project scope and the magnitude of the deviations on the total budget will not be significant. Otherwise, it proceeds to make a modification of budget and re-baseline. Moreover, with a fixed price procurement system, more typical of the private sector, such errors could be avoided whenever it is used the percent completed for each WU and there will not be deviations in quantities.

After completing all planned works, by definition, the EV must match the BAC, regardless of the last value certificated.

4 The Data Set

There have been 5 health building projects collected for the development proposal, promoted by the public administration (open measurement), and a private residential building project (fixed price), all performed by different contractors. All projects are located in southeastern Spain and the works were completed between the years 2006 and 2012. None of the projects underwent changes in its scope during the construction phase. The general project data are shown in Table 2. According to monthly character of certifications, once work starts there is a control point with data at the end of each month.

It is necessary to indicate that in the final certification of the 5 public projects (prior to settlement certification) the sum of deviations in absolute value to chapter level was about 4 % of the total budget. However, in all projects the amount of this

Table 3 Methods and proposed scenarios

N	Expected performance to remaining work	Forecast methods		
		Planned value	Earned duration	Earned schedule
#1	According to plan	$EAC(t)_{PV1}$	$EAC(t)_{ED1}$	$EAC(t)_{ES1}$
#2	Following the trend of performance indices (SPI/SPI(t))	$EAC(t)_{PV2}$	$EAC(t)_{ED2}$	$EAC(t)_{ES2}$

final certification matches the planned budget (EV = BAC), indicating a clear tendency for compensation of errors during the execution of works. Bearing in mind all this, the excesses of measurement were not deducted from the EV.

5 Forecasting Final Duration and Evaluating Its Quality

In order to predict the project duration defined by EAC(t) (Estimate at Completion (time)), three forecasting methods have been selected from EVM methodology: the planned value method (PV, [2]), the earned duration method (ED, [3]) and the schedule earned method (ES, [4]). Both PV and ED methods are based on traditional metrics while the ES method is based on a new metric developed to improve controlling of the execution time by two new indices (SV(t) and SPI(t)). With each of the proposed forecast methods we use two possible scenarios that define the performance of work remaining. These methods have been evaluated several times using the simulation and for greater depth in knowledge of proposals EAC(t) predictive equations it is recommended to consult [5]. Table 3 summarizes the methods and proposed scenarios.

The quality of the forecasts has been assessed according to the criteria of accuracy and timeliness. For measuring the accuracy criterion, the MAPE (Mean Absolute Percentage Error) has been selected. Regarding the timeliness of forecast, the study has followed the approach that divides the horizon of the project in three phases: Early (0–30 %), Middle (30–70 %) and Late (70–100 %) [5]. However, the practical validity of the forecasting methods should be evaluated in the context of a larger decision making system, setting critical thresholds for the selected criteria [6]. For accuracy, in some studies related to construction projects, maximum acceptable errors around 10 % have been set (see e. g. [7]). Table 4 summarizes criteria, error metrics and thresholds used in the experimentation performed.

Table 4 Criteria for assessing forecasts

	Criterion	Error metric	Threshold		Equation
1	Accuracy	MAPE	≤10 %		$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert \text{RD-EAC(t)}_i \rvert}{\text{RD}} \quad (5)$$
2	Timeliness	MAPE	Early (0–30 %) Middle (30–70 %) Late (70–100 %)	≤10% ≤10% ≤10%	(5) $$\%\text{C} = \frac{\text{EV}}{\text{BAC}} \quad (6)$$

where

n is the total number of control periods,
%C is the percentage completed of the project and
RD is the real duration.

6 Results and Discussion

In this section the MAPE average values are analyzed. Figure 2 shows these values in each project stage as well as the overcoming frequency of the critical thresholds.

Overall accuracy Using the scenario #1 it is achieved, on average, a more accurate forecast, regardless of methods used. All three methods obtain similar accuracy for scenario #1 but with scenario #2, considering the performance indices SPI and SPI (t), there is a noticeable difference of accuracy in favor of the ES method. Furthermore, according to the thresholds defined, only the ES method under scenario #1 obtain, on average, a MAPE lower than 10 % although all three methods reach values very close.

Early stage The accuracy results obtained during this phase of the project follow the same pattern as those achieved for the entire project, only that with higher error values. If we consider the thresholds defined above, any method yields a MAPE lower than 10 %, but the results are much more accurate when the methods are used under the scenario #1.

Middle stage In this stage it is repeated the same trend in accuracy results but with significantly lower errors. Regard to determined thresholds, the ES method yields a MAPE less than 10 % with both scenarios, while the PV and the ED methods reach this result only under scenario #1.

Late stage The ES method clearly outperforms both ED and PV methods, using any of the two scenarios, and in the same way the ED method outperforms the PV method. Only the ES method yields a MAPE less than 5 % in both scenarios.

While being aware of the small sample size, we also performed non-parametric tests of significance using SPSS. In the early, middle and general stages, using in-

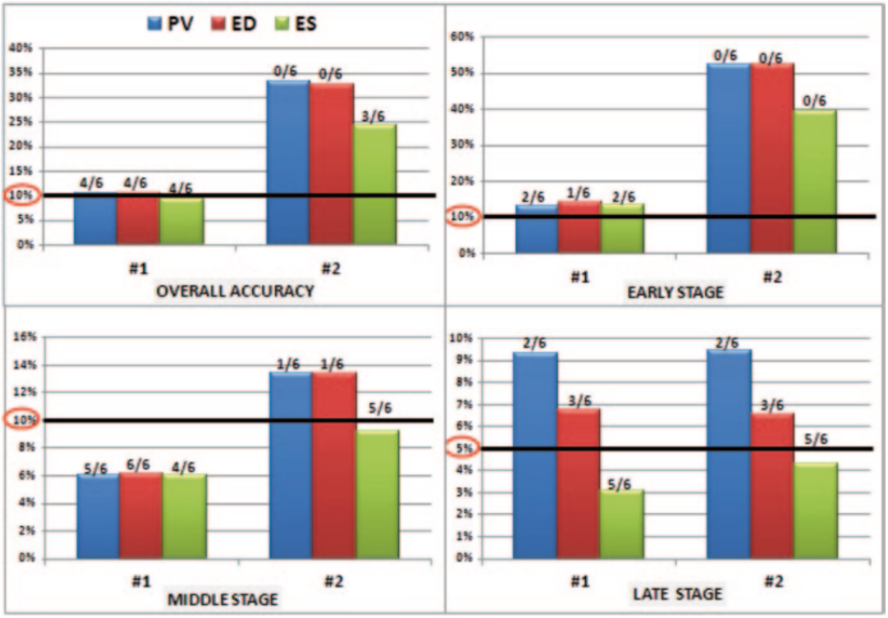

Fig. 2 Average values of accuracy

dividually the Mann-Whitney test with both PV and ED methods, we found that differences in accuracy between scenarios #1 and #2 were statistically significant on the 5 % level. Also, applying the Kruskal-Wallis test with the three methods in each scenario of the final stage, we found values of $p = 0.069$ with scenario #1 and $p = 0.134$ with #2. These values do not become significant on the 5 % level, but are a good indicator of the results observed in the final stage graphs (Fig. 2).

7 Conclusions

The developed research revises a simplified model of application for EVM methodology, focused on the Spanish construction industry. In order to verify the practical validity of the control time with this model, we apply three prediction methods on real data of six building projects and compare the results obtained with established critical thresholds.

The results of experimentation show that the scenario assuming the remaining work will be developed according to the planned schedule produces, on average, more accurate forecasts during the early and middle stages of the project, regardless of the prediction method used. Under this scenario, practical results are obtained during the middle stage with any method and in the final stage only with the ES method. On the other hand, considering the scenario based on performance indices

SPI and SPI (t), only the ES method does not outperform the thresholds fixed in the middle and final stages. Consequently, in the final stage, regardless of the scenario considered, the method ES outperform, on average, both PV and ED methods, that accuse the known anomalous behavior of the SPI index [4].

The summary of the study is that using the simplified model to apply the EVM methodology at project level, in the Spanish context of the building sector and once overcomed the initial stage, practical results can be obtained in the final duration forecast, even accepting with this model certain errors in the measurement of the earned value. However, it should be noted that the study developed is based on a relatively small sample of projects and although the results appear consistent, confirming partially other studies [5], in order to generalize them, it would be necessary to apply the same research methodology to a considerably larger sample with different types of real building projects. It is also noted that the critical thresholds established in the investigation, although reasonably based on other studies, may vary according to the needs of each organization and other parameters of the project (e. g. the kind of contractual penalty).

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International Project Management Based on the British System in M.E.N.A. Countries. Comparative Analysis

M. R. Chaza

Abstract The main for this paper is to analyze the differences, advantages and disadvantages between the Building projects design process currently existing in Spain, and the one used in countries belonging to M.E.N.A. area (M.E.N.A. countries (Middle East and North of Africa)), mainly based on the British Projects management system.

Keywords International • Management • MENA • Projects

1 Introduction

The current situation of the Spanish building market caused by the high incidence of the financial crisis in the country and the bursting of the housing bubble, has motivated that most companies are betting on the internationalization of their products that leads, apart from a logical economic investment, a deep change of attitude and a need to know and understand the development tools of construction projects in the international market.

This call paper pretends to carry out a comparative analysis of the system of traditional project management in Spain and the international system, based largely on the British model of management. This model is present in a large majority of countries, not only English speakers, but also those located in North Africa (except for countries like Algeria and Morocco, aimed at the use of French-speaking systems) and the Persian Gulf. This study is structured in three sections. Antecedents for this topic has been founded in previous works as “Review of manufacturing capabilities and potential in MENA countries” [1] and “An assessment of regional constraints, needs and trends” [2]

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Fig. 1 Main types of Works related to Building Engineering projects. (Authors 2012)

2 Metodology

The paper pretends to analyze in its first section the possible types of projects that could be developed based on the British system of project management [3]. The second part will propose an operating schematic of an international project on the British system in MENA Countries. Finally, the third section proposes a comparison between the project management system analyzed and the current Spanish one, followed by conclusions and possible future research.

3 Types of Projects Based on British Project Management System

Following today's standards of Building project management system based on British system and considering RIBA [4] requirements, the most common types of projects concerning building construction and architecture could be structured as follows (Fig. 1):

1. *Masterplanning: Define how the plots will be developed, roads, streets, traffic circles, avenues, parks, etc. The following disciplines can be included:*
2. *Infrastructures:* Provides general facilities of the buildings, supplies and networks such as the electrical grid, water, sanitation, irrigation, telecommunications, storage, etc.
3. *Landscape:* Design of green areas, bike lanes, pedestrian areas, etc.
4. *Architecture and Building Engineering:* Building design, installations, structures and construction of buildings.
5. *Consulting:* Technical reports and specialized consulting.

4 Operating Scheme of an International Project Under the British System in M.E.N.A. Countries

In the management system used in countries of the MENA region (Middle East and North of Africa) to develop architecture and infrastructure projects, there coexist a wide range of professional profiles interacting with each other, which could be structured in general as follows:

1. **Investor—Promoter:** Investor decides he wants to invest in one property and hire a consultant Feasibility and Profitability.
2. **Consultant Feasibility and Profitability**: analyzes the market advising on product type (type of housing, quality, etc.) also analyzes the market, sales price and maximum costs for selling the investment is profitable.
3. **Trader Developer:**With the data provided by the Consultant Feasibility and Profitability, Trader Developer hires the best for the optimal development of the project.
4. **Project Manager:** the developer hires the Project Manager, acting as general coordinator of the process and means the team of editors of the various types of projects needed to carry out works and to prepare specialized reports.
5. **Team of consultants and Project designers usually required**: an interdisciplinary specialized team is frequently required. Usually profiles required for these projects are the following:
    1. Master planning (Urban planners, Civil Engineers, Architects)
    2. Landscape (Landscape designers, Biologists)
    3. Infrastructures (Civil Engineers, ITC, MEP Engineers)
    4. Architects and Building Engineers
    5. Structures consultants
    6. ITC consultants (Telecom. Engineers)
    7. MEP and FF consultants (mechanical, electrical, plumbing and fire fighting engineers) and other specialized consultants as required.
6. **Building company or construction team.** Company responsible for developing the project by constructing the infrastructure, landscaping and buildings planned (Fig. 2).

5 Comparative Analysis Between International Projects Under the British System and Current Spanish Projects Management System

In comparison with the management system of Spanish building projects, where there are currently four main Figures (the developer, the builder, the architect and engineer of building), in the system used in countries of the MENA region (Middle

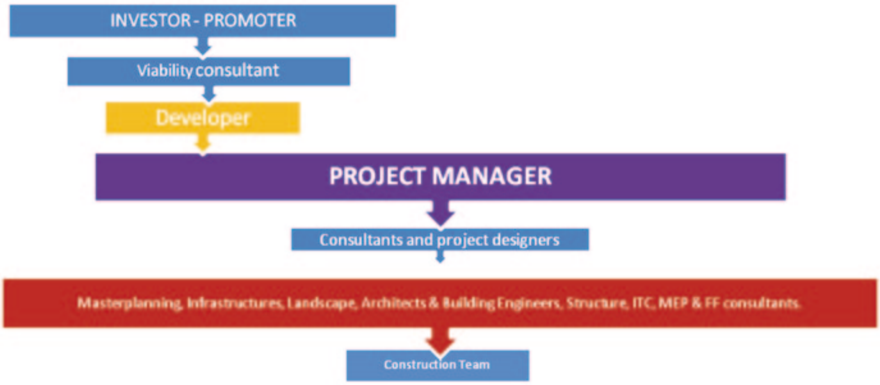

Fig. 2 Operating scheme of an international project under the British system. (Authors 2012)

East and North of Africa) there coexist a wide range of professional profiles interacting with each other. Therefore, we analyzed the main differences between both project management systems:

1. **Investor—Promoter**: This figure is similar to the existing management system in Spain. Notechnical specialization is required; it can be only an investment company.
2. **Consultant Feasibility and Profitability:** In our system, the feasibility study carried out on promotions, determines the maximum cost to be considered by the masterplanner and the consulting project teams and should be adjusted to that figure, while in British system this report can be considered merely as an additional advice to the investor's decision.
3. **Trade Developer:** It is not an independently existing figure in our market, so it is customary for the developer to develop these functions, either directly or indirectly.
4. **Project Manager:** It is a prevalent figure in Spain, but only in works of great specialty, size or complexity.
5. **Team of consultants and project designers,** the main differences observed are:

   - Master planning: In Spain, even without that profile with this same name, it is an architect specialized in urban planning which develops these functions. To perform a full Master plan, it is also taken into account the necessary infrastructure and the cost study (and maximum costs set by the Consultant Feasibility and Profitability).
   - Landscape: is developed by specialized landscape architects, although in Spain this type of work is usually included in the general building project, not being an independent project as it tends to be in the British system.
   - Infrastructures (civil engineers, ITC, MEP engineers): in Spain, these functions are developed within their own development projects, so it does not require independent professionals.

- Architects and Building Engineers: There currently are equivalent figures in the national market.
- Structures consultants: advice the team of architects who developed the project promoter, in a similar way as in the British management system for Building projects.
- ITC MEP & FF consultants: advice the team of architects who developed the project promoter, in a similar way as in the British management system for Building projects.

6. **Building company or construction team:** Construction Companies in Spain usually enters the management process of construction projects, near the end of the design period and immediately before the tender process and the start of construction. However, in the British system used in the countries of the MENA region, the construction company is involved in the process even during the project design process, providing information about the building materials to be used in the future development of the work, technical requirements, necessary equipment and details to be considered for the project and that will be taken into account during the construction works.

6 Conclusions

To sum up, we could conclude that, in general, the number of teams or consulting companies required to develop a building project under the British project management system is much higher than the ones usually needed in the Spanish one, so that costs and the construction development period could be considerably reduced. As a possible future research, we could suggest the research on the possible benefits of the multidisciplinary adaptation of the British system to our current project management system, considering all technical profiles graduates of our universities since the implementation of the Bologna Process.

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The Professional Career of Spanish Architects: Obstacles and Facilitators

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Abstract Architecture as a profession has been already studied in countries such as Australia, Canada, France, the UK and the USA. However, there is a paucity of work with respect to the situation in Spain, a geographical context with specific cultural, social and economic features. In an attempt to address this research gap, we aim to depict Spanish architects' experiences and concerns regarding their career and professional life. This paper draws on qualitative data comprising 38 semi-structured, in-depth interviews with Spanish architects of different age, gender and employment setting. Findings show that social capital is among the factors helping their careers the most, while women also identify reasons related to gender and work-family balance as a barrier.

Keywords Architecture • Careers • Qualitative research • Spain

1 Introduction

Existing research in the architectural profession has focused on different countries such as Australia [1], Canada [2], France [3], the UK [4–9] and the USA [10]. Literature review suggests that Spain has not often been the setting for research studies about architects. In fact, only the recent works authored by Sánchez de Madariaga [11, 12], focused on women architects, and reports analysing the state of the profession through surveys to registered architects [13, 14] have been found.

Most of these empirical studies have focused on women and the lack of equality in architecture [1, 2, 8, 10–12] and why women leave [7]. A dearth of research has also dealt with motivations for entering the profession and remaining [6, 9, 15], with job satisfaction and work purpose [4, 5] as well as with ways of handling the profession [3].

At present, the fact that professional occupations are different between nation-states and that contexts are constantly changing is well accepted [16]. Some authors

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defend the study of state-specific projects in order to show international similarities and variations [17]. Besides, learning about different national systems and their cultural contexts "helps to inform us about the constraints and opportunities existing in our own" [18]. Research approaching the influence of cultural diversity on the realities of work in the architectural profession, is still at an incipient stage. This supports the case in favour of this paper, which sheds light on Spanish architects' work. We aim to explore and depict Spanish architects' experiences within their career, identifying the barriers and drivers they have met.

2 The Spanish Context

When attempting to find data regarding the structure of the profession in Spain, it is evident that the "Consejo Superior de Colegios de Arquitectos de España" (CSCAE), an umbrella organization for the professional bodies, keeps very little in the way of records and lacks transparency, with scarce updated information on professional earnings and modes of practice. On the other hand, there are no contributions or studies made to the sector study commissioned by the Architects' Council of Europe [19]. Indeed, other authors have mentioned the paucity of information on the profession in Spain referring to the "absence of specific studies" [11, p 206].

Spain stands out as the third country with the largest number of architects in Europe, 50,000, following Italy (145,000) and Germany (100,500) [19]. Analyzed as a proportion of the population, the Spanish 'density' of architects is 1.1—measured as the number of architects per 1,000 population—which is above 0.9, the average European density of architects. Half of them are located in two cities: Madrid and Barcelona. Furthermore, there are 31 schools of architecture with 30,149 students enrolled and architects' supply keeps growing at a speed of 3,000 per year [20].

Recent data from the CSCAE reveals that in November 2011, there were 50,205 registered architects, 71 % male and 29 % women. In terms of the gender divide, Spain seems to reflect greater equality than other countries such as the UK or France with 14 % and 22 % of registered women respectively [15]. However, in Spain, women entered the profession later, and they concentrate, in a higher percentage than their male colleagues, in the professional categories of salaried, civil servants or teachers, clearly showing horizontal segregation [12]. In general, it is a young profession, with an average age below 43 [14].

As regards the mode of practicing, the 2007 survey on the state of the profession shows that 68 % of registered architects worked as "professional liberal" with their own practice (22 % at a limited company with partners), 22 % were associates or salaried, 8 % civil servants for the public sector and around 2 % were devoted to teaching [13].

In relation to earnings, the average gross annual salary of architects is 15,842.89 €, while for professionals working abroad is 24,564.71 € [21]. 18.2 % earn between 6,600 and 15,000 € per year, 17.6 % between 15,000 and 21,000 and only 1.9 % earns over 39,000 €. Due to the present economic downturn, 63.1 % confirm that their salaries have been reduced and 26.7 % are unemployed.

The 2011 trade union survey also acknowledges the existence of a widespread illegal practice among Spanish architectural practices: 24.4 % of participants are currently working as "false self-employed" and 70.6 % confirm having done so before [21]. This is an illegal category of workers which conceals an employee-employer rapport simulating a commercial rapport between businessman and customer. Under this category the architect is not hired but has to carry out all kind of tasks with no social rights, unemployment benefits, and sick or maternity leaves, being also subjected to the employer's will in terms of holidays, working schedule, intellectual property, etc.

3 Method

In-depth biographical interviews were carried out with 38 Spanish architects. The interviews explored reasons for choosing the architectural profession, factors which have helped or hindered their careers, as well as the realities of their working lives, analyzing pressures and satisfactions. This paper summarizes the outcomes of the analysis of two sections of the data related to the research objectives: career obstacles and facilitators.

In reference to the sampling strategy, 38 architects were selected via the membership list of the professional regulatory body (Colegio Oficial de Arquitectos) of two Spanish regions: la Comunidad Valenciana and Castilla la Mancha. Both regions show a mixture of contexts for architectural works from urban to rural and public and private sector projects. The principle of saturation was applied for determining the sample size [22].

Interviews were conducted face to face between February and April 2011. They varied in length between 30 and 120 min, the majority of them were conducted at the participants' architectural practice, some at the researchers'offices, three at cafeterias and one at the interviewee's home. All interviews were recorded and transcribed prior to analysis. Data were analysed following the conventions of content analysis [22].

The sample consisted of 38 architects, of whom 20 were men and 18 women. Their ages ranged from 27 to 60: 4 respondents were under 30; 14 between 30 and 40; 9 between 41 and 50; and 11 were over 50. 34.2 % were childless, while 23.7 % had between 2 and 4 children, 34.2 % had two children; and 7.9 % had one child. In relation to their mode of practice, a wide range of occupations has been studied: full-time employees in local public sector authorities, full-time salaried professionals at construction companies, principals of partnerships, sole practitioners, "false self-employed" and both part and full-time university lecturers. Reflecting the current Spanish economic situation, 4 women architects were unemployed when the interview took place.

In line with the profile of European architectural practices [19, p. 44), the size of the 16 practices participating in this research is clearly skewed very heavily towards small firms: 4 are one person firms, 11 have between 2 and 5 architectural staff, which includes principals, partners and directors, associates, salaried architects and technical staff and one was a bigger practice with 14 staff. Other organizations represented in this research are public and private Universities (Schools of Architecture), small and medium town councils and construction companies.

4 Results and Discussion

4.1 Career Facilitators

When asked about factors helping their careers, all architects point out the importance of their social capital, that is, who you know as distinct from what you know. As defined by Pierrre Bourdieu [23], social capital is the sum of resources that accrue to a person or group from access to a network of relationships or membership in a group, tribe or club that can produce useful relationships. In this research, participants outlined their professional connections, people they knew that had helped them in getting clients. This is true not just for self-employed architects, but also for architects working in the civil service and even for those working at the University.

This supports the fact that recruitment methods in Spain are informal, favouring personal contacts, unsolicited applications and internal advertising [24]. In the light of our interviews, the strategy of "pulling strings" seems to be pervasive in the Spanish architectural labour market. Family members, friends, former clients, colleagues at work or even ex-teachers have been facilitators for our participants:

> My dad was a developer and I knew people from the construction sector. He introduced me to a quantity surveyor who was a family friend and he allowed me to meet people. That was my beginning and my facilitator. For some of my University colleagues who didn't have connections, the process was much longer. At the time I had 400 houses being built, they had only done the refurbishment of just one house. (Nº 23)

Pierre Bourdieu's framework of personal assets [23] has been most influential in Europe, explaining how people not born into money can still be successful in capitalist societies, through their use of other forms of capital. Some people get ahead because their talents get them into the right schools or universities (cultural capital); others make the right kind of friends (social capital).

As it was expected, due to the strong vulnerability of the Spanish construction industry in relation to changes in the economy [25], the economic situation was highlighted either as a driver or barrier, depending on the direction of the economic cycle. Older participants clearly remember the various economic downturns they lived trough and their negative influence in their studios. As a 59 year old architect, principal of a medium size partnership, states:

> I've experienced the economic downturn of the 70's, the one of the 90's was also tough. In the 80's there were also some difficult years but we survived. During the economic crisis of the 90's there wasn't too much work, we had difficulties, but this is the worst, this is a financial one with structural consequences in construction and real estate markets. Nobody

> has escaped. We had lots of work every year and now there's no urban planning, no industries, no housing, nothing. We even have projects with building permissions that we haven't been able to develop. (Nº 30)

In addition to their social capital and economic influences, the following positive personal traits have been highlighted as drivers in their careers: work capacity, hard work and effort, responsibility, flexibility, empathy when relating to others, curiosity, will power and above all, eagerness and desire for learning.

4.2 Career Obstacles

The most striking result among the evoked constraining career factors is related to the lack of gender equality in Spain. Although the interview guide did not include any specific question aiming at surveying opinions about gender diversity, expressions such as "being a woman" and "work-family balance" appear as negative aspects among women. Gender barriers existed both within the firms (micro level), in the wider working environment involving clients and construction site workers (meso level) and in the wider social, cultural, political and economic context (macro level).

In the first place, at a micro level, we found examples of women complaining about male employers being discriminatory and paternalistic when supporting traditional gender roles at the studio. As a 35 year old interviewee explains: *"Had I been a man, I'd have had access to certain parts of the job, it would have been easier for me to go on site, or to carry out projects with more autonomy. My bosses were the ones controlling the building site, my work had to do with the plans, and I stayed at the practice… because we (women) are supposed to be tidier and calmer". (Nº 2)*

Another woman also mentioned how male architects she had worked for preferred to hire women, since they thought "we aren't as competitive, we complain less, are less ambitious, work harder and are more faithful". Workloads were always divided and while women ended up drawing the plans and projects, men were in charge of the social relationships with clients and of the site control. In agreement with Agudo and Sánchez de Madariaga [12, p. 167), women architects "are pushed into the background, becoming invisible for the client, taking on the work inside the practice with little attention" and maintaining occupational segregation.

Secondly, at a meso level, several women reported not enjoying working on building sites. A 58 year old interviewee, recalls with bitterness her first experiences on site in the 80's: *"Women do have a handicap there, you would go on site and they would start whistling at you, and you're supposed to be the site director. I suddenly started disliking the site" (Nº 18).*

Still, according to the words of a 27 year old participant, things on Spanish sites seem to remain unchanged nowadays, since construction workers do not take a woman seriously: *"you're just a beautiful face for them and that's all*". This Spanish result differs from the situation in the UK, where courtesy and respect, instead of whistling or calling out, are widespread on site [15].

Client organisations were also seen as problematic in perpetuating gender stereotypes. A 43 year old respondent was restricted to designing small projects because a developer *"wouldn't place his investment in the hands of a woman, especially if she's young, that was an obstacle I felt I couldn't overcome, I always had to resort to my male colleagues at the practice." (Nº 26).* Our interviewee here felt her career opportunities were being restricted as she was not being given an opportunity to prove herself.

Finally, macro level barriers were also raised in relation to work-family balance. Most women architects with family responsibilities illustrated this barrier as follows: *"when I decided to become a mother*. That was *a burden for my career because the fact of asking for part-time was like passing to another level (…) my professional life was completely cut short"* (Nº 3). Some traditional attitudes, which pervade Spanish culture were outlined: "*it would look bad if a man said "I can't attend the meeting because I have to go to pick up my son". So traditionally it looks better if you go (the female)… (Nº 36).*

Spain belongs to the Mediterranean welfare regime, also known as "familialistic". This model views caring responsibilities as a private duty, and families (women) have assumed and played an important role in the care of dependents, while public administration just helps people under extreme circumstances or social exclusion. In line with this, State provisions for families are much more limited in Spain than in other European countries. Since public family policy is very weak, it is the family itself who somehow takes over the role of institution. Obviously, this compensates for the lack of work/family policies [26].

5 Conclusions

Social capital and networks of influence, rather than personal merit, emerges as one of the main career drivers for Spanish architects, something which has not been acknowledged in previous research on the profession.

In relation to gender, despite there being more women registered in the professional body and studying architecture than in other countries, this 'critical mass' has not served to improve their situation, as they report high levels of discrimination and find it difficult to progress in their careers. The gap identified in the literature review, together with the results of this exploratory paper and comparison with works in the UK, clearly show the need for further specific analysis of the situation of Spanish women architects.

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The Role of Corporate Architecture in Urban Transformation an Italian Paradigm the Chiesi Research and Development Building 2011

Maria Pilar Vettori

Abstract Corporate architecture is a significant field for the research on the themes of complexity, multidisciplinary and interscalarity that caracterize the transformation of the scientific paradigms of the technological project. In the light of the extensive changes taking place in where and how work and research are carried out, together with the move from mass production to streamlined production, the spread of new technologies, flexible working and the increasing fluidity of society and markets, corporate architecture has assumed a significant and strategic role in the shaping of cities and the transformation of the landscape. The new Chiesi Research Centre in Parma (Italy) is a part of that scenario: an initiative that finds its premise within the processes of structural expansion, organisational rationalisation and technical innovation that are leading design research to offer new levels of performance and services, that maintain the balance between speed of change and the demands of the longer term.

Keywords Corporate architecture • Project management • Technology

1 Introduction: Objective and Methodology

Objective of the work is to study the contribution of technological innovation in terms of systems, methods and processes for the project, in the case of corporate architecture. The research uses a methodology aimed to derive from a concrete paradigm important guidelines to face the project organization.

In the history of modern architecture, corporate buildings, as places of work and social ferment, have always been a field for formal research and immaterial innovation. The contemporary corporate architecture represents a strategic architectural type of great importance for the future of the city. Condensing urban functions and methodological approaches, it involves both regeneration processes of public spaces and the interacting factors involved in the transformation and regeneration of disused areas of the territory.

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In the light of the extensive changes taking place in where and how work and research are carried out, together with the move from mass production to streamlined production, the spread of new technologies, flexible working and the increasing fluidity of society and markets, business-related architecture has assumed a significant and strategic role in the shaping of cities and the transformation of the landscape.

From the methodological point of view, the architectural project of a contemporary paradigm (the Chiesi Resarch and Development Centre) therefore can serve as a privileged place of research on the themes of complexity, multidisciplinary and interscalarity that are currently fueling the debate on the transformation of the scientific paradigms of the technological project.

2 Corporate Architecture in Urban Transformation

The supersession of Fordian logic, in which productivity is the primary objective over and above the architectural message, coincides with the new era of the corporate type building. This logic leaves aside the issue of integration into the geographical or cultural context: in the great conurbations such as London, Marseille, Istanbul, Lagos, São Paulo, Mumbai, Singapore, Shanghai, Hong Kong or Tokyo, the demographic increase and urban concentration, caused by local and global migration, together with the concentration of technico-financial and economic resources as well as communications and human resources, form the engine of corporate architecture [1]. Meanwhile the age of information and access has replaced the compartmentalisation of human activities with a "collective mentality", that creates a need for integration, multi-functionality and new synergies.

In such a strategic valorisation process of the city, the Italian context is a scenery for the current architectural debate, by reassessing its own role of privileged context within which theoretical reflections and substantial reasons deepen their roots in a solid cultural background to be thoroughly reinterpreted and reviewed.

Reflecting on the role that the corporate architecture has been playing in the production of Italian architecture of the twentieth century, means interrogating ourselves on the meanings that "modern" has taken in the European cultural context, with respect to a concept of construction that has ever been representing the characterizing trait of the transformation processes of the city and of the territory.

The European critical thought, divided on the American issue between the interest towards the technological aspects and the pressures exerted from the architectural tradition, orientates its own research towards the coding of typological models being capable to interpret the needs of the society rather than tending to define forms suitable to represent interests of economic nature.

In Italy the large scale changes generated by urban growth phenomena, the logic behind the location of industrial and residential settlements, the location of services, the development of the infrastructural systems, invite to define recognizable models capable of interpreting the physical and cultural context: many corporate buildings suggest different interpretations of the genre, by triggering a critical-theoretical debate about their relationship with the urban context.

The Pirelli Skyscraper, designed by Gio Ponti in the period 1955–1958, inaugurates the age of italian corporate architecture, given its role of conveyor of the principal's image and renewal strategies. It is conceived like a monument, overwhelming, isolated, having a high communication value and it can be considered the first example of italian modern project management.

Gio Ponti, Pier Luigi Nervi, Franco Albini, Ignazio Gardella, Marco Zanuso, the BBPR, and may others represent the protagonists of a technical and formal research by consolidating also the Italian contribution to the construction of the new imagine of the corporate architecture [2].

The hope for a deeper debate on the control strategies and methodologies, the evolution and shape of the cities shall have to concern all the involved discipline spheres: technology represents with this respect a useful tool for the dominance of cultural and designing intentions of an extremely complex age [3].

In the society of networks, corporate architecture, located between formal quotes and technological contaminations, does represent a topic which favours the comparison between the trends and the development of the contemporary building. The increasing integration of *design*, technology, structural designing and building plant designing, and energy saving strategies, shall lead towards an interdisciplinary designing model being able to combine such aspects in their interacting complexity, by crystallizing them into a unitary form.

2.1 The House of Research: An Italian Paradigm

The new Chiesi Research Centre is a part of that scenario: an initiative that finds its premise within the processes of structural expansion, organisational rationalisation and technical innovation that are leading design research to offer new levels of performance and services, that maintain the balance between speed of change and the demands of the longer term.

The position of the site, that has a high strategic value given its proximity to major infrastructural elements (the airport, motorway and high speed railway line), made it necessary to assess the character of a major access point to the city of Parma, from an architectural and town planning point of view, as an element that is indicative of the landscape of the city and of its ability to compete nationally. Hence the design aims to achieve reconciliation with a landscape dominated by infrastructural works, by means of a structure with a very urban character which is modelled on the concept of a "corporate citadel" consisting of open spaces and structural elements that differ in character both functionally and morphologically.

The concept of functional integration, introduced with the supersession of Fordist logic, translates into a planimetric arrangement founded on the compositional concepts of aggregation and connection and, at the same time, of rotation and transferral, aimed at differentiating areas by the layout of the spaces and the links between them.

The functional layout of the buildings results not only in areas expressing a distinct flavour and style, but also in an offering of integrated, interactive and all-encompassing spaces for services and quality of the environment, as well as integration with the landscape and green areas in order to guarantee a high degree of comfort and quality of the work space.

The heart of the complex is the building accommodating the research laboratories and offices, around which are arranged the buildings and spaces housing the various essential support services which can be summarised as technological (utilities and plant), functional (warehousing and stores) and organisational (security, parking and ancillary buildings).

The generous proportions of the main building are a reflection of the company that occupies it. The layout of the floor-plan came about through a process of optimisation of the work space and customisation and differentiation of the various functions without sacrificing their integration: three wings (two used for laboratories and one for offices) connected by a barycentric element (the atrium) intended to form a vertical and horizontal interconnection point as well as a meeting point containing services and areas set aside for social interaction (meeting rooms, conference room and seating and entertaining areas) conditions of work hallmarked by multiplicity, creativity, team spirit, communication and motivation.

The era of information and easy access has replaced the compartmentalisation of human activities with a "collective mentality", that generates a need for integration, multifunctionality and intra-company relationships. The search for quality is based on the non-standardisation of spaces, of levels and the logic of traffic-flows, in an attempt to create areas on a human scale within a large-scale structure: floors with different layouts, differentiated common areas, internal pathways and piazzas, and theme-based areas.

The floor-plan of the entire building complex is based on the identification of appropriate functional modules that relate to the spatial and dimensional demands of the work and the research activities that in turn determine the differing depths of the buildings, thus defining the spans of the load-bearing structures and establishing the pattern for the cladding.

The design, in contrast to the recent trend of transitory fashions, that turn the breaking of geometric patterns into expressions of their own style, relies on the power of the elements of orderliness and rationality, heightened by the generous dimensions, expressed in the even spacing of the rigid structural framework and the modularity of the components of the building envelope [4].

This leads to a material differentiation also of the volumes: the light transparency of the central element is contrasted with the massive and solid appearance of the two structures set aside as laboratories, and the office building that is narrower and more adaptable due to a cladding system that seeks to maximise the amount of natural light reaching the work stations inside.

The material and chromatic properties of the elements making up the façade characterise an envelope that is not detached from the activities being carried out inside, finding in the geometric structure of the elements, in the composition of the parts and the modules, and in the different technologies an expression of its own style.

Within this logic the envelope presents an opportunity for research and specialised design, encompassing a stratification of various functions: the technical and structural themselves, the management of internal comfort, and image.

In case of corporate buildings, the awareness of energy issues becomes even more important if we consider the huge amount of energy required by such facilities: the contemporary approach is based on the use of ever more complex technologies able to reduce consumptions and making such facilities as much as possible energy self-sufficient.

Two main objectives are targeted: the optimization of thermal exchanges through high-performance lining materials and components for the cladding and energy self-sufficiency through passive-mode systems to meet – even if partially – the energy needs of a building.

Modern strategies aiming at the reduction and optimization of consumptions have been focussed on the identification of the most suitable technologies being compatible with the typological features of the corporate building in order to achieve a remarkable reduction in the building management consumptions. Such technologies have to be fully and harmoniously integrated in the building design therefore becoming integral part of the project objectives. Such an approach – based on a rethinking of design practices in the light of environmental issues – seems to be the only feasible approach to give convincing answers as to the design performance and to sustainable development of the 21st century city.

The definition of an unambiguous model applicable to the different geographical realities is therefore impossible, on the contrary it is necessary to develop actions directed through punctually designed strategies.

The design of the new Research Centre, in accord with the requirements of contemporary architecture, addresses the issue of energy resources in line with research that is increasingly oriented towards the use of technologies that reduce consumption and make production structures as energy-independent as possible. Through a multiplicity of solutions, from the orientation of the buildings, to the regulation of daytime lighting and direct sunlight, to the choice of low maintenance materials through to the strategy for building plant, the project pursued the twin objectives of optimising thermal exchanges through very high performance components and cladding materials for the envelope, and generating energy using passive systems to meet, in part at least, the building's energy needs.

A sustainability not interpreted merely as a cliché but as a design aimed at the application of high technology systems and materials, the utilisation of sustainable techniques and materials, the optimisation of surfaces and volumes to limit thermal dispersion and the sensible use of transparent materials. As with any architectural project of high complexity, the new Chiesi Centre is the result of a systematic integration of collective contributions focussed on a common goal, from the initial design phase to completion of the execution: an integrated collection of activities by different professions that brings together architectural design and engineering solutions aimed at the creation, the durability and the real sustainability of an architecture that aspires to make a contribution to a town's urban values and to be the expression of a company's ethical values.

2.2 Conclusion: The Role of the Architect in the Complexity of Building Management

The principal developments carried out in the contemporary panorama of corporate architecture are founded on operating models characterised primarily by a private clientele (banks, companies, businesses), by reduced construction times for reasons of financial investment, and by location in areas with high property values. Within this scenario the demands of the client have led to a radical separation of the conception and construction phases of buildings: if in the former priority is given to the communications potential of the architectural concept, even ahead of the feasibility of its construction, when the operation meets the political, economic and technical conditions for its realisation, preference is given to the adoption of codified design methods and processes that can be monitored through structured engineering.

In the disorder generated by solutions that are increasingly flashy and spectacular, the individuality of the architectural work is enhanced at the expense of a collective and organic vision of the design process. By contrast, often the only operational logic focussed on the optimisation of times and costs places rationalisation and procedural control at the centre of the process at the expense of the continuity of the concept of the project.

In the face of pressure from the clientele and for financial reasons, today there is a risk that the architect could lose his role as interpreter of the needs of society, giving up working for the betterment of environmental quality and of the cultural independence of the community, reducing himself ever more to the role of a "stylist" of forms and messages.

The corporate building, more than other buildings, has placed before the architect issues of the management of complexity, of the necessity for mediation with the clientele and settling of financial arguments, of the importance of a systematic and disciplined approach.

Since many years the decisive role of the business world emerges in its ability to transform the industrial project into a project for the evolution of society capable of combining productive efficiency with environmental sustainability and social issues.

Corporate architecture can be assumed as occasion to investigate the issue of managing complex projects and to understand the dynamics of modern Project Management: new approaches to design that can help to interpretate a dynamic and flexible context that requires well-defined techniques and methodologies, demonstrating the activities required at an organizational and managerial level in order to lead complex architectural projects to success. The new Chiesi R&D Centre is one of the many examples of application of the techniques of Project Management combined with the quality of project contents in answer to the complexity and eco-compatibility of projects required by the modern context.

In truth, the corporate architecture, in its complex dimensions, can continue to be the paradigm of modernity [5]: a modernity no longer interpretable as a purely technical possibility, but, as in the temples of the Pirelli Tower and the Seagram Building, as a "mental attitude" and the capacity to express itself through a designing methodology and not through the absoluteness of either linguistic or technical values, without anyway renouncing to the communicative value of architecture (Table 1; Fig. 1).

Table 1 Chiesi research centre, design team and data

Location	Parma (PR)—Italia
Client	Chiesi Farmaceutici Spa
Chronology	2005–2009 *project*
	2009–2011 *realization*
Urban planning	Emilio Faroldi Associati
Preliminary project pharmaceuticals	Jacobs Engeneering Group Inc.
Architectural design and art direction	Emlio Faroldi Associati
	Designers Emilio Faroldi, Maria Pilar Vettori
	Chief architects Francesca Pesci, Laura Piazza
	Architects Dario Cea, Pietro Chierici, Francesca Cipullo, Roberto Grassi, Andrea Roscini
Engineering design and construction management	Jacobs Italia SpA
Dimensional data	60,000 sq *land surface*
	*28,*400 sq *gross area built*
	27.5 m *maximum height above ground*
	6 *number of floors above ground*
	22,*000* sq *green area*
	450 *workstations*
Cost of construction	90,000,000 €

Fig. 1 Chiesi research centre, Parma Italy 2011

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Perceptions Prediction Model in Architectural Library Spaces

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Abstract Determining as "Good design" architectural products is an extensively studied topic. Moreover is a constant discussion between technical colleagues.

Most of the currents investigations analyses these factors from the empirical point of view attending established parameters from different associations or lobbies, such as functionality, adaptability and accessibility among others. However there are quite subjective components inherent to every new architectural creation, such as perception of good design, versatility and sense of comfort, what makes completely necessary to incorporate techniques which allow analyzing these perceptions in a quantitative way.

Kansei engineering is a designing technique which allows picking up emotional users needs and establishes prediction models in order to connect product characteristics with those emotional needs. This technique could allow to limit to the point till which certain sensations are based on objective characteristics or which of those are just subjective perceptions, no less predictable because of this.

This research aims to analyze, throughout the Kansei Engineering, perceptions users have from the Universitat Politècnica de València campus libraries.

Results may be interesting for engineers and architects, planning their architectonic and designing solutions in order to maximize human wellness.

Keywords Kansei engineering • Emotional design • Perception • User response • Libraries

1 Introduction

Much has been written about the design of library buildings conformed to the objectives of the century and it has tended to focus on space, services and user needs.

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In the 1980's and 1990's, some regarded learning resource centers as a new building type with qualities distinct from traditional [1]. But today as McDonald postulated [2] new libraries offer similar facilities and in practice are "hybrid" services with, perhaps, a different balance of traditional collections, electronic services and reader places, whether in support of learning and teaching, or of research or both.

Nowadays the International Federation of Library Associations (IFLA) based on the research of Harry Faulkner Brown and his 10 commandments, establishes guidelines for library buildings by 10 basis points to a more holistic and humane point of view. They are founded on researches and experiences designed by technicians and professionals based on their knowledge of the parameters involved in the process of creating an architectural space. These works however do not deep onto the subject's emotional reaction. Working the subjective part of the process requires a methodology that takes into account these users subjective perceptions.

From the field of user-oriented products it's been developed a methodology to identify and quantify the sensations or feelings that a product produces in the user, thereby incorporating into the design the "voice of the user". Kansei Engineering Systems (KES) is a design method to determine the emotional needs of users and establish predictive models to relate the objective characteristics and product configurable parameters with the emotional realities of users [3]. This technique allows defining how certain feelings are based on objective characteristics or parameters, and which are merely subjective perceptions, not least predictable. Once established the objective characteristics from the user point of view these can be parameterized in design objective concepts and quantify its interrelationships. The methodology consists of two distinct phases [4], the first identifies the set of expressions or feelings that users use to describe the perception of the analysis matter. This phase is performed using semantic differential following Osgood et al. [5]. The second phase will identify the elements of design, parameters or conditions that cause these feelings on the end user. The techniques used in this second phase may be, among others, linear regression [6], [7] or fuzzy logic [8].

The novelty that this tool presents respect some other methodologies that have been being used is that the attributes that are taken as a basis for finding the relations with the design parameters are not defined by the experts, but otherwise, involves users in the definition. This way, the user communicates directly, eliminating the filter that is imposed in most studies, in which the user desires are interpreted by researchers, experts or manufacturers. Only once defined the variables that measure the user's subjective response, it is possible to establish the relationships between each perceived attribute on the overall valuation of good library.

The aim of this paper is the applying KES engineering in the analysis of a good library at Universitat Politècnica de València campus (UPV).

Table 1 Descriptive analysis of libraries areas, m^2

Library	*ETSICCP*	*ADE*	*ETSINF*	*ETSII*	*ETSID*	*ETSIAMN*	*BBAA*	*ETSA*	*CENTRAL*
Area (m^2)	250	421	495	500	543	600	600	700	5762

2 Methodology

2.1 Field Study

The methodology focused on a field study which collected both areas of architectural spaces, as the judgments made by a number of respondents for each of the libraries analyzed.

This involved 324 libraries users of the UPV, most of them were students (95.5 %), although responses were obtained from teaching and research staff (2.7 %) and administration and services staff (1.8 %).

The set of stimuli consisted of the total of 9 UPV libraries. These spaces have several and distinct features as some of them are single study rooms of the different college schools. Table 1 shows the size range the different libraries present.

The survey included two types of information, the objective one gives the performance of the subject (gender, age, frequency going to the library, studies, relationship with the university…) and, secondly, the subjective information for the Semantic Universe, consisting of 61 descriptive adjectives of the emotional reaction of library users. To obtain this semantic universe, an initial search of words among library users was made (427 adjectives), these after applying Terninko criteria's [9] were reduced to 61. In addition to this list, we included a variable reflecting the overall assessment, from the expression "Overall, I consider it as a good library." For the evaluation of each library a 5-level Likert scale was used, with ratings as: strongly disagree, disagree, neutral, agree and strongly agree.

2.2 Data Treatment

For the data treatment various statistical analysis techniques were used with the SPSS 17th software.

On first term, a principal components factor analysis (PCA) was performed, reducing the Semantic Universe. Secondly a reliability analysis was made for each of the axes with the Cronbach's Alpha to check the consistency of each of them. The PCA technique allows to structure the set of emotional attributes of the subject according to their own conceptual scheme. PCA identifies the set of concepts that users use to describe their emotions in a library. In addition, the factors obtained by applying a PCA are completely independent, ensuring that these perceptions are unrelated to each other, which is essential for the following phases.

Next step, and in order to quantify the impact of each factor on the overall library assessment the technique of linear regression was used. Using as the dependent variable the question "Seems to be a good library" and the set of factors as the independent one from the previous phase. This technique allows to sort the set of subjective variables that affect the overall assessment of the subject.

Subsequently, and in order to check whether there were significant differences in the responses of different groups of subjects (based on the variables gender, age, education, relationship in college…) the technique of analysis of variance (ANOVA) was applied. This technique was also applied to identify whether there were differences in responses based on the characteristics of the libraries analyzed (area of the library, type of space: open or close room…). Once identified the variables that cause differences in the subjects responses averages were analyzed for each group in order to analyze in detail these differences.

Finally, the quantitative model validation was performed in order to estimate the overall assessment of a library. Such validation was performed from a control sample of 20 surveys. These questionnaires corresponded to the responses on Escuela Técnica Superior de Ingeniería de Edificación (ETSIE) library that had not been used in previous phases. Therefore, we have compared the results of this control sample with the predicting model.

3 Results

Semantic space obtaining Using a principal component factor analysis reduced the 61 variables of the survey in 15 independent factors that explained 62.77 % of the variance. Table 2 shows the semantic axes and the corresponding correlation with the original expression, the percentage of variance explained and Cronbach's alpha.

In this paper, in view of assessing the consistency of the measures, we used Cronbach's alpha. Of the 15 semantic axes obtained in 8 of them this ratio showed values greater than 0.6. According to Hair [9] alpha's below 0.6 shows an unacceptable level of reliability in exploratory research. These were: good design, silence and calm, friendly service, good distribution and functional, with good temperature, clean and tidy, pleasant and friendly and versatile. The other factors are eliminated by the presence of low levels of consistency.

Impact of factors on the overall library assessment Having identified the semantic space axes corresponding to the key attributes or qualities used by users in assessing the different libraries, the importance of each of these independent axes was determined. For this, axes were related to the overall library valuation and identified the axes or concepts that had a major influence on the overall judgment about a particular library.

Linear regression between the independent factors corresponding to the axes identified as consistent and the overall valuation variable "Seems to me a good library" was quantified by the following expression, with a correlation coefficient of 0.71:

Table 2 Semantic axis synthesis

Axis	Factor	Semantic space which includes	Variance %	Cronbach's Alpha
Axis 1	With good design	Innovative (0.816), Smart (0.753), New (0.742), Cool (0.703), With good design (0.681), Original (0.666), Current (0.662), Luxury (0.587), Atractive (0.531), Quality (0.488), Dynamic (0.478), Chest (0.419), Happy (0.426)	11.49	0.90
Axis 2	Silence and calm	Silence (0.850), Quiet (0.849), Lets concentrate (0.720), With good environment (0.609), Busy (−0.559), With privacy (0.532), Serious (0.524)	6.80	0.84
Axis 3	Friendly service	Good loan service (0.754), Well managed (0.661), Good customer service (0.645), Teaching (0.417)	4.76	0.80
Axis 4	Good distribution and functional	Well distributed (0.689), Functional (0.580), Practice (0.489), Well equipped (0.484), Comfortable (0.425)	4.59	0.70
Axis 5	With good temperature	Cold (−0.727), Good temperature (0.600), Humid (−0.573), Warm (0.570), Hot (0.407)	4.40	0.63
Axis 6	Clean and tidy	Clean (0.740), Sorted (0.644), Adecuate colors (0.530), Poor (−0.408), Cramp (−0.407)	4.28	0.73
Axis 7	Nice and cozy	Nice (0.629), Cozy (0.526), Pleasant (0.472)	3.78	0.73
Axis 8	Well organice and afficient	Well organized (0.509), Efficient (0.494)	3.24	0.50
Axis 9	Versátile	Versatile multipurpose (0.623), Well computered (0.610)	3.23	0.64
Axis 10	Wide opening	Wide schedules (0.707), Specialized (0.480), Sustainable (0.423)	3.00	0.40
Axis 11	Well oriented	Well oriented (0.646), Sheer (0.643), With good views (0.590)	2.35	0.50
Axis 12	Fresh and ventilated	Fresh (0.735), Ventilated (0.492), Warm (−0.465), Well climate (0.443)	2.72	0.40
Axis 13	Simple and safe	Simple (760), Safe (0.432)	2.59	0.39
Axis 14	To connect	To connect (0.633), Happy (0.498)	2.54	0.49
Axis 15	Youth	Youth (0.699)	2.38	0.36

Good Library = 0.813 + 0.328 Good design + 0.201 silence and calm + 0.191 good distribution and functional + 0.185 good temperature + 0.160 nice and cozy + 0.158 friendly service + 0.132 clean and tidy + 0047 versatile

Differences perception identification between answers in response to different groups of subjects and characteristics between analyzed libraries Different ANOVAs have been done in order to identify significant differences in the responses of different subjects and also taking into account the different libraries characteristics. Through this technique, significant differences (for a significance level of 0.05) in

Table 3 ANOVA descriptive assessments means of each factor according surface ranges

	ANOVA	Area(m^2)			
	Sig.	≤250	251–500	501–750	>750
1. With good design	0.000	−1.036	0.068	0.430	−0.010
2. Silence and calm	0.000	−0.372	0.258	0.006	−0.247
3. With good service	0.113	−0.220	−0.068	0.106	0.185
4. Good distribution and functional	0.000	−0.323	−0.159	0.195	0.328
5. With good temperature	0.000	−0.400	−0.205	0.413	−0.031
6. Clean and tidy	0.010	−0.294	0.201	−0.104	0.101
7. Nice and cozy	0.869	0.036	−0.053	0.005	0.087
9. Versatile	0.000	−0.558	−0.053	0.056	0.708
Good library	0.000	0.200	0.852	1.025	1.070

the parameter "size" to the overall assessment of good library are clear, as said, the size of the reading chamber or library affects its final assessment (Table 3). A library will be globally better appreciated as bigger as it is. However, the assessment seems constant from 751 m^2 and increasing.

In which factors that represent the library semantic universe are there significant differences in terms of the same parameter "size" have also been identified. As shown in Table 3, significant differences were found in the factors: good design, silence and calm, good distribution and functional, with good temperature, clean and tidy and versatile. Instead, the factors with good service, nice and cozy have no significant differences in response to the libraries size.

Analyzing the assessments average of each factor according the library size (Table 3), the identified differences can be shown. For example, the variables "Good Design" and "With good temperature" are poorly valued in the libraries of small size, but this is improving its assessment as the size increases to a certain level (501 m^2–750 m^2) and decreases again with large libraries.

The factor "Silence and calm" receives a negative rating in both, small size libraries (≤250 m^2) or large ones (>750 m^2). On the other hand are highly rated in these aspect libraries of average size.

On the other hand, the average ratings made for perceptions such as "Good distribution and functional" and "Versatile" increases while increasing those libraries size.

Finally, "Clean and tidy" perception assessment is negative at small size libraries and at size rank as 501 m^2–750 m^2, however is positive in the rest of them.

Model validation At this point, validation of the obtained quantitative model was done to estimate the overall library assessment.

Results obtained, for a control sample, in the Escuela Técnica Superior de Ingeniería de Edificación (ETSIE) library were compared (Table 4) with that predicted by the model defined.

By substituting the value obtained from each of the factors in the model, gives a prediction of the overall score of − 0.25.

Table 4 Results ETSIE library

Subjects assesement	ETSIE M^2	F 1. Good design	F 2. Silence calm	F 3. Friendly service	F 4. Good distribution functional	F 5. Good temperature	F 6. Clean tidy	F 7. Nice cozy	F 9. Versatile	Global assessement
	230	−1.590	−0.950	−0.060	−0.320	−1.065	−0.560	0.007	−0.260	−0.500

4 Conclusions

This paper has attempted to apply the KES methodology for the "Good library" perception at UPV libraries as an architectural product.

The contributions of this work can be approached from two different points of view, methodology on one hand and results on the other.

From a methodological standpoint, the contribution is KES application itself and analysis valuation of good library as an architectural space. The semantic differential technique in KES has been applied in other architectural cases, façades design [10], doors [6], property offers [11] or city neighbours [12]. However, this works presents for the first time this technique for a library design analysis. This tool novelty respect previous methodologies is that most previous works does not delve into the user's emotional reaction, studying the relationship between the physical building parameters and global assessments such as the good library or good design. In this research, attributes that are taken as a basis for finding the relationship with the design parameters are not defined by experts. This way the user communicates directly demonstrating his voice straight onto the research, removing the filter that is imposed in most studies, in which the user's wishes are interpreted by researchers. Only this way is possible to establish relationships between each perceived attribute and the overall assessment of good library.

From the results point of view there are these contributions:

The first one is to obtain the semantic space or set of expressions that users use to describe their perceptions within libraries. This space has 15 dimensions that explain 62.77 % of the variance. These axes represent aspects of management (with good service, clean and tidy, well organized and efficient, versatile, and with an open schedule), design (with good design, with good distribution and functional, with good guidance, single), environment (quiet and peaceful, with good temperature, comfortable, cool and ventilated) and the social aspect (to relate, cheerful and youthful). These represented areas are a very useful tool to objectively measure the perceptions of library users.

Secondly, the linear regression has a good correlation, being the axes with more weight in the assessment of good library design tips and silence, and with less cleaning and versatility

Third, with ANOVAs was obtained that the library overall assessment improved with increasing the size of libraries.

Fourth from model validation we conclude that the model is good at predicting the global assessment from the different perceptions defined.

We must take into account the following limitation, the sample stimulus is made up of real college libraries. Being real stimuli, the combination of parameters cannot be changed, so there may be nesting. This limitation is assumed for being relevant to the job to collect the perceptions while using the spaces.

At later stages each of the perceptions used at the model may be decomposed in different design elements such façade, windows amount, luminaries type etc, to identify what specific characteristics of each of these factors are those that most influence the library assessment.

This tool will identify key parameters a product design must follow to be perceived by consumers a particular way or, predict users response at perception level for a given stimulus. This will achieve lower products development costs to ensure its relevance to the objectives.

The application of these methods is of great interest for designers of architectural spaces. This is an initial step to introduce perceptions and feelings of the users into architectural design. The methodology implementation in the complex building process and proper management of the building construction project not affecting its primeval concepts end with the capture by the future users of the perceptions and feelings intended. This sort of methodologies could be a distinguishing feature of the building process. Given the current scarcity of resources strategies to help decision making to improve construction management should be assessed.

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Part II
Building Technologies

Inmaculada Oliver-Faubel

Abstract In these times of global economic crisis there is a growing demand for research, development and innovation in the building industry.

As far as building technologies are concerned, the interaction between science, technology and, of course, economics is a priority for new buildings. But so is the implementation of new technologies and regulatory requirements in buildings that already exist.

This chapter focuses mainly on research in energy efficiency. The authors discuss new envelope systems for residential buildings that contribute to energy efficiency; modular, sustainable, flexible and industrialized construction to reduce manufacturing costs and maintenance; application systems and new materials for this type of prefabricated construction like translucent concrete, but also traditional materials like ceramic facades or natural wood structures; prefabricated systems and their application in the renovation of existing residential buildings in pursuit of compliance with current efficiency requirements. The authors also discuss 3D façade systems and digital fabrication.

Keywords Energy • Energy efficiency • Energy control • Sustainable construction • Bioclimatic architecture • Building envelope • Housing renovation • Modular housing • 3D modular building • Industrialized systems • Digital fabrication • Ceramic skin • Translucent concrete • Wood • Timber structure

Energy Efficiency and Daylight Transmission in the Current Envelope of the Arquitecture

P. Gómez and A. Rolando

Abstract State of the art in photovoltaic energy production and integration of different sensors devices on the market in the architectural envelope, focusing especially on the electrical performance and natural lighting.

Keywords Photovoltaic • Natural lighting • BIPV

1 Introduction

It is intended to check the state of art in photovoltaic energy production and integration of different modules on the market in architectural envelope, studying what would be the most successful design criteria under natural lighting inside these enclosures.

2 State of the Question

2.1 Traditional Systems

The fact that a module can be semitransparent will affect the light transmittance, which can be continuous or discontinuous.

The light transmittance can modify the energy behavior of the building, allowing for the passage of natural light inside, reducing the power consumption of artificial lighting, and affecting the solar factor.

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Table 1 BIPV—Building Integrated Photovoltaics (Source: Authors)

BIPV (Building Integrated PhotoVoltaics)	Traditional S C I O N A LE S	Laminated Safety Glass Laminated	Ventilated façades
		Opaque	Monocrystalline silicon cells separated
			Multicrystalline silicon cells separated
		Semitransparent Thin Film	Cis-sulfide
			Copper and Iridium
			Telluride CdTe Cadmium
		Transparent	
		Placed Double Insulation. Glass	Curtain Wall
		Opaque	Monocrystalline cells zilicio separate
			Multicrystalline silicon cells separated
		Semitransparent Amorphous Silicon Thin Film	Cis-sulfide
			Copper and Iridium
			Telluride CdTe Cadmium
		Transparent	
	Innovatives	IC-Integrated Concentrating	Concentrator Systems
			Solar Facade
			Organic solar Concentrators
			Photovoltaic Holographic Elements

2.2 Innovative Systems. Integrated Concentrating Systems. IC

One of the strategies to optimize the performance of PV systems is to use concentrator systems. These consist of an optical system that concentrates sunlight into a much smaller area of solar cell, allowing more natural light.

Integrating photovoltaic (BIPV-Building Integrated Photovoltaics) seeks to replace conventional construction materials for new architectural photovoltaic power generators. See Table 1. PV energy production depends on the orientation and inclination of the surface.[1]

3 Energy Efficiency

The energy efficiency of a PV cell decreases with increasing temperature. A PV cell produces residual heat to be evacuated. This is easier with ventilated rear module. In most cases of architectural integration is not possible and losses due to heating of the modulus must be calculated. Amorphous cells have a worse behavior with temperature but this affect less than in the crystalline technologies.

According with the development of solar cells over time we can establish the following classification: [2].

First Generation: monocrystalline and multicrystalline silicon. Cost per square meter increase considerably to slightly increase efficiency..

Second Generation: polycrystalline thin film (CuInS2, CIS, CdTe, amorphous silicon thin film) monocrystalline thin film (GaAs). Cost and efficiency are limited.

Third Generation: photoelectrochemical cells, polymer and nanocrystalline. The increase is proportional to the increased of cost.

3.1 Photovoltaic Cells of First Generation

The first generation of solar cells are crystalline silicon, Si-c, (monocrystalline silicon, Si-sc, and multicrystalline Si-mc). The efficiency in the laboratory was 25 % in 2007 and is expected to yield 27 % efficiency in 2015. The commercial efficiency was 12–18 % in 2007 and is expected to be between 15 and 21 % in 2015.

The module manufacturing cost was $ 2/W in 2007 and is expected to cost $ 1/W. [3].

3.2 Second Generation Photovoltaic Cells

Thin film cells, being crystalline silicon or not, using concentrated light. Laboratory efficiency increases slightly, from 13 % to 2007 to 15 % to 2015.

Efficiency in commercial module increase, from 5–8 % in 2007 to 10–13 % in 2015. Cost decrease with the production volume. [4]

CIS cells and CIGS, are the most promising in terms of the thin film photovoltaics.

Efficiency in commercial module increase, from 5–11 % in 2007 to 10 to 15 % in 2015.

Efficiency increase, from 19.5 % (in 2007) to 21–23 % in 2015. [5]

Research focuses in the study of the electronic properties of CdTe polycrystalline thin films, to control conductive and photoconductive properties and their influence on the improvement of the characteristics of photovoltaic cells and modules.

The commercial module efficiency goes from more than 9 % (in 2007) to 13 % (possible value in 2015). The best results go from 16.5 % in 2007 to 18–20 % in 2015. With reduction of production cost in a half. [6]

In this second generation of thin films, in highlight those of gallium arsenide (GaAs) with good characteristics for absorbing energy from solar radiation, but high cost.

Efficiency in the cell is 14 % in the commercial solar and 27 % in commercial concentrated solar. Installation cost is 7.0 €/Wp in the commercial solar and 2.7 €/Wp in the concentrated solar. Power productions cost in commercial solar is 1.40 W and 0.27 W in concentrated solar. Cost of electricity in commercial solar is 36 c €/kWh, and concentrated solar is 9 c €/kWh). [7]

3.3 Third Generation Photovoltaic Cells

In the field of cell concentration, has succeeded in obtaining an efficiency of 41.1 % in the multi-junction cells. This has concentrated solar radiation 5mm^2 GaInP/GaInAs/Ge. Commercial efficiency is 17 % in 2007 and 29–36 % in 2015. The cost in 2007 was 10–15 \$/cm^2 and 3–5 \$/cm^2 in 2015. [8]

Crystalline Silicon Cells, either monocrystalline or multicrystalline have high efficiency, have extensive experience, but also costs are high.

Thin-film technologies: [9]

a-Si show economic process, low efficiency and degradation.
CdTe show an medium efficiency, low cost process and experience the high toxicity of Cd Cadmiun and scarcity Te.
CIGS good efficiencies, complex expensive process.

The dye cells (dye-sensitized solar cell, DSSC) or Grätzel cells, have lower manufacturing cost and are easier to incorporate into the architectural structure, have a transparency that provides greater ability to capture light from different angles. Efficiencies are lower of the cells based on silicon the efficiency was 5–7 % in 2007 and 10 % in 2015. [10]

Organic solar cells cheap, have efficiencies less than the silicon or DSSC. Record efficiency 5.2 % in 2007 and 12 % in 2015.

Another cell is the hybrid mass heterojunctions (obtained as fusion of the two types above mentioned) incorporating inorganic semiconductor nanocrystals (CdSe, ZnO, TiO2, etc.) in the form of nanoparticles homogeneously mixed into the polymer matrix conjugate. [11]

Technology quantum dots (QDs, English Quantum Dots). Cells able to get materials together in a single cell the three types of bands.

We obtain in 2015 a record of 1 sun efficiency of 25 % without concentration a record of efficiency and with concentration of 30 %. [12]

Generation solar cells by multiple excitation (MEG, Multiple exaction Generation). Training of more than one electron per absorbed photon, so part of the energy lost in today's solar cells will also become electricity. Technology excitation reports efficiency 3 % in 2007 and 25 % in 2015. [13]

Photonic crystals are structures with band gap for photons (photonic band gap, PBG), formed by periodic variations in the refractive index of the material that is. The design of the bands prevent or promote the propagation of photons with certain energies.

SJ3 The solar cell (cell binding site for high efficiency CPV applications, capture different frequencies of light throughout the day, thus ensuring optimum conversion of photons into electrons) developed by the Department of Energy U.S.'s (DOE) National Renewable Energy Laboratory (NREL) The cell uses band gaps, and ultra-concentration with to achieve a conversion efficiency record of 43.5 % (under the lens focused light with 418 times the intensity of the sun) with potential to reach 50 %.

At the Institute of Microelectronics of Madrid-IMM-photonic crystals fabricated in III-V semiconductor materials such as GaAs and InP and their alloys. This solar cell has produced a two-dimensional photonic crystal by nanotechnology processes, forming a periodic lattice of triangular symmetry.

MIT researchers invented a solar film did not interfere with the opacity of the windows and managed to generate electricity from organic molecules. Now, at UCLA have created a high performance polymer photovoltaic solar cells (PSC) that generates electricity by absorbing infrared light and allowing the passage of the rest of the visible spectrum, making it transparent. Energy conversion efficiency of 4 %, though not very high (solar cells now exceed more than 15 % efficiency), could be placed on any device.

4 Conclusions

Taking account the evolution of the conversion efficiencies of different cell types we can say:

Thin film technologies are the first to be present in 1976, namely amorphous SiH stabilized since 1990 and those of CeTe. The latter have an efficient around 9 %, having a homogeneous evolution, almost all the way, experiencing a sharp increase between 1991 and 1993 and between 1993 and 1999 with a slightly slower growth. Something further is the appearance of Cu (In, Ga), starting with efficiencies of 6 % experiencing significant gains between 1980 and 1981 and between 1994 and 1996. Since 1997 its growth has been steady but not with efficiencies higher than 20 %. Now, seems to be clear is that with the massive price decline of silicium and thus crystalline PV cells, the competitive advantage of thin-film with its lower production costs it doesn't compensate his lower efficiency.

The Nano-, Micro-, poly-Si will not appear until the year 1997 but with an efficiency of 10 %, reaching values of 16 %. Those of multijunction polycrystalline not appear until 2006 with an initial near-zero growth, but with efficiency values of 14 %. Monocrystalline silicon technologies appear in 1983 with initial efficiency of 13 %, reaching 24.7 % in 1999. More pronounced growth than multicrystalline silicon.

The multicrystalline silicon with 14 % in 1999 and reaching values of 20.3 % in 2005. Have very slow growth, achieving one of the highest efficiency values.

The multijunction concentrator technologies (three bands) appears in 1983 with an efficiency of 16 % reaching an efficiency of 40.7 % in 2008. It does not experience a pronounced development until 1989 when they begin to see a significant growth, reaching, along with multicrystalline silicon, efficiency higher values.

Emerging technologies.

The Dye appear in the early 90's with 6 % efficiency quickly increasing it up to 11.1 % six years later, but since then growth has been very low or zero.

Organic cells are the most recent appearance, with low efficiency, 2 % and even in 2003–2004 shows high growth efficiency value that reaches is higher at 5.4 %. [14, 15]

Expectations of future [16]: Because of its potential for exploitation and low environmental impact, solar photovoltaic (PV) contribute largely to meet the future energy needs.

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A Ceramic Double Skin in an Educational Center in Melilla

Á. Verdasco

Abstract In this article we discuss some aspects of the design and construction of The Old Market of Melilla (North Africa). The works are the result of a competition held in 2008 to restore and restructure the Old Market, which I won and which is currently in progress construction.

The Old Market of Melilla is being restructured and turned into the most important educational and cultural centre of the city; the new building will hold a Conservatory of Music, a School for Adults and a Foreign Languages School, while maintaining the unique personality of the old market.

The original upper decks have been removed, extruding in height each warehouse of the old market, while the new facades will be covered with ceramics.

A double skin made of ceramics (a light latticework + a ventilated facade) manages and adequately distributes the energy–acoustic, thermal energy and light- into the building. The double skin made of ceramics serves the purpose of energy control and management through the building and has been designed and elaborated specifically for this project.

Keywords Ceramic skin • Latticework • Celosia • Energy control

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1 Introduction

The restructuring process of the building has resulted in the introduction of new uses, multiplying the volume of the building three times its original capacity.

The general aim is to densify the city, but not meaning necessarily compacting the city; the idea is to achieve high density but with light appearance.

On a pre-existing solid base, the intervention reinterprets the materials and becomes vertical, thus lighter. This is accomplished with a double skin made of ceramics (lattice + front ventilated) which controls and manages the energy in the building: thermal, acoustic energy and also light.

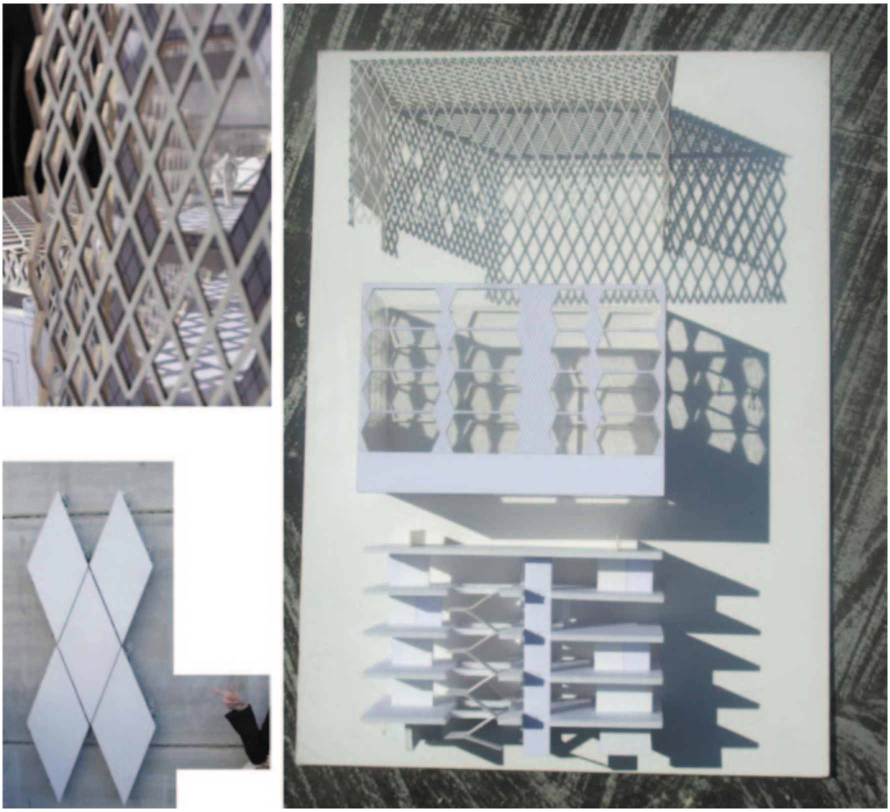
The diamond shapes are inspired in the old wooden latticework, which were the old shutters in the market.

This is a facade that has been fluffing through the development of the project, differentiating two skins. The two skins are interdependent and without one of them the energy equilibrium is lost. The skins cover the building, since any surface is subjected to impact factors.

We performed a study of the climate which serves the purpose of balancing the impact of external noise, since most of the programme for the building uses includes classrooms (either for music, language classes etc.). Taking into consideration these factors, we have achieved the equilibrium of the model. The gradient of the two skins varies according to the impact factors (orientation, noise, wind, etc).

The metallic structure also splits. The new structure is anchored to an external diamond shaped "cage".

One of the problems of the city of Melilla is its low technological level and the need to transport materials by ship, in addition to a low budget. The choice of using ceramics serves the purpose of linking the intervention to the local materiality; also, ceramic protects the metallic structure, easies ventilation and is more suitable to manage the energy impact received by the building.



2 Description of the Construction System

2.1 Envelope and Climatic Aspects

The outer shell of the building arises from the idea of giving the building a coherent picture which will enable to create harmony between the old, existing building and the proposed extension in height.

We propose a continuous envelope in walls and roofs formed by two ceramic skins.

This envelope acts as a camera that minimizes the noise impact from the outside, what we need for applications to implement (mainly classrooms). It also acts as a thermal control chamber, which we believe is very necessary when working in Melilla.

2.2 The First Skin

The first skin is a ventilated ceramic facade made of alternating blind and transparent panels, which follow the pattern of diamonds in the outside in order to be as unnoticed as possible.

This is a classic ventilated façade with the thermal advantages this type of facade entails.The blind panels are composed of ½ foot wall of solid brick with plaster inside, polyurethane thermal insulation of 5 cm, ceramic ventilated chamber and mounted on aluminum profiles. It provides a long used and tested façade type such as Faveton.

The glass panels have aluminum frames with glass fixed on the bottom, and practicable at the top. The windows are insulated, transparent or translucent, low thermal emissivity qualifying to take advantage of solar incidence. The proportion of glass depends on the different orientations.

2.3 The Second Skin

The second skin is a diamond lattice also made of ceramic and separated 60 cm from the ventilated facade.

The lattice covers the building, the covers and is anchored to the slab edges of the new structure. This outer skin acts as a sunscreen, providing thermal and acoustic insulation.

This second skin is open or closed depending on the orientation.

All the tiles are mounted on a metal frame. Therefore within the ceramic lattice is a lattice of metal.

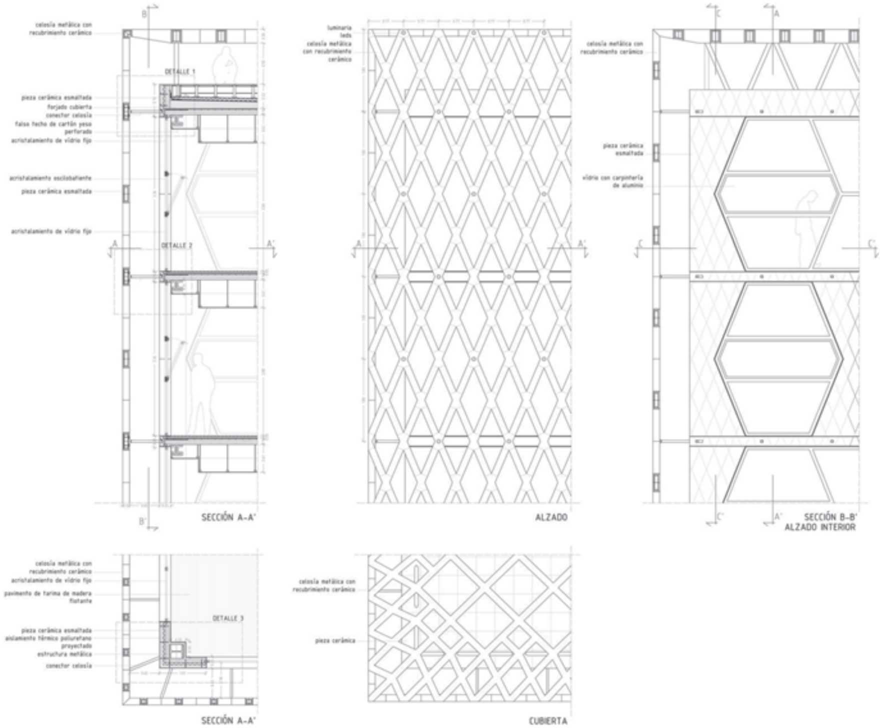
The entire building is 'wrapped' by the lattice which is an element of composition and climate.Geometrically the lattice planes for each occupies 5 building: a horizontal plane situated above the upper deck and 4 planes parallel to the walls 4.

Formally, this lattice is composed of vertically symmetrical and elongated diamonds.

On the upper deck a ring of perimeter beams has been constructed, on which lie the metallic lattice supporting the deck.

The metallic lattice is constructed with a square tube of 10 × 10 cm. The tube is later wrapped and stapled with ceramic pieces in a "U" 15 × 15 cm. Thus the outer skin is a diamond lattice made of steel tubes with termination of ceramic pieces mounted, stapled and sealed.

Minimizing the number of elements and the whole lattice can be fitted with three U-shaped pieces, ensuring a quick and easy implementation.



3 Conclusions

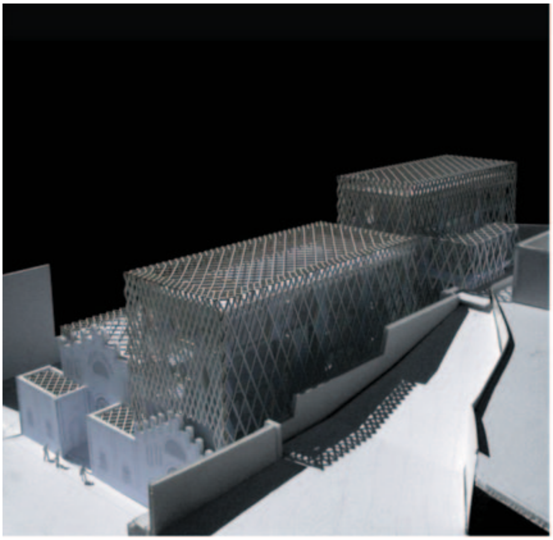
The ceramic double skin is an outer shell with low thermal inertia that enters in "thermal resonance" in the time it is used and also optimizes the use of natural light.

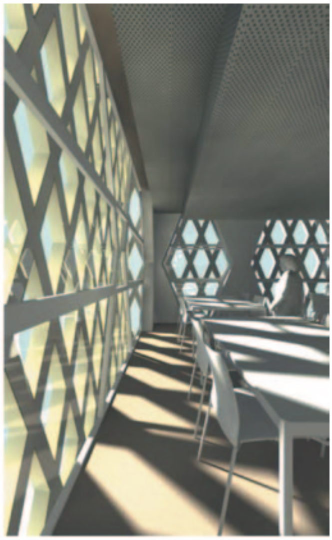
This envelope acts as a camera that minimizes the noise impact outside, what is needed for the uses to implement (mainly classrooms) and otherwise behaves as a thermal control chamber, which is very necessary when working in Melilla.

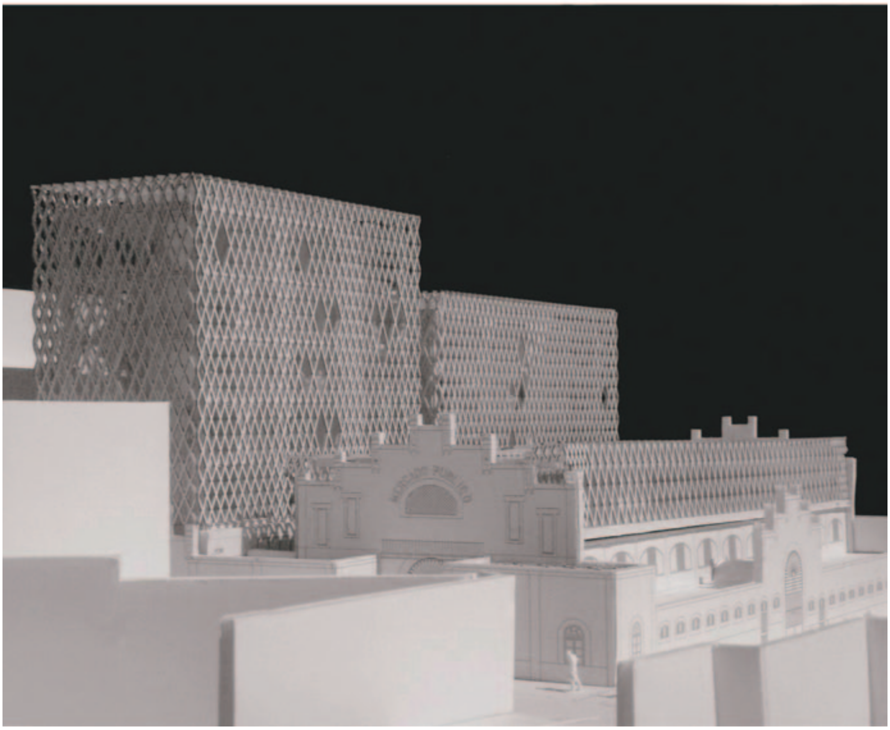
VRV air conditioning system for heating and cooling is suitable for a building with different orientations and allows the control of homogeneous spaces with different orientation. The combinatorial camera and VRV system ensures considerable saving of energy.

The ventilated chamber solution is easy to assemble and it seems appropriate for the City of Melilla, ended up with these solutions up to 30 % less expenditure and energy intake. The thermal envelope trasmitancias meet the CTE for this geographical focus perfectly.

The technological contribution of this system is to move from the two-dimensionality of the classical three-dimensional ceramic piece to be able to create spaces which function as intermediate energy mattresses.







Ventilation and Sealing in the Current Envelopes in Architecture

E. Sánchez and A. Rolando

Abstract State of art in relation to the legislation, research and technology of envelope systems in architecture taking into account natural ventilation and sealing to the penetration of wind driven rain.

Keywords Building envelope • Natural ventilation • Sealing • Wind-driven rain

1 Introduction

The article focuses on analyzing the current state of envelope's design for an optimum natural ventilation and sealing in buildings taking into account interrelated the legislation and the present research on the subject.

2 State of the Art in Relation to Legislation

While reviewing and analyzing the legislation related to research, shows that there is a disparity in ideas, on one hand are the legislations that regulate the ventilation, and on the other hand those dealing with sealing.

2.1 Legislation that Takes into Account the Ventilation

The Technical Building Code (CTE), approved by **Royal Decree 314/2006** on May 17, recognizes the importance of good ventilation and binds to establish natural ventilation systems, hybrid or mechanical in all buildings.

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The **Technical Building Code (CTE)** in its **DB-HS 3 Health. Indoor Air Quality** [1], establishes minimum ventilation flow rates for the different rooms of residential buildings and the design criteria for ventilation systems, the terms of sizing of the different construction elements, as well as the technical characteristics required to products and conditions of maintenance and preservation.

In Sect 1.1. Overview. Scope., refers to residential buildings and not to office buildings, leaving aside the facade treatment in office buildings. In Sect 3.1.1. Design. General conditions of ventilation systems. Housing., in Sect c) establishes that "*when the outdoor frames are of class 2, 3 or 4 according to standard UNE-EN 12207:2000 should be used as inlets, vents or fixed openings of the frames; when the outdoor frames are of class 0 or 1 joints can be used as openings*".

Standard **UNE-EN ISO 15251:2008** [2] is about the indoor environment that affects health, productivity and welfare of the occupants. This standard specifies how to establish the indoor environment parameters for building system design and the methods for long-term evaluation of the indoor environment. It also establishes the flow of ventilation and the indoor air quality required in residential and non-residential buildings to design the natural ventilation system.

Standard **UNE-CR 1752 IN** [3] is about the design criteria for indoor environment. It specifies the requirements and methods of the indoor environment quality for the design, the starting, the running and the control of ventilation systems. It also defines the categories in which the indoor environment is classified and how the ventilation rate should be determined.

2.2 Legislation that Takes into Account the Window's Sealing

Standard **UNE-EN ISO 12207:2000** [4] classifies windows and doors according to the resistance to their air permeability. The classification is based on a comparison of the air permeability of the test sample by reference to the total area and its air permeability by reference to the joint opening length. After testing, the results are shown in tables 1 and 2, where the frames are classified in Class 0, 1, 2, 3 or 4 depending on their air permeability. The test method is defined in the standard **UNE-EN ISO 1026:2000** that measures the amount of air passing through the sample because of the pressure.

Standard **UNE-EN ISO 12208:2000** [5] classifies windows and doors according to their sealing. The test method for determining the sealing limit is defined in standard **UNE-EN 1027:2000**. It measures the test sample ability to resist the penetration of water and gives a classification.

Standard **UNE-EN ISO 12210:2000/AC:2010** [6] classifies doors and windows according to withstand wind load. The test procedure is defined in standard **UNE-EN ISO 12211:2000** in which samples are subjected to positive and negative pressures.

Standard **UNE-EN ISO 15927-3:2011** [7] specifies two procedures for analyzing wind and rain data, so as to provide an estimate amount of water that is likely to fall on a wall penetrating through the doors and windows edges or through cracks in the building facades.

2.3 Legislation that Takes into Account the Light Envelope's Sealing

Standard **UNE-EN ISO 12152:2000** [8] specifies the requirements and the classification of the air permeability of light envelope elements. The classification in based on an air permeability comparison by reference to total area and the length of fixed joint. After testing, the light envelopes are classified in class A1, A2, A3, A4 or AE depending on their air permeability. The test method is defined in standard **UNE-EN ISO 12153:2000** [9].

Standard **UNE-EN ISO 12154:1999** [10] defines the requirements and the classification of sealing performance of the different parts of a light envelope. The test method is shown in the standard **UNE-EN ISO 12155:2000** [11]. After the test five classes are defined: R4, R5, R6, R7 and RE.

3 State Of The Art In Relation To Research

3.1 In Relation To Ventilation

In 1994, M. J. Holmes [12] published an article about double skin facades fully glazed, in which explains that the energy demand of a building can be reduced by controlling the amount of heat passing through the outer skin. This concept leads to prescriptive building regulations associated with the thermal insulation properties of the facade. He explains that one solution is to design the facade by a careful choice of glazing with ventilation inlets through the whole facade.

There are researches on solar stack effect that say that minimize the energy waste of a modern facade and guarantee a suitable indoor environment. The researches focus on testing on ventilation rate models simulating the thermal variations that occur in natural ventilation. As a result, ventilation rates for different exterior and interior facade designs are obtained. The research shows that the natural ventilation of spaces occurs even in high winds and sunlight cases. It has also been demonstrated that the use of conditioning devices is reduced. An example is the patented Twin-Face facade systems (Fig. 1)

In 2011, Karava [13] presented an experimental study of airflow in buildings that employ cross- ventilation for a proper design of the natural ventilation. The research used specific areas models and tested them in a wind tunnel under wind-driven rain conditions. It was also investigated the influence of air velocity in cross-ventilated buildings. Explains that the location of the openings on a building facade in addition to the wall porosity, are parameters to be considered. Its purpose was to provide

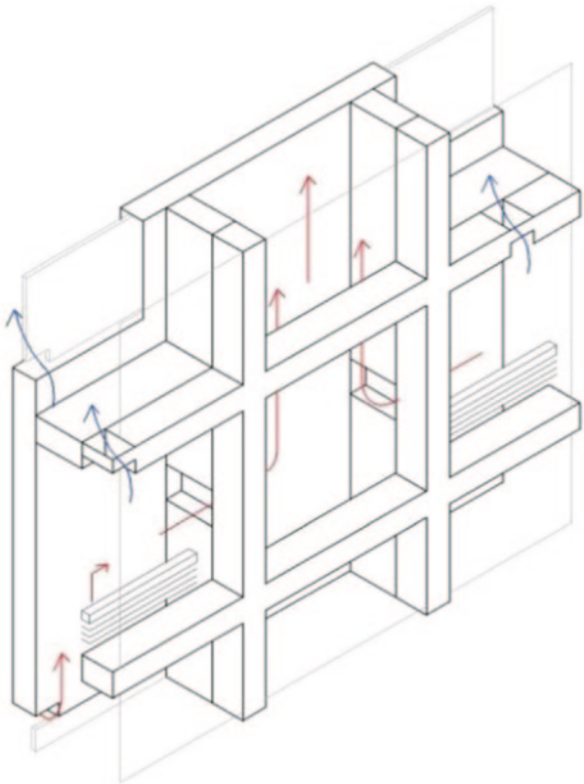

Fig. 1 Twin-Face facade functional principle

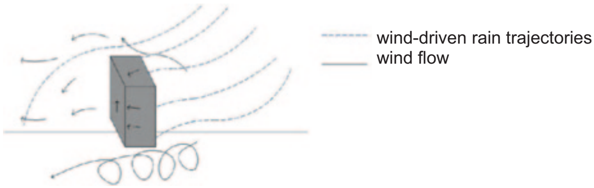

Fig. 2 Representation of the wind flow pattern and of raindrop trajectories around a building

some criteria for the design and control of facade elements using cross-ventilation and natural ventilation.

3.2 *In Relation to Sealing*

In 2004, Bert Blocken and Jan Carmeliet [14] published a study about the state of art in relation to wind-driven rain (WDR) research in building science. WDR is rain that is given a horizontal velocity component by the wind and falls obliquely in the façade (Fig. 2). This phenomenon has destructive properties for the facade and repair and replacement will be needed and, therefore, costs increase. This problem persists because the innovative design features, building technologies and materials in present day construction don't take into account this parameter. Previously, the same authors had already presented a practical numerical method [15] in order to determine the spatial and temporal distribution of WDR in low rise buildings.

4 State of the ART in Relation to Technology

4.1 In Relation to Ventilation

4.1.1 Centralized Ventilation

It consists of a ventilation system concentrating the extraction at a single point of the building and, by mechanical means like extractors and fans, control the air flow. A network of ducts and suction/discharge/transfer elements, guarantee a uniform distribution.

4.1.2 Decentralised Ventilation

Modern forms of construction make possible a high air tightness. This demands careful planning of ventilation systems [16], which can be carried out via the building envelope or by building services.

Natural ventilation

Pressure differences caused by temperature differences always result in a natural circulation of the air.

Ventilation via windows

- Exposed or concealed ventilation flaps incorporated in frames. They are grids placed horizontally or vertically in door or windows frames that allow the air change. They also minimize the air currents and can incorporate filters. They permit different adjustments so that the ventilation can be regulated.
- With an opening on one side only. The exchange of air takes place by the same opening and depends on the temperature difference between the internal and external air.

By way of wind forces Wind flows around a building lead to forces acting on the buildings. Pressure and suction forces are the result, the magnitude and the distribution of which are influenced by the height and geometry of the building itself. On tall buildings, a double-leaf facade with appropriately designed opening elements

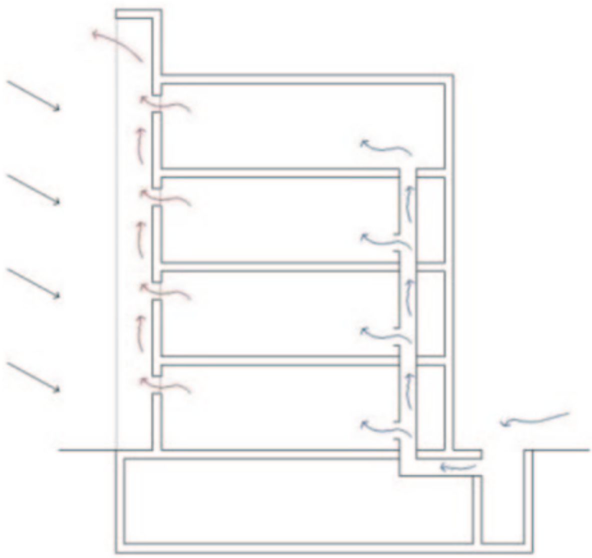

Fig. 3. Solar Chimney integrated into facade

can control the wind forces to such an extent that natural ventilation is possible via the inner leaf. Various principles can be used: Wind towers, Venturi spoilers, Cross-ventilation.

By way of thermal currents They can be employed for extracting air for the interior. The strength of this suction effect depends on the temperature difference and the suction effect.

Three basic principles apply to the constructional implementation of this type of system:

- Double skin facade. It can make use of the thermal currents induced by the higher air temperature in the cavity to establish a ventilation concept.
- Glazed atria.
- Solar chimney. Natural ventilation is possible thanks to the physics variable known as convection. There are different facade systems that employ this principle:
- Twin-Face facades. This patented system allows to ventilate the air spaces of high buildings, which are exposed to high wind loads, using conventional windows and reducing the waste in conditioning systems.
- Solar Chimney integrated into the facade for building ventilation (Fig. 3). An example is the Mario Muelas' and Agustín Mateo 's building in Madrid [17].
- Natural ventilation integrated in the window jamb. This natural ventilation system is employed in the Sheffield University building by Hutton and RMJM [18] in 2009. It utilizes the stack effect to integrate an air supply and extraction system into the building envelope enabling natural ventilation. The incoming air is drawn in, through the attenuator under the window, to a vent between the outer

and inner window jamb. This vent can either be allowed into the occupied room by opening the inner window or utilized to draw heat up through the chimney through the stack effect.

5 Conclusions

After the review and the analysis of the existing legislation related to the topic of research, it can be concluded that there are standards that take into account ventilation and sealing independently, but there is no legislation that takes into account these two issues, analyze them interrelatedly and define a design methodology for the envelopes.

There are standards that regulate ventilation and others that regulate sealing in facades. A clear example of this fact are standards **UNE-EN ISO 12207:2000** and **CTE DB-HS 3**, discussed above. The conclusion drawn is that there is a comparison of ideas between the ventilation and the sealing criteria for the design, so that, on one hand, standard UNE-EN ISO 12207:2000 establishes that the best frames are the more watertight, and on the other hand, CTE demands to place vents to produce ventilation, while the less watertight don't need to place them.

It also must be said that the CTE DB-HS 3 establishes its scope to residential buildings, storage rooms, parking lots and garages; leaving aside the treatment in office buildings facades.

The technology used in envelopes for the ventilation of the building has evolved. First came the large solar chimneys integrated into the facade for building ventilation; then the Twin-Face facades that allowed to ventilate the air spaces of high buildings; and finally a sophisticated and discreet system that utilizes the stack effect to integrate an air supply and extraction system into the frame of the building envelope enabling natural ventilation.

Research is been done into natural ventilation in large chambers of double skin buildings. It must take into account the effect of the double skin facades configurations in reducing the air pressure on the inner frame's leaf in relation to the wind-driven rain penetration. It is also involved in reducing the energy waste and in the building thermal conditioning.

6 State of the Art in Relation to Computer Applications

Simulation programs can be used as a tool to predict the behavior of the building envelope according to the natural ventilation and the sealing system incorporated. These tools provide the possibility of implementing iteratively multiple cases, so that we obtained results that are otherwise impossible to assess. They are also useful to facilitate the architect to make a decision to improve the ventilation conditions of the building envelope. The following simulation programs can be mentioned in relation to ventilation in buildings: COMIS, Cype Building Services, Design Builder, EnergyPlus, ESP-r, FLOVENT, I-BEAM, SMILE, SPARK and STAR-CCM+.

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Translucent Concrete. Research with Glass, Optical Fiber and Glass Fiber

E. Jiménez-Muñoz and F. Fernández-Martínez

Abstract The work of this Master Thesis has focused on research and development of translucent concrete with aggregates of **glass**, **optical fiber** and **glass fiber.** This Master Thesis has been possible with the collaboration of the **Polytechnic University of Madrid** and the **Polytechnic University of Torino** with the support of several companies sector.

The decrease in energy expenditure in the production process and the life of the building is the premise of this project with the 2020 target set by the European Union. It has an international pursuit of product development by testing several of these products.

Keywords Translucent • Optical • Glass • Energy

1 Introduction

Concrete is a composite material that has been studied along the history for thousands of researchers throughout the world. Their research papers cover almost every field, and today a great innovation in this material is required. The main element found in the concrete, which does not have any change and it is in this research study, is the Clinker. The remaining elements of the final mix have changed including different materials. The search for a concrete that meets the requirements of energy efficiency has motivated the research in the design of a new material.

One of the architectural aspects less taken into account in the designing approach is the natural lighting. The use of natural light as the main element in the architecture design must be something to take into account from the start. The translucent concrete is newly established and it is still under development. It has been completed a detailed research study on the inclusion of recycled glass fiber and glass fiber

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Fig. 1 *Left* test rupture in detail. *Right* test: flat glass breaking 30 % at 28 days

Table 1 Compressive strength with different addiction of glass

	Glass 0 %	Glass 5 %	Glass 10 %[a]	Glass 15 %	Glass 30 %
Strength 7 days	33.6	28.9	33.6	29.9	25.7
Strength 28 days	34.2	29.5	34	30.3	26.9

[a] Optimum results

as concrete aggregates in different percentages testing their mechanical behavior and especially designing a process that seeks an optimal development not manufactured. Sustainability is binding thought in the conception of a project.

With the translucent concrete it is possible to use recycled materials (glass, used in a type of test), using abundant materials in nature as the optical fibers (the main component is silica) and save energy in artificial light. This is the beginning, since we live on a planet devastated and highly degraded.

In the first part of this research in La Granja de San Ildefonso (Segovia, Spain), glass with the characteristic of a high lead content (18 %) was added to the concrete. The resistance has been compared with different percentages of addiction (5%, 10%, 15% and 30%) by weight, removing coarse aggregate content by% addition of glass (Fig. 1).

The result meets the compressive strength respecting European policy on the integration of waste in the final mix concrete (< 18 % alternative fuels, < 5 % in alternative raw materials and 12 % in alternative components of the cement) (Table 1). Taken into account document RILEM TC 121 on concrete recycling.

In the second phase a method of working with optical fiber lighting [2] diameter of 0.75–1 mm is implemented, by testing its resistance to compression as aggregate (4 wt%), without diminishing the strength and carrying probes that tests the ability light transmission and its angle of incidence (Fig. 2)**.** Concrete is a concrete [3] CEM II 42.5 LL-A-R eliminating the fraction of coarse aggregate and increasing the fine aggregate.

In the third phase to improve the strength of concrete with a glass fiber [5] test Anti-Crack HP 67/36 OCV Reinforcements varying length (10–20 mm and 20–40 mm) and percentage (0.5%, 1 and 2%) of the same working together with the optical fiber has been analyzed. The concrete has been used is a self-compacting

Fig. 2 Optical fiber/concrete manufacturing process

Table 2 Compressive strength with different addiction of glass fiber

N/mm^2	Glass fiber (10–20 mm) 0.5 %	Glass fiber (10–20 mm) 1 %	Glass fiber (10–20 mm) 2 %	Glass fiber (20–40 mm) 0.5 %	Glass fiber (20–40 mm) 1 %	Glass fiber (20–40 mm) 2 %	G. fiber (10–20) 2 % Optc. fiber 2 %
Strength 7 days	33,6	38	39.2	50.4	38.3	33	34.4
Strength 28 days	34.2	47.1	46.9	56.9[a]	46.1	39.1	41.7

[a] Optimum strength

concrete with limestone filler (640 kg/m^3 totally fines). The results are optimal in the mix prepared with a length of 20–40 mm (glass fiber) and a weight percentage of 0.5 % (Table 2). It presents problems of addiction workability of 2 % or high.

2 Conclusion

The full investigation is a comparative study of translucent concrete with various addictions. Providing the concrete with glass addiction, the concrete does not decrease its compressive strength. Also, if glass fiber is added to the self-compacting concrete the resistance is higher than using only the second material. If the optical fiber is also added, the light passes through the latter material without any problem while a precast method.

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Technical Evolution of 3D Modular Construction from the Nineteenth Century to World War II

G. Ovando-Vacarezza, B. Lauret-Aguirregabiria, J. M. Lirola-Pérez and E. Castañeda-Vergara

Abstract 3D Modular construction is poorly known and scarcely published in technical literature. In spite of that there are an increasing number of manufacturers offering their products in different countries. This method has largely evolved from early examples such as the American Gold Rush prefabrication in the nineteenth century, the Sears precut homes or Voisin's prototypes for modular homes, to the end of the first half of the twentieth century. In this period a non negligible number of attempts in 3D modular construction have been carried out, ranging from theoretical proposals to several hundred or thousand units produced. Selected examples of modular architecture will be analysed in order to illustrate its technical evolution, concerning materials, structure, transportation and on site assembly. Success and failure factors of the different systems will be discussed. Conclusions about building criteria shown in them and their applicability in current architecture will be drawn.

Keywords Modular housing • 3D modular building construction • Prefabrication

1 Introduction

Modular construction evolution has a close relationship with the prefabrication history. Moreover, one of the most highly prefabricated methods of construction such as 3D modular accounts barely for a small share in the developed countries building market.

The reasons for success and failure of prefabrication methods can be clearly seen in its history an evolution during XIX and XX centuries. Housing shortages, during colonial migrations, or post war periods fueled prefabrication industry occasionally. But only long term conditions, commercial opportunities and strategies, and customer acceptance have provided several systems survival as successful trademarks. The end of the Second World War could be taken as a turning point after

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which systems and techniques have evolved in a quiet peace-time competition with traditional building work, and additionally a time that has seen the birth of modern modular home industry. The study of modular construction precedents is of key importance in the correct interpretation of current modular houses prototypes such as Solar Decathlon ones.

2 The Nineteenth Century

If it is true that several examples of prefabrication in Scandinavia, Japan [1], England or U.S. [2, 3], took place before the nineteenth century, it was not until then when several companies began to market their off-site made buildings.

Wood construction has been involved in prefabrication from its very beginnings. Progress in sawmill's techniques led to a certain level of accuracy in lumber sizes that, for instance, allowed the development of the "balloon frame system" in the U.S [2].

By the time could be found a few examples of the early prefabrication of houses as the Manning Portable Colonial Cottage [3], in 1830, in England; the Fredrik Blom experiences in Sweden, in 1840 [1]; and the Gold Rush event in 1848, that brought California along an urgent demand of shelter for workers, receiving almost any type of prefab dwellings from every country that were able to produce them [4].

One interesting fact that characterized the last decades of the century were the emergence of the mail-order-from-catalogue selling system [4] being one of their earlier examples the Hodgson houses, whose catalogue appeared by 1894. Most of these buildings were essentially a set of precut lumber and light panels, broadly known as "Portable" buildings [4].

3 First Half of Twentieth Century

Perhaps one of the best illustrative examples of catalogue houses in the U.S., though not the first, was Sears Roebuck and Co. (Fig. 1), in 1910. Several companies offered their catalogue houses by the time in the U.S., accounting for the non negligible sales figure of 250,000 until 1943 [2].

But in spite of portable houses were already a healthy business in the turn of the century, 3D modular constructions still were in an embryonic stage. Early attempts in this field can be found in Hennebique's concrete cabin for French railways by 1896 (Fig. 3c). Post war periods and their associated housing shortages were to play a big influence in the development of new prefabrication systems. In this way at the end of World War One, a French airplane factory made 3D modular houses by 1919, Maisons Voisin, that was published by Le Corbusier L'Esprit Nouveau Nº 2, in 1920. Although it was an industrial failure due to strong opposition of French building unions, it showed all the features of current 3D modular construction (Fig. 2).

Many experiments and prototypes were planned in this period, from Edison's poured concrete houses in 1908 [1] (Fig. 3a, b), Prouve's panelized houses and

Fig. 1 Sears Simplex, process of erecting in 8 h. (Source: Sears Modern Home Catalog, 1921)

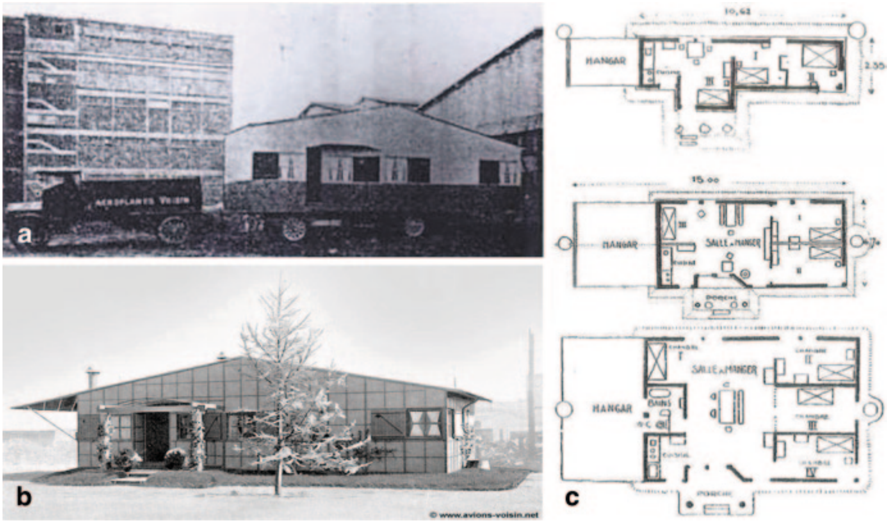

Fig. 2 **a** Truck transporting the Maison Voisin, 1920. **b** Final prototype [8]. **c** Three floor plan types Maisons Voisin of 400, 700 and 1,000 sq. feet [9]

bathroom module [5] (Fig. 7e), Buckminster Fuller Wichita house and Deployment Unit [1], to Gropius and Wachsmann Packaged House [1]. Equally more and more elaborated and non wooden kit or panelized houses were produced as the enameled-iron Lustron house in 1948 [6] (Fig. 4b, c), or AIROH house (Aircraft Industries Research Organization on Housing) in 1945 [7] (Fig. 4a).

Another non-architectural industry was going to be the natural precedent of the American mobile home. We are talking about the trailer, that grew in size from 1919 to 1953 [13] (Fig. 5). Mobile homes as the last evolution of the trailer even grow by duplicating its size with the double-wide versions. Very representative of this type of prefabricated 3D homes are the Tennessee Valley Authority double-wide mobile homes by 1942 in the U.S. [14] (Fig. 6).

In 1979 the H.U.D. (U.S. Department of Housing and Urban Development) code would finally separate mobile homes from modular homes, changing their name from “mobile” to “manufactured” homes.

The aim of combining plumbing, electrical, heating, etc, inside a compact mechanical core was an engineering concern. Several attempts in this field can be seen

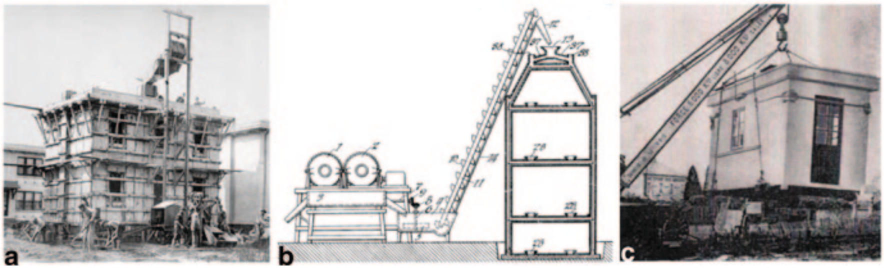

Fig. 3 **a** Poured concrete houses, Edison, 1908 [10]. **b** Patent houses Edison [11]. **c** Concrete 3D module for the railways of France, 1896, F. Hennebique [12]

Fig. 4 **a** Truck transporting the house AIROH, 1945 [7]. **b** Truck transporting the house Lustron, 1948 [6]. **c** Exterior house Lustron [6]

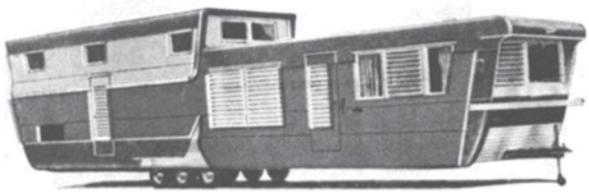

Fig. 5 Pacemaker Bilevel, 1953, had a double level that allowed to separate day zone from night zone [13]

in this period such as B. Fuller prefabricated bathroom in metal [17] (Fig. 7a) and his mechanical core integrating bathroom, kitchen, heating and lighting, in 1943 [18] (Fig. 7b). Other examples are Gugler's crane mounted module, in 1936 [19] (Fig. 7c), Ingersoll core bathroom and kitchen in 1947 [2] (Fig. 7d) and Prouvé's kitchen-bathroom module for Abbé Pierre's house, in 1956 [5] (Fig. 7e).

4 Discussion

As above described 3D modular houses were actually invented and factory made for the first time, yet in a short number, by Voisin in 1920. First half of twentieth century have provided the basis of the technology used in modern modular homes.

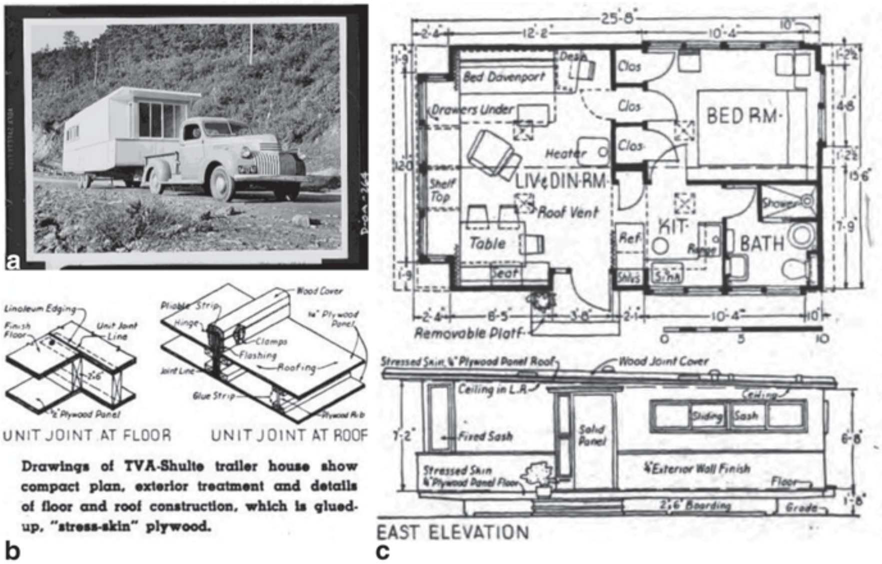

Fig. 6 **a** Tennessee Valley Authority (TVA) [15]. **b** TVA floor and roof details [14]. **c** TVA plan and elevation [16]

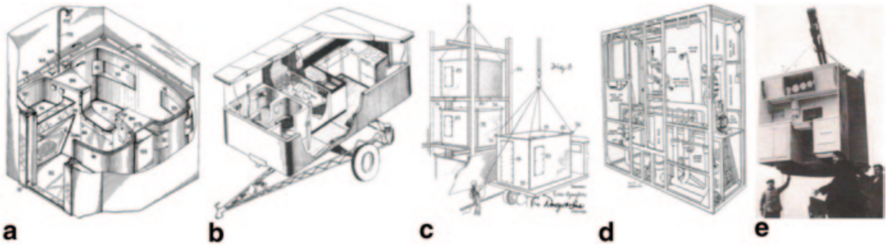

Fig. 7 **a** Prefabricated bathroom, B. Fuller [17]. **b** Mechanical core (bathroom, kitchen, heating and lighting), B. Fuller [18]. **c** Prefabricated bathroom, Gugler [19]. **d** Ingersoll core bathroom and kitchen [2]. **e** Core bathroom and kitchen, Prouvé for the Abbé Pierre house [5]

Wooden prefabrication success in the U.S. combined with the particular evolution of the bigger and bigger sized trailers have originated the steel-chassis wooden construction factory made mobile homes. Almost the same building criteria, joint design, and construction detailing of double-wide mobile homes are used in today modular homes in the U.S. Some of the Solar Decathlon prototypes are based on mobile homes technology.

Equally modern modular homes in Japanese industry are based in the same principles shown in these early examples (1920).

5 Conclusions

- First documented attempt in actual modular housing construction is Voisin, although there previous partial experience, such as Hennebique in France. Commercial success of modular homes will happen in the second half of the century.
- Balloon frame and trailer development in the U.S. have lead to mobile homes and then to double-wide homes as a modular housing construction antecessor.
- Several historic events that caused occasional increase in housing needs, such as post-war periods, fuelled house prefabrication industry, but only long term conditions as government support, customer culture and market viability have granted their survival, as today cases such as Japan and U.S.
- Building criteria shown in this period, such as road transportation requirements, light timber or steel construction, single unit, double wide or multiunit arrangements, are currently in use in current modular house building industry. Same can be said about mechanical modules. These criteria are widely applied in modular solar house prototypes such as Solar Decathlon ones.

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Architrave: Advanced Analysis of Building Structures Integrated in Computer-Aided Design

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Abstract This paper describes the characteristics of a new high performance computing application (Architrave v.2011) designed for structural analysis of buildings or civil engineering structures. To check its performance against the well-known and widespread computer programme, SAP2000® v.15, a set of test has been designed for static and dynamic analysis. Calculation speed, tools, usability, cost and graphic efficiency have been measured and compared on standalone. The results show that Architrave v.2011 is more than five times faster than SAP2000 v.15 while performing structural analysis, its graphic interface and visualization performance is ten times more efficient and the cost of a standalone license is less than a fifth.

Keywords Structural analysis • Cloud computing • SAP2000 • Architrave • software

1 Introduction

Structural analysis of buildings, or civil engineering structures, is the process to determine the response of a structure to different prescribed applied loads. This response is usually measured by the stresses and movements that experiences any point of the structure.

Depending of the changing nature of the external load applied to the building, a static or dynamic structural analysis will be needed. In a linear static analysis,

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where the external loads (dead loads, snow load, etc.) do not change along the time, the Stiffness Method [1] requires to solve a large-scale system of linear equations, as the main computational problem. However, in a linear dynamic analysis [2], where the external loads (earthquake, wind load, etc.) do change along the time, the second order differential equations in time that governs the motion of structural problems must be solved. Direct time integration algorithms are techniques usually applied for solving this computationally demanding equation of motion, using a time step-by-step numerical integration procedure that provides the response of the structure along the time. In general, they involve the solution of a large dimension linear equations system at each time increment. The accuracy of the results depends on the time increment employed.

In order to find the most appropriate structural design, according to distinct criteria of safety, economic limitations or construction constraints, a large amount of different configurations have to be simulated, following a trial-error process. Each of these alternatives is defined by the structural engineer varying the size of the structural elements, the material that composes them (concrete, steel, etc.), or the external loads applied. As an example, the Spanish Earthquake-Resistant Construction Standards (NCSE-02) demands a building to be analysed with at least five different representative earthquakes. Once all these structural alternatives are simulated, the results must be interpreted, maybe giving place to a new iteration in this trial-error scheme. Obviously, this situation largely increases the computational cost of the problem.

Therefore, the realistic 3D structural dynamic analysis of large scale structures can demand an important computational power, give place a huge volume of data and become one of the most time consuming phases in the design cycle of a building or a civil engineering structure. For this reason, this analysis has been traditionally solved by introducing a variety of simplifications (unsuitable for complex structures) in order to reduce the problem size and the volume of the data, and obtain the results in reasonable simulation times.

Architects and structural engineers need thus powerful software applications able to simulate efficiently the accurate response of the structure. High Performance Computing (HPC) techniques provide powerful numerical and programming tools to develop applications able to simulate, efficiently and in a realistic way, large scale structures, in very reasonable response times. However, the commercially available applications usually offer traditional approaches, computing sequential structural analysis on the user's local machine. As a result, the size and the complexity of the structure to be analysed, the type of structural analysis employed and the total number of the different structural solutions or even earthquakes evaluated are limited by the performance of the computational resources available for the users.

In this paper, a new advanced software environment for the design, 3D linear static and dynamic analysis and visualisation of buildings and civil engineering structures, Architrave® v.2011 [3], is presented and its features, capabilities and performance are compared with the well-known and widespread computer programme, SAP2000® v.15 [4].

2 Architrave. Developers, Components, Features and Capabilities

Architrave has been developed at the Universitat Politècnica de València and is the result of the collaboration between two research groups: CiD (Departamento de Mecánica de los Medios Continuos y Teoría de Estructuras) and GRyCAP (Grid y Computación de Altas Prestaciones, Instituto de Instrumentación para Imagen Molecular).

Architrave is a Windows® based computer programme composed of three independent components that closely interact among them: Architrave Design, Architrave Analysis and Structural Simulator.

2.1 The Design Component

Architrave Design is a graphic user interface based on VisualLISP/OpenDCL language and implemented as a plug-in of AutoCAD®. The structural model is defined using AutoCAD graphic and non-graphic entities. Mechanical properties are embodied on such entities. Model edition and visualization is performed using the powerful and well-known capabilities of AutoCAD. The model can include: bars, two or three-dimensional finite elements, supports, releases, materials, user cross sections, loads and load cases definition. A model generator based on prototypes creates: trusses, grids, 3D frames, slabs, shells and walls. Structural surfaces are automatic and dynamically meshed using Delaunay procedures.

2.2 The Analysis Component

Architrave Analysis is an interactive graphic user interface application created for visualizing and managing the structural model. The high performance 3D graphic engine can manage on real time many views (wireframe or solid dynamic rendering) of the very complex models. This module manages the calculation procedures and its results (internal forces, movements, stress, etc.). It also performs, on demand, the edition of the model and the process of sizing/checking bars dimensions.

This component can run as a standalone application or connected to a local network. However, recently it has been implemented as a Cloud Service [5, 6] to perform on-demand structural analysis over the Windows Azure-based Cloud infrastructure provided by the EC VENUS-C [7] project. Thanks to the high throughput and reliability of this system it will be possible to solve larger scale problems, increase the complexity of the structure to be analysed, and carry out a larger number of realistic dynamic simulations without simplifications.

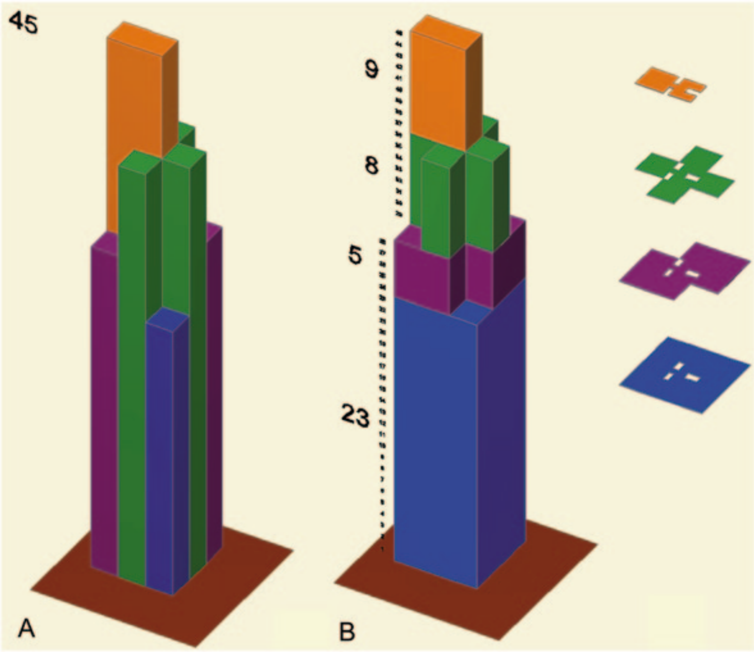

Fig. 1 Reference building of 45-story, conceptual design and floor surface reduction

2.3 The Structural Simulator

A batch Message Passing Interface (MPI) based on parallel application is used by the Analysis Component to simulate the response of the structure by means of the Finite Element Method. On this component have been implemented high performance computing procedures for simulating: Linear static and Modal, Response Spectrum and Time History dynamic behaviour.

3 Characteristics of the Tested Structure

An "ad hoc" structure has been designed for a 45-story building that resembles the Willis Tower [8] (formerly named and still commonly referred to as Sears Tower) at Chicago, Illinois. See Fig. 1B. The model includes bars and two-dimensional finite elements arranged appropriately to bear, statically and dynamically, the loads—gravity, wind and earthquake—prescribed by the Spanish codes of practice (CTE and NCSE-02) for such kinds of buildings.

The structure is composed of a 3D portal frame structure solved with steel beams and columns working as a bunch of structural tubes (Fig. 1a). The floors are slabs of

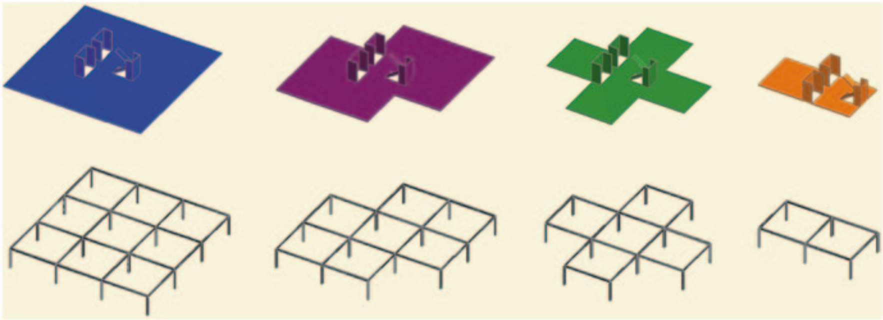

Fig. 2 Steel bars (beams/columns) and reinforced concrete finite elements (slabs/walls/stairs)

reinforced concrete as well as the stairs. The vertical communication core is materialized as reinforced concrete walls serving as vertical structure and lateral bracing. See Fig. 2. The spans and story heights are moderated (8 and 3.5 m respectively). The foundation consists of a deep system of piles not included on this model.

Two structural models were defined for the analysis. The first (Fig. 3a) combined the steel 3D portal frame with slabs and stairs defined as 2D finite elements of reinforced concrete. The second one (Fig. 3b) included the same 3D portal frame and the stair/elevators shafts represented as 2D finite elements of reinforced concrete.

The dynamic response of the structure was simulated under the influence of a seismic load of 15 s of duration, with a simulation time increment equal to 0.01 s. These results were stored every 0.05 s. The accelerations used for the time history were those registered on 1999 earthquake occurred at Turkey.

4 Compared Performance

Both structural models were analysed using Architrave v.2011 and SAP2000 v.15 in order to study their functionality and efficiency. Table 1 shows the characteristics of the computers used to compare the performance.

The main aspects taken into account on the compared assessment were:

1. Cost of licensing and software maintenance.
2. Computation time required for analysing large scale or complex structures under static linear conditions.
3. Implemented features on high performance computing for managing large sets of structural simulations under dynamic loads (Modal, Response Spectrum and Time History).
4. Tools provided for each computer program for defining, visualizing and editing the structural model: geometry, dimensions, support conditions, loads, released degrees of freedom and 3d solid rendering.

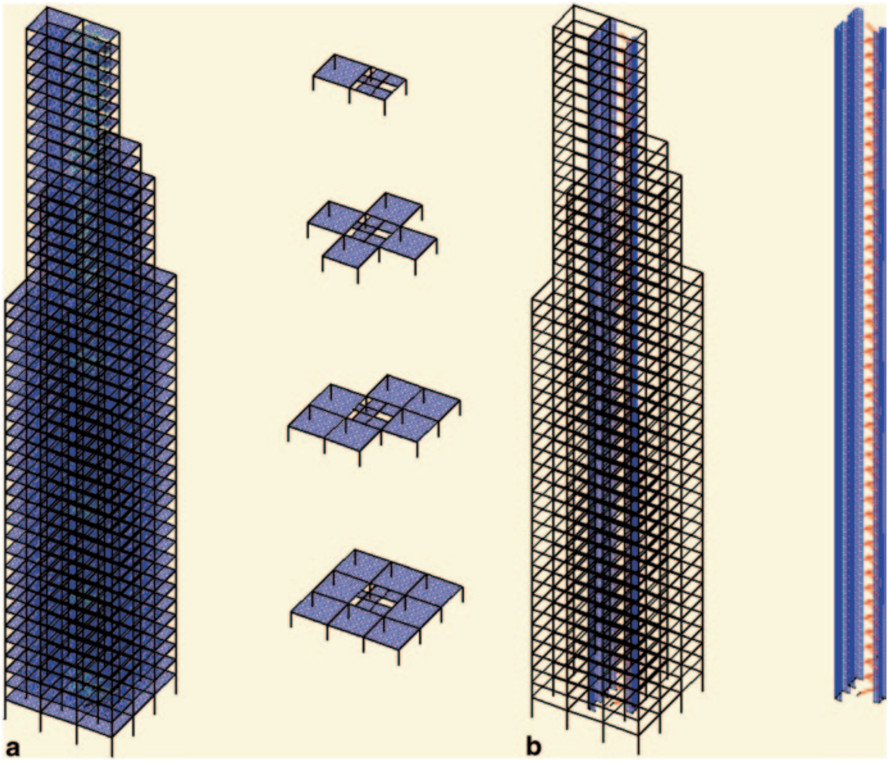

Fig. 3 Structural models analysed. **a** 3D rigid frame of steel bars and mesh of reinforced concrete finite elements for slabs and stairs. **b** 3D rigid frame of steel bars and mesh of reinforced concrete finite elements for shear walls and stairs

Table 1 Computers used to analyse the structural models

Features	Computer 1	Computer 2
Operating system	Windows 7 Enterprise 64-bit	Windows 7 Professional 64-bit
Processor	Intel Core2 Duo	Intel Core2 i5
	CPU P8600 @ 2.40 GHz	CPU M520 @ 2.40 GHz
RAM memory	4.00 GB (3.87 GB usable)	4.00 GB (3.86 GB usable)

The standalone licence of Architrave v.2011 costs 1200 €. The price of SAP2000 v.15 ranges from 6300 € (Plus level) to 14600 € (Ultimate level). SAP2000 includes more analysis procedures than Architrave although both have implemented Linear static and Modal, Response Spectrum and Time History dynamic behaviour. A compared assessment shows that Architrave v.2011 offers the same features than SAP2000 v.15 Plus but it costs 80 % less. It should be noted that the implemented version of Architrave v.2011 on the Cloud Service will reduce even more the cost because the user will not need to buy a licence but only pay per use.

Table 2 Processing time and statistics for structural model A (in seconds)

	Architrave 2011		SAP2000 v.15	
Type of process	Computer 1	Computer 2	Computer 1	Computer 2
Export from AutoCAD	28	29	–	–
Import from TXT exchange file	201	124	485	333
Refresh 3D wireframe visualization	2	0.4	10	4
Refresh 3D solid visualization	1	0.2	Inadequate	Inadequate
Linear static analysis	37	30	94	580
Dynamic (Newmark) analysis	3,057	2,145	14,378	12,680
Modal (6 modes) + sprectrum	98	76	485	870
File size (in Mbytes)	9.36		36.04	

Model statistics: Stories (45), Joints (81,015), Degrees of freedom (486,090), Bars (17,253), 2D finite elements (75,366), loads (135,600), basic load cases (3), combined load cases (5)

Table 3 Processing time and statistics for structural model B (in seconds)

	Architrave 2011		SAP2000 v.15	
Type of process	Computer 1	Computer 2	Computer 1	Computer 2
Export from AutoCAD	3	8	–	–
Import from TXT exchange file	14	7	60	40
Refresh 3D wireframe visualization	0.2	0.1	2	1
Refresh 3D solid visualization	0.1	0.1	Inadequate	Inadequate
Linear static	6	6	20	19
Dynamic (Newmark)	856	567	5,125	4,930
Modal (6 modes) + sprectrum	14	13	61	58
File size (in Mbytes)	1.92		5.80	

Model statistics: Stories (45), Joints (13903), Degrees of freedom (83418), Bars (4813), 2D finite elements (11950), loads (14388), basic load cases (3), combined load cases (5)

Tables 2 and 3 show the results obtained for every process on both models for each computer while using Architrave v.2011 and SAP2000 v.15.

5 Conclusions

Architrave v.2011 is performing structural analysis more than five times faster than SAP2000 v.15, its graphic interface and visualization performance is ten times more efficient and the cost of a standalone license is less than a fifth. Using Cloud Service is even more convenient. In this way, the reliability and safety of the results obtained will be improved and new structural problems will be tackled. Since the time spent on the design of buildings and civil engineering structures will be reduced, the engineering companies and the architectural studios will increase easily their productivity and volume of business.

Finally, there will be no need of acquiring software licenses in property and expensive hardware for solving large-scale structural problems (just pay per use), and the users will not be worried about new software updates.

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Adapting Architectural Theories by specifying criteria for compliance with new requirements. The implementation of the Open Building in Residential Building

S. Hernando and A. Del-Águila

Abstract This research is a small part of the complete PhD. The origin is the need for the methodology which allows the implementation of Open Building theory, recognized internationally. Having examined the state of the art, there is a need to redefine the criteria previously defined by the original theory. The reasons were mainly two, the obsolescence of the original defining criteria, and adapting to a specific market, in this case, social housing in our country.

The new criteria are defined by the requirements which must be met to achieve the objectives in research, a new concept of sustainable housing, industrialized and flexible and able to adapt to changes. It is a complex process, based on the search for specific targets, which allows us to bring theory closer to practice.

Keywords Open building • Industrialized • Industrial technology • Social housing

1 Introduction

Society is constantly changing and housing, as a reflection of that society, needs to adapt to these changes in a functional manner in accordance to its needs. A new model of sustainable, flexible and industrialized social housing, characterized by functionality and quality, is the main objective to be achieved through this research. Economic, social and environmental factors should be taken into account when developing this new model [1].

Concepts such as sustainability, flexibility and industrialization in construction are intrinsically linked. The advantages offered by an industrialized production—especially by Open Building—compared to traditional or closed industrialized systems, have an influence on improved production and product sustainability throughout the building's life cycle.

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The implementation of the internationally recognized theory as Open Building, in our housing production model, can be a breakthrough in the modernization of the building. Open and adaptable industrialized building makes the technological innovation to generate large benefits to the production model possible [2].

The most general of these characteristics are as follows: interior and exterior flexibility; social aspects (for example, the inclusion of women in the workplace and management processes and the implication of the end user in decision-making phases) and finally the achievements of a more sustainable sector which takes the whole building life cycle into consideration.

Secondly, in the case of those that imply a greater technological and economic responsibility the following can be listed: greater site control; production processes adapted to project needs, the so-called "just in time", greater optimization and economic and timeframe control, greater quality control and, what is no less important, workforce productivity, with more specialized, more stable staff whose performance levels are better and whose wage costs are also stable.

2 Research on the Open Building Theory and CIB W104

Open Building is an approach to the design of buildings that is recognized internationally to represent a new wave in architecture, but a new wave with roots in the way ordinary built environment grows, regenerates and achieves wholeness.

Throughout North America—and increasingly, throughout the world— non-residential buildings are constructed in an Open Building (OB) approach. Office and retail developers, their design and construction teams, and the associated regulators, lenders, owners, tenants, and product manufacturers are reorganizing the building process. They routinely work according to principles and methods that have developed over recent decades in direct response to extraordinary and accelerating change in the shaping of environment [3].

Developments in commercial construction are now moving into the residential sector. In Europe, Asia and North America, residential Open Building principles, variously known as OB, S/I (Support/Infill), Skeleton Housing, Supports and Detachables, Houses that Grow, etc.— are now spear-heading the reorganization of the design and construction of residential buildings in parallel ways. In many cases, residential Open Building is based on the reintroduction of principles intrinsic to sustainable historic environments around the world.

The principle tool used by those working in an open building way is the organization of the process of designing and building on environmental levels (Fig. 1).

The idea of environmental levels is not new, but the clear formulation of the principle of levels is rather new, having been framed most recently in The Structure of The Ordinary: Form and Control in the Built Environment (Habraken, MIT Press, 1998).

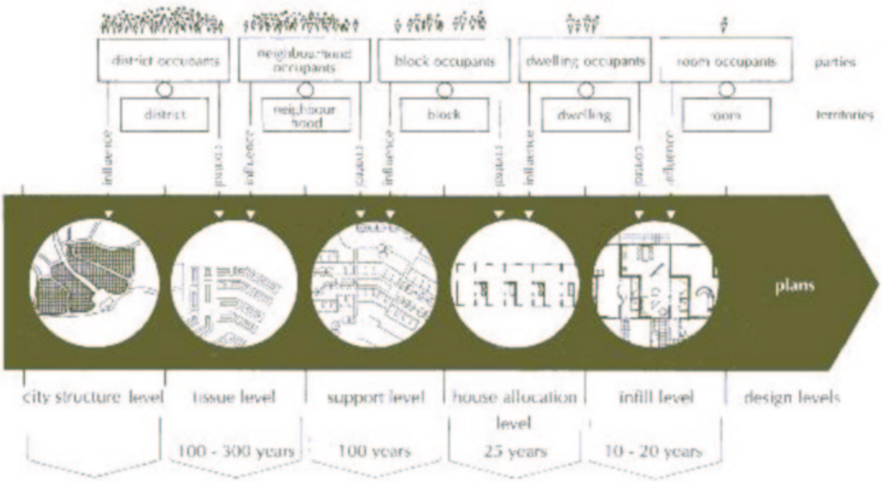

Fig. 1 Schematic representation of the environmental levels

The design professions, for their part, have evolved naturally in correspondence to the behavior of environmental levels: urban planners, urban designers, architects and interior architects each operate according to a certain level of intervention.

CIB* W104 is an international network of researchers and practitioners who subscribe to the Open Building approach. In doing so we seek to formulate theories about the built environment seen in this dynamic way and to develop methods of design and building construction compatible with it.

The Open Building Implementation network (www.open_building.org) was formed in 1996, under the auspices of the CIB (International Council for Research and Innovation in Building and Construction). Members of the CIB W104 come from many countries including the USA, the Netherlands, the UK, Finland, France, Japan, Korea, China, Taiwan, Mexico, Brazil and South Africa [4].

3 The Criteria Defined by the Open Building

The characteristics that define Open building are described in Kendall and Teicher's book (2000), based on the first professional work of Beise (1998) and Tiuri (1998),although they are limited to a catalog of specific approaches.

These include:

1. Recognizing and organizing work according to environmental levels
2. Distributing decision-making
3. Physically separating support, infill and other environmental levels
4. Disentangling building subsystems

User as decision maker	
A1	User decides on floor plan with infill
A2	User participation at the support level
B1	Optional floor plan for the first user
B2	User participation without changeability
Open spatial structure	
A3	Regulation of the distr ibution of spatial units
A4	Free configuration of the floor plan
Separation of support and infill systems	
A5	Open frame structure
A6	Independent distribution of service to units
A7	Access floor or service zones
A8	Infill systems for services
A9	Infill systems for partitions
A10	Infill system for facades
Open Building process	
A11	Distribution between support and infill
A12	Procedures for user participation
A13	Functional and technical design distinguished
A14	Implementation of infill unit by unit

Fig. 2 Table of defining criteria for Tiuri, 1998

5. Structuring professional services in support of household choice
6. Using specific Open Building methodological tools
7. Using specific Support technologies in conjunction with infill systems
8. Using specific infill technologies
9. Using specific Open Building financial instruments

Professional works of Tiuri on the Open Building field led to a series of criteria that have set the foundations for many research studies on the implementation of the Open Building. Some of them are methods of assessment of the degree of application of existing theory to date, are shown in the following table:

4 The Analytical Study as a Method for Developing Criteria

Early in our research we thought that the theory, about which so much has been studied and researched, set criteria able to solve technically the demands we had previously marked.

One of the first conclusions of the research led us to consider a new objective. This first conclusion is obtained from the definition by specific criteria. Is there enough current criteria defined? Do they need to upgrade? Is it necessary to define specific criteria to obtain our objectives?

One of the main characteristics that define the theory is the flexibility and adaptability of its intrinsic characteristics. These intrinsic characteristics cannot be perfectly defined within themselves, they need to change over time, update, expand and adapt to different circumstances. This feature showed us the need to make these modifications and adaptations to our specific requirements.

The research objectives are set based on the need for a change in the current housing situation, specifically in the case of social housing which is mainly promoted by the government.

The need for a change in this model warrants the investigation already undertaken as well as the tools to implement the original theory that must be defined in the research.

To achieve all this, we have developed a method which involves a first phase the following analytical studies:

4.1 Sectors with high technological and innovative industrial production, from the standpoint of the application of the methodology for production and technological development in the building sector. The aircraft industry, shipbuilding, automotive, railway or the furniture industry serve us as a basis for trying to extract the concepts and technological developments that have some ability to be transferred to housing production, to facilitate the implementation of the theory of Open Building.

4.2 Case studies of industrial construction sector, mainly in the auxiliary industry, which has a high-tech and important industrial production worldwide.

Analyzing the state of the industry and the construction sector based on the experience gained during the investigation in INVISO Project as part of the team Subproject 5 “Optimization of the production of housing”.

In the investigations carried out in the “Cathedra of Industrialization” doing more than 80 visits to factories and construction sites.

By work of critical analysis of the database industrialized components and systems in Spain and can thus get a panorama view of the industrialization of the construction sector.

4.3 Cases of concrete actions for residential construction, which have implemented some of the innovative technologies, we could analyze the result we have taken the experience of this type of experimental building.

For these cases, we have chosen the most representative in Japan and Central Europe as the most innovative examples and a study of the state of the experiment in our country, mainly in housing promoted by the government, and the specific case of Madrid.

These three points correspond to the first phase of the research methodology. The second phase can be understood as an applied way in pursuit of predetermined objectives.

5 From Theory to Practice: Redefining Criteria to Facilitate the Implementation of the Architectural Theory

There is a need for setting criteria that define the new concept of social housing with the needs required to the circumstances in which it will be located. With the new requirements of sustainability, industrialization and adaptability or flexibility features that a home should have in public protection arrangements.

A new definition is set by updating, adapting and enlarging the new criteria that defines the Open Building, taking into account the studies conducted so far.

A new definition criteria is created, based on the schema defined by Tiuri, is modified in some cases, though usually expands due to the need to incorporate new concepts studied in upstream of the research.

The use of methodologies and technologies from other advanced industrial sectors, the analysis of the industry's construction sector, and case studies of implementation, and analysis of previous experience so far.

With all these new additions, we set the criteria defining the characteristics of each, being always divided into three categories depending on their possible compliance.

The first is the criterion of non-compliance or non-significance (considering the usual choice in the context of current housing production).

The second possibility is considered an option where there is an improvement compared to that first practice.

The third, the highest level of implementation, which is the best practice possible for a relatively reasonable cost.

After defining the necessary criteria in can be applied in two different ways:

a. By the proper choice, evaluation and feasibility study of systems and components, which belong in today's market, to promote the establishment of the Open Building in residential projects of social character.
b. By proposing new solutions based on the study of the first stage of the methodology, and according to the requirements of the second phase, by choosing, evaluating and analyzing the viability of implantation as in the previous case. We were able to move the original ideas of the theory to a practical level from a scientific point of view, by setting criteria defined by the objectives to be achieved with tools for study and analysis of technology transfer.

6 Conclusions

An essential part of the research is based on the definition of new criteria that are defined for the possible implementation of the Open Building in our production housing system.

A phase, not considered necessary in principle, has had a great significance within the research process, being essential for the achievement of the objectives.

It has become a tool that facilitates the use of any building systems or components, with the added bonus of being able to extract further evaluation of the same by comparing the different elements evaluated.

Other work can be developed without this update and adaptation of criteria, the results will therefore be different.

The use of this tool allows the implementation of this theory to practitioners and researchers interested by the application of solutions with a high degree of technological innovation and constructive, and which are conducive to the choice of systems that ensure the implementation of the Open building.

The new criteria definition has facilitated that new demands and ideas have been incorporated and new concepts transferred and adapted from other technology sectors, taking advantage of other technologies and methodologies capable of providing a significant improvement in the search of new targets.

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Renovation Using Industrialized Systems In Collective Housing

M. García-Moratalla and A. Del-Águila

Abstract The research project arises from an analysis of the present situation of housing in Spain. The bursting of property bubble has produced a sudden halt in new housing construction. There is an urgent need of house renovation using efficient, economic and sustainable constructive solutions that makes possible a significant improvement in living conditions of existing houses, to comply with current legal standards.

This research develops a renovation proposal using industrialized systems for the collective housing of *Poblado Dirigido de Fuencarral*, Madrid (Architect José Luis Romany, 1958–1961). It demonstrates that housing renovation using industrialized systems results in a significant energy saving and a major improvement in living conditions, with a notable reduction in tenant's troubles during the renovation works, compared with the ones produced by using non-industrialized renovating systems.

Keywords Industrialized systems • Housing renovation • Sustainable construction

1 Introduction

The great number of houses built in Spain during the "property bubble" of the first decade of the twenty-first century, has produced an important surplus of vacant new houses. Because of this and due to the global economic recession, new housing construction has been suddenly stopped. There is an urgent need for house renovation using efficient, economic and sustainable systems, that make possible a significant improvement in living conditions of existing houses, according to current legal standards, and allowing to reintroduce this housing stock into the current real estate market. Meeting the need to make residential buildings more sustainable and liveable [1], and to reduce energy costs, depends strongly on the use of industrialized materials and systems, because of its superior constructive properties, and its easy establishment that results in an important reduction in tenant's troubles during the renovation work.

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We have selected *Poblado Dirigido de Fuencarral* for an integral renovation proposal using the aforementioned systems. This kind of estate has been built with minimum resources and under severe economic restrictions. This is the main reason why the need of improving its living conditions.

2 Objectives

This research's main target is to evaluate the efficiency of industrialized systems in integral renovation of traditionally built collective housing buildings by using a real case.

To accomplish this evaluation, we have analyzed, from several points of view, the advantages given by using this kind of systems, (constructive properties, economic, sustainable and energy analysis). The research also is aimed to determine how the use of industrialized systems results in an important reduction in tenant's troubles during the renovation works, compared with the ones produced by using non-industrialized renovating systems.

3 Material and Methods

To evaluate the efficiency of using industrialized construction systems in housing renovation, we have developed an integral renovation proposal over collective housing buildings of *Poblado Dirigido de Fuencarral (Arch: José L. Romany Aranda, 1958–1961).* First of all, we analyze the original project, the renovation made in 1965, and the current condition of those houses. Other similar estates renovations have been studied [2]. Afterwards, the restoration proposal using industrialized systems is developed, dividing its procedures in four types: actions aimed at functional improvement, actions aimed at sustainable improvement and energy saving, actions aimed at architectural barriers removal (i.e. for disabled access), and actions aimed at infrastructures improvement.

Finally, we analyze the efficiency of solutions generated by using industrial systems in the renovation proposal, from an energy and financial point of view, and reduction in disturbance to the tenant during the renovation works.

4 Application in a Real Case. *Poblado Dirigido de Fuencarral*

4.1 Current State

Specifications
Architect: José Luis Romany Aranda

Fig. 1 Estate image

Fig. 2 Collective housing. Floor plan

Developer: Instituto Nacional de la Vivienda
Location: Distrito de Fuencarral, Madrid
Date: Project, 1957 Construction, 1958–1961
Renovations: 1 (1965)
Houses: 2039 Type: Collective housing (4–5 floors) [3]

General Characteristics The *Poblado Dirigido de Fuencarral* is a part of second phase of National Housing Plan in 1956. It was built to receive the growing migration from rural zones to the cities. Seven of this type of settlements were done in Madrid, all of them designed by Spanish young and avant-garde architects; Oíza, Romany, Cubillo, Sierra, Alvear, Vázquez de Castro, Íñiguez de Onzoño, Carvajal, Corrales, Molezún y Gª de Paredes [4]. The houses were very economical, most of them completed by autoconstruction, (i.e. system that allows future owners to take part in the actual house building process resulting in a house final price reduction) (Figs. 1 and 2).

The *Poblados dirigidos* are unique examples in a general overview of Spanish social housing in the fifties and sixties [5].

Constructive Characteristics
Structure: Brick masonry walls perpendicular to facades. (flemish bond)
Facade: Brick masonry walls (running bond)
Windows: Aluminum frame. Simple glazing
Roof. Inclination 7 %. Waterproofed by an asbestos ply (1st renovation, 1965)
Infrastructures: Plumbing, electricity, fixed telephony and data on facade.
Accesibility: Non-guaranteed. No elevators. Level changes in access.

4.2 Renovation Proposal

Next, there is a summary of procedures to complete the integral renovation of the collective housing buildings of the settlement, using industrialized systems and components.

The objective of this proposal is to adapt these buildings to current regulations (energy saving, accessibility, infrastructures, etc.) in a short time, with fixed costs, and producing minimum troubles to tenants during the renovation works. This proposal also has a target to recover the unitary character that featured all these settlements and particularly *Poblado Dirigido de Fuencarral,* [6], damaged by partial renovations individually completed by tenants.

1. Procedures for Functional Improvement
House living surface area extension. (Current standards [7]) (Figs. 3 and 4).
2. Procedures for Sustainable Improvement and Energy Saving

Facade	Setting-up of ceramic ventilated facade (Fig. 5) Windows substitution
Roof	Controlled removal of current asbestos roof Setting-up of industrialized roof system (Fig. 6)

3. Procedures FOR Infrastructures Improvement
Infrastructure cavities in vertical shafts (Fig. 7).
4. Procedures for Architectonical Barriers Cancellation
External elevators and footbridges to access (Fig. 8).

5 Results

5.1 Evaluation of House User's Troubles During the Renovation Works

All the procedures of this integral renovation proposal are completed from the outside of the buildings. Because of this, the disturbance to tenants during the completion of the works is very small. Using industrialized systems makes it possible to reduce the work schedule over those using non-industrialized ones [8]. Evacuation of tenants is not necessary in any part of renovation proposal works.

Tenant's disturbance caused by renovations proposed have been analyzed one by one.

Facade. The ceramic ventilated façade with the insulation arranged over the external face of current facade, replaces the internal insulation of traditional solutions that usually results in a partial or total evacuation of tenants during the renovation

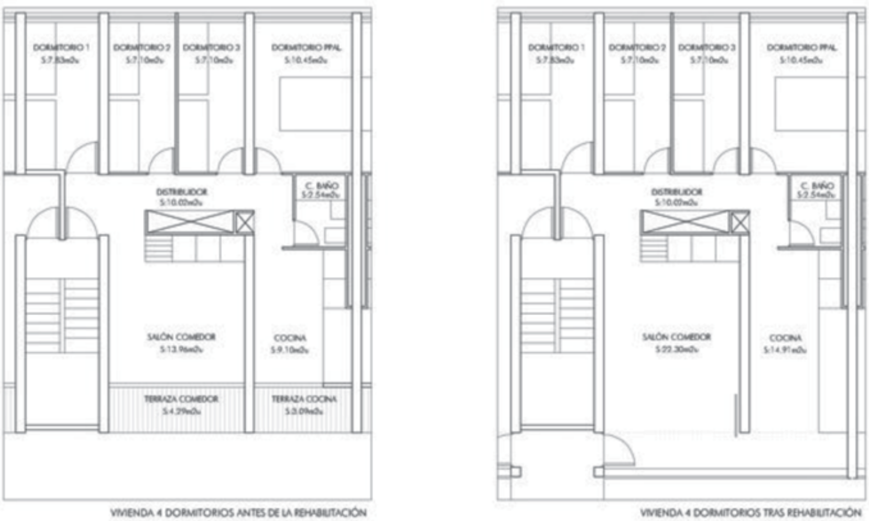

Fig. 3 House extension. Before & after

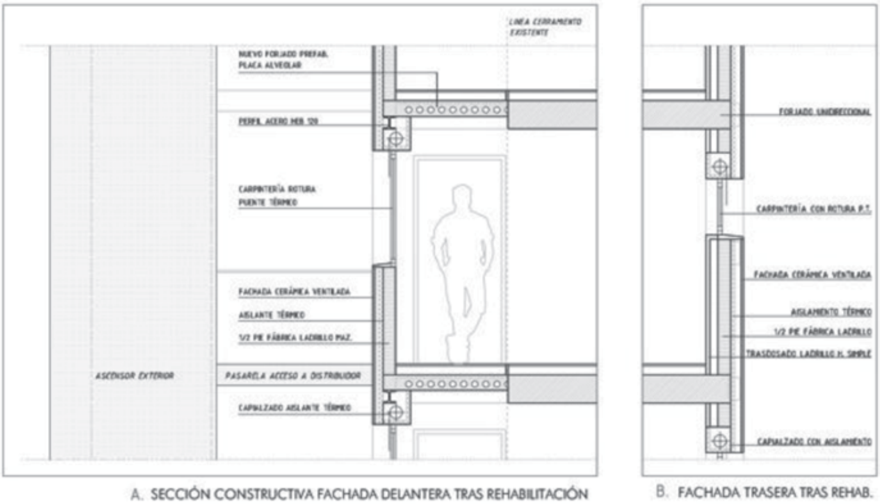

Fig. 4 House extension. Section

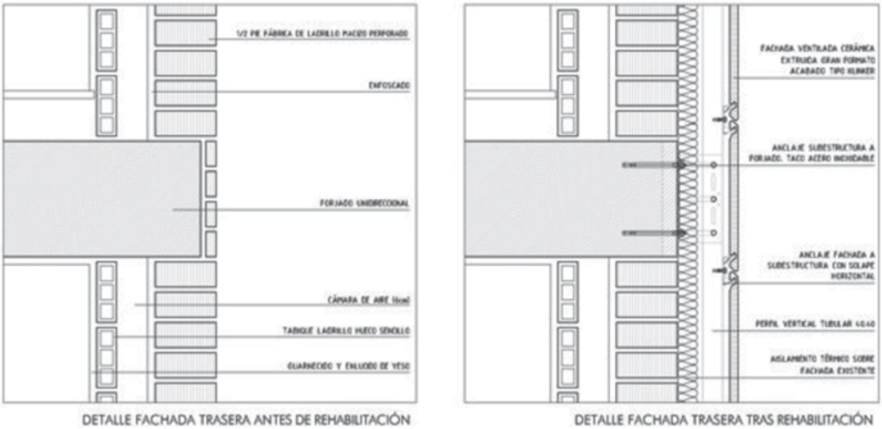

Fig. 5 Facade renovation. Before & after

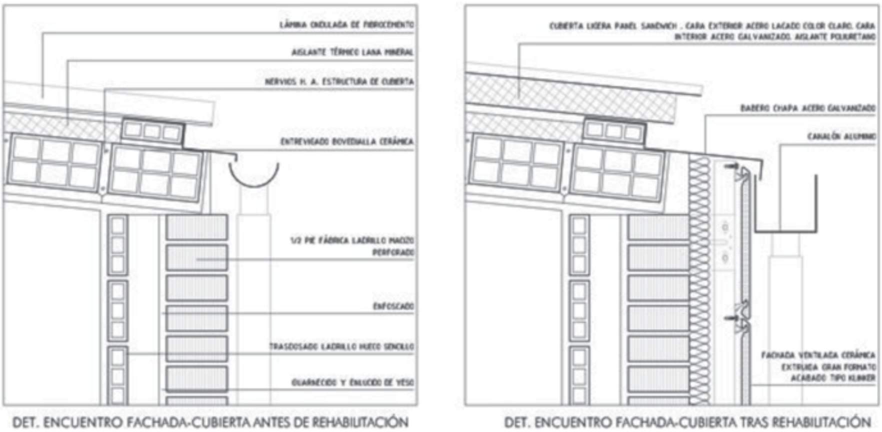

Fig. 6 Roof renovation. Before & after

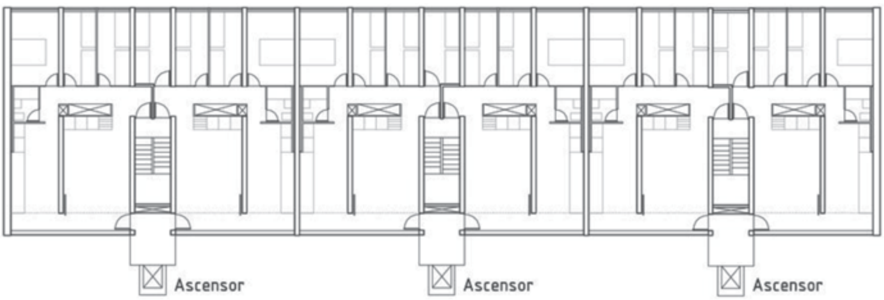

Fig. 7 External elevators

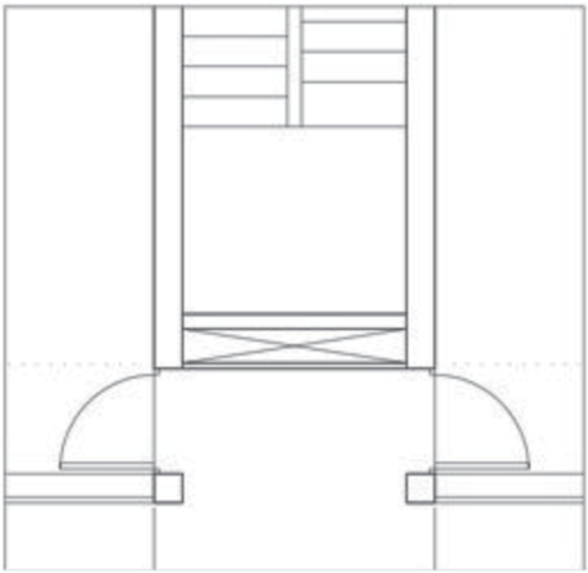

Fig. 8 Infrastructure shafts

works. Its time to set up is also shorter than traditional ones. Tenant's disturbances are limited to work noise and the covering of the facade by scaffolding structures.

Roof. Asbestos fiber roof removal doesn't generate troubles to house users. It has been done in a high controlled procedure, by highly qualified staff. The aim is not to create dust clouds that should be damaging for human health. Roofing by sandwich panels over existing roof structure, and solar panels positioning in roof, limit disturbances, (they are also completed by external face of buildings).

House living surface extension. Inconveniences caused by the widening of houses are also reduced. This extension would be made independently of houses. As a final part of the extension works, existing casing would be removed, giving access to the extended part.

Accessibility: Installation of elevators outdoors does not obstruct doorways during the works. The new entrances made in new living rooms render it unnecessary to open entrances in existing walls. The initializing of elevators, footbridges and house extensions should be completed simultaneously.

5.2 Evaluation of Energy Saving Resulted by Renovation Proposal

An evaluation has been completed of the energy usage arising from the rehabilitation proposed, through comparison of the thermal transmission values in each element of the facade, before and after rehabilitation (Table 1).

Table 1 Facades transmittances (before and after renovation)

Facade	Transmitance (W/m²·K)	
	Before	After
Long facade	1.55	0.40
Cross facade	1.20	0.37
Roof	0.51	0.24
Glazing	4.13	2.60

Evaluation's results demonstrates that renovation hits the target of reducing heat transmission through facades, leading to a major energy saving, and making possible the adaptation of houses to current Spanish regulations [9].

5.3 Evaluation of Economic Cost of Renovation Proposal

We have completed an economic assessment of the costs of renovation, using one of the blocks of flats of the estate. Total 30 apartments (5 floors, 6 apartments per floor) (Table 2).

Owner's expenses should be reduced, because of grants given by different public administrations for housing renovation [10], for sustainability improvement and energy saving, common elements of houses improvement, and for improvement of functionality work [11].

6 Conclusions

Analysis of renovation proposal of collective housing buildings of *Poblado Dirigido de Fuencarral*, demonstrates that industrialized systems in housing renovation have high efficiency levels from many points of view. First of all, looking at energy analysis, this research demonstrates high levels of efficiency in houses conditioning. Using ventilated facades, combined with industrial insulation on the external face of existing walls, results in constructive systems with very good energy performance, and important reduction of thermal transmittance. Using windows with modern properties double and low-e glazing also contributes to reduce energy demand.

One of main advantages of industrialized systems is to reduce user disturbance during renovation. In this case, the use of this kind of systems have made possible that all procedures could be accomplished on the external face of the building, shortening work time, and limiting nuisance to users.

Assessing the whole building as a target of renovation, contributes to recover the unitary character of the original project, unifying facades and windows, and respecting materials employed in the original project, by using the same kind of ceramic materials, resulting in an improvement in the urban image of the estate.

Table 2 Economic cost of renovation proposal

Materials estimate	398,264.00 €
Gral. costs & Industrial benefit (15 % M.E)	59,739.60 €
Contractors estimate	458,003.60 €
VAT (7 %)	32,060.25 €
Total	490,063,85 €
Technical fees (10 %) M.E	39,826.40 €
VAT (18 %)	7,168.75 €
Total	46,995.15 €
Licenses (4 %) PEM	15,930.56 €
Total renovation	552,989,56 €
Total expenses by apartment (30 apartments)	18,432.99 €

The analysis of the economic costs of renovation illustrates that the use of industrialized systems helps to limit costs. Due to its industrialization and qualified staff set-up, costs could be controlled more exactly than those generated by non industrialized systems.

Environmental impact produced by industrialized systems is low. Construction is carried out by waterless systems. All components are factory manufactured, quality control is more exhaustive, and waste material volume is reduced, resulting in a low ecological impact.

Conclusions demonstrate that at this moment, when housing renovation is more necessary than ever, the use of industrialized systems could become the best way to give housing the equivalent constructive properties of new housing, making possible its adaptation to current regulations.

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Free-Form Architectural Façade Panels: An Overview of Available Mass-Production Methods for Free-Form External Envelopes

L. Alonso-Pastor, B. Lauret-Aguirregabiria, E. Castañeda-Vergara, D. Domínguez-García and G. Ovando-Vacarezza

Abstract Factory made free-form external envelopes in architecture are a major demand. Recent advances both in computer generated 3D forms and in digital fabrication offer a new opportunity of mass production free-form panels for architectural envelopes. However there are some disadvantages that seem to block a successful application of them, as not yet achieved goals such as: getting a suitable division of the form, strength of the material produced available materials for CNC milling/tooling, affordable cost of the process. Examples of actual buildings will be presented to illustrate the feasibility of digital production of free-form envelopes. Scientific literature will be also reviewed. Effective methods for free-form panels factory produced will be discussed. Conclusions will be drawn both on the availability of digital fabrication of free-form panels and on further research required.

Keywords Free-form architecture • Mass-production methods CNC milling/tooling • Digital fabrication • Bioclimatic architecture

1 Introduction

Free-form architectural envelopes have been successfully handcrafted on site, working with traditional materials such as brick, wood and concrete. But this type of construction is generally expensive and time consuming. From Sydney Opera House to the present days factory made free-form architectural envelopes is a major demand [1]. In the digital age computer generated 3D forms are easily achievable and architects benefit from a series of computer software applications to help them get a broader freedom of design [2]. However, construction industry does not always offer a straight path from design to fabrication at a reasonable cost [3]. Several

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methods offer a new opportunity of digital fabrication of free-form panels but their suitability for architectural envelopes is yet to be assessed.

Regarding the freeform, there are three major challenges; getting a suitable division of the form, strength of the material produced available materials for CNC milling/tooling, affordable cost of the process. These three challenges can be summarized in a goal for the architecture industry which is the generation of variable-geometry surfaces using relatively large panels that can be produced with a given technology at a reasonable cost.

2 Free Form Background

One major issue when dealing with mass-production components for building construction is the usually short number of repetitive parts. Moreover, given that flexibility and customization are a desirable virtue of a good industrial process, methods that allow for single unit production are of great value. In this way digital processes could be the answer to the inherent architectural variation.

There are a wide and increasing variety of systems; they can initially be divided into 2D and 3D ones. 2D digital production essentially involves the free-form cutting of material sheets. 3D on the other hand, could be of three types: material creation, forming or subtraction. Furthermore material selection becomes critical as far as not every material adapts to every process.

Another virtue of digital processes is that they could be well connected to design process, broadly extended among architects. To divide building surface into reasonably sized panels is often a necessary task. Several advances in this field are being carried out.

3 Panel Division Software

Recent advances in processing a free-form surface for suitable division for optimum panel production are found in the work of Michael Eigensatz [4]. In it the so called operations of "paneling" the surface involve computational processes that create a more or less coarse mesh over the surface and determine several types of panels: planar, torus, cylinder, parabolic and custom. The program allows varying the maximum kink angle between panels obtaining different amount of each type of panel thus getting higher/lower budget results according to better/worse accuracy in the form (Fig. 1).

Other attempts have been realized by Stargate Resources [5], for the company Formtexx, working in combination with Engineers at ARUP, Buro Happold, Whiston Industries, and in particular with the Architects and Technicians at Zaha Hadid Associates. The aim was to develop a software application called S-Form, to provide real-time Architectural 3D surface penalization for Formtexx clients. This required

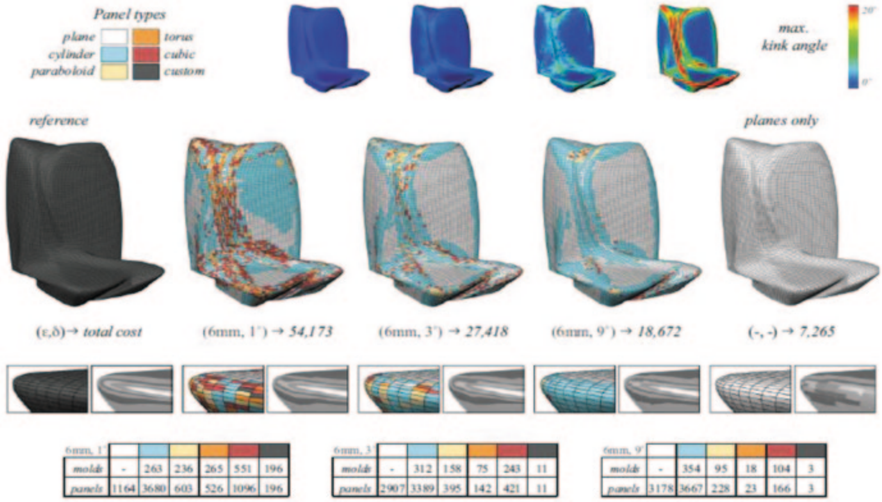

Fig. 1 Panelling results with varying kink angle thresholds δ and fixed divergence thresholds ϱ = 6 mm for the design of the National Holding Headquarters

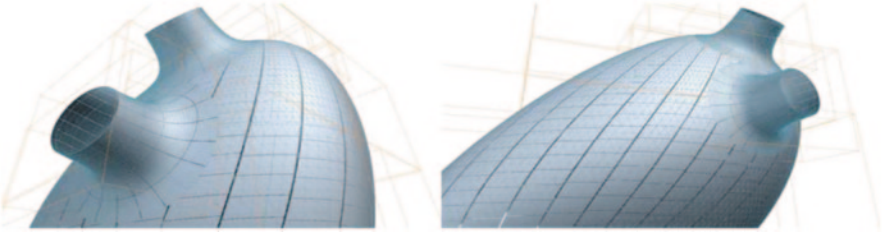

Fig. 2 Coherently divided and then subdivided into sub-surfaces suitable for manufacturing

that a NURB surface, or a set of NURB surfaces, be coherently divided and then subdivided into sub-surfaces suitable for forming by the Formtexx manufacturing process. Unfortunately this work seems to have stopped due to a lack of agreement between Stargate and Formtexx, or more likely to the ending of the later. (Fig. 2)

4 Materials and Systems

Every construction material has its own cutting and forming techniques. However, to achieve the correct form of the surface of a double curved panel almost always a mould is needed. Fiberglass, GRC, plywood and glass are materials formed in moulds from long ago. Here the bulk of free form panels are the cost of the moulds, which cannot be hidden or diluted by long batches. Soft materials CNC cutting or

Fig. 3 Glass reinforced Concrete. Medienhaus K42, Friedrichshafen (Germany). Matthäus Schmid

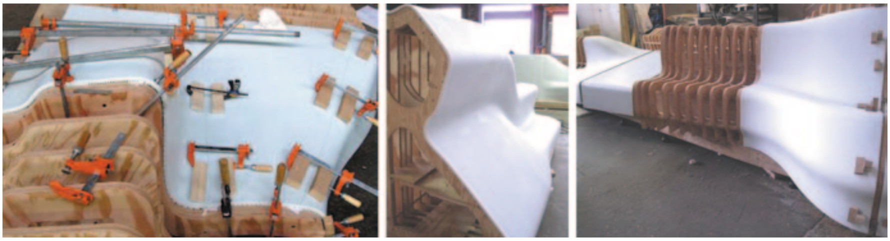

Fig. 4 Corian panels forming on 2D sectional wooden mould. (Associated Fabrications)

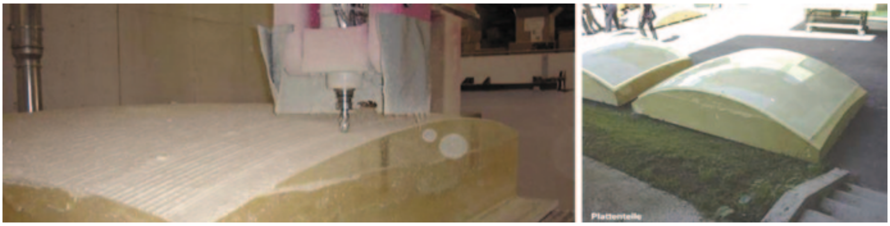

Fig. 5 Polycarbonate panel for BMW Bubble, by Bollinger & Grohmann

milling for making molds are an interesting option to cut down costs. Expanded polystyrene (EPS) is an excellent option for non heating post process: fiberglass, GRC [6] (Fig. 3).

2D cutting is cheaper and faster than 3D milling. In this way materials as Corian can be 3D formed using digitally cut 2D wooden sections at acceptable separations [7]. (Fig. 4)

Other thermoformed materials such as plywood, pre-cured composite or cellulose panels could be formed efficiently the same way since only one smooth face is needed. For transparent panels both surfaces must be perfect, that is why in this case 3D milling is required. Soft materials (Balsa, plaster, others) capable to cope with forming temperature are the option in this case [8]. (Fig. 5)

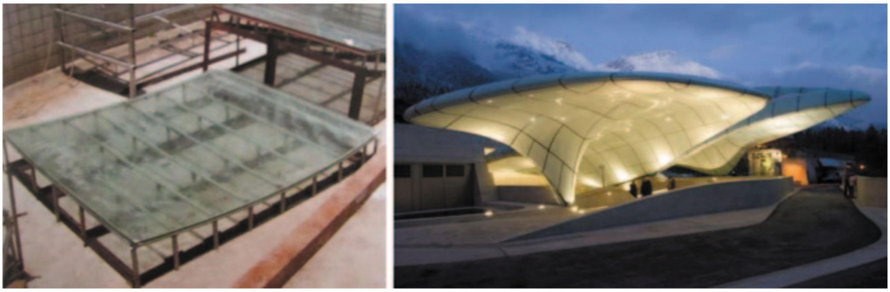

Fig. 6 Glass panels on moulds

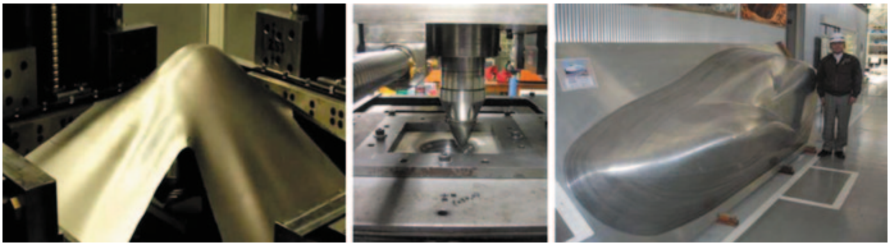

Fig. 7 An example application of ISF: a 1/8 scale model of the front section of a Shinkansen (*Bullet Train*) made by Amino in Japan

High temperature transparent glass forming is a big challenge, not yet achieved at an affordable cost but already built. Metallic member moulds have been used at Zaha Hadid's Insbruck railway stations, to form the double curved glass panels using an expendable glass pane as a sacrifice first molding layer (Fig. 6).

Successive plasma CNC cut metal sheet in the same fashion as wooden boards for Corian forming could do the same job for glass forming.

Sheet metal (aluminum, steel) have been traditionally formed by hand or in stamping moulds. If digital processes could be used to form metal sheet it would be solved their main problem: cost. Three promising processes on metal forming are under development: flexible roll bending, incremental forming and multipoint forming. Incremental sheet forming (ISF), is an umbrella term for a range of processes in which a sheet is formed incrementally by a progression of localized deformation. The key advantage of ISF over conventional sheet forming processes is that specialized dies are not required; a wide range of shapes can be achieved by moving a spherical-ended indenter over a custom-designed numerically controlled tool path (Fig. 7).

Multipoint panel forming (MPF) technology is similar to the forming process with solid dies. Where the latter uses two opposite solid dies that are pressed on a sheet metal blank to conform it to a particular shape, MPF technology replaces the solid die with a matrix f several punches that are adjustable in height by means

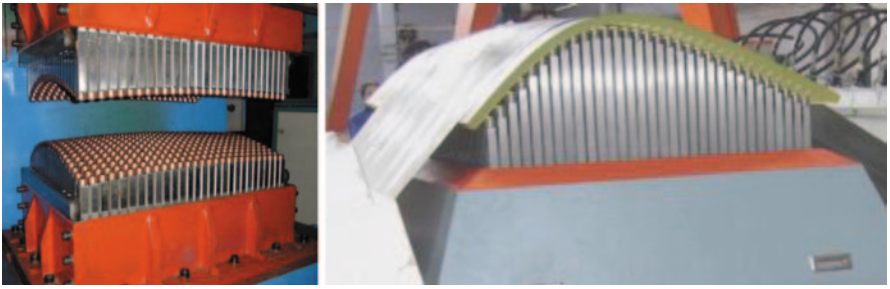

Fig. 8 A multipoint forming (MPF) prototype unit was built at Jilin University in China

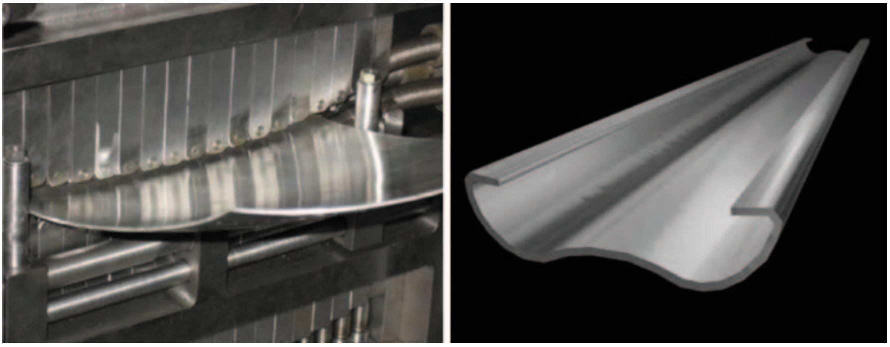

Fig. 9 Three-dimensional sheet metal continuous forming process based on flexible roll bending

of linear actuators. This allows for fast changes in the kinds of shapes that can be produced from a particular unit [9] (Fig. 8).

Flexible roll bending process requires an upper flexible roll and two lower flexible rolls as a forming tool. The sheet metal is curved with the rotation of flexible rolls in longitudinal and transverse directions simultaneously. The flexible rolls are made of steel wire and they're useful to manufacture freeform sheet metal parts with diverse curvatures [10] (Fig. 9).

5 Discussion of the Results

As it has been described, several advances have been made both in the field of free-form computer design and in digital fabrication. The challenge of building complex forms in architectural envelopes generally requires true availability of affordable or controlled cost free-form panels.

Though several attempts in computer surface paneling have been recently performed, these type of design tools are not yet of regular use in architecture offices.

In spite of all, a complex surface can be divided into a network of panels manually. Then individual 3D panels can be accurately defined. Industrial feasibility of such panels requires well integrated digital information to component fabrication, which at least must overcome two barriers: industrial production of small batch or single unit components and effective, strong and durable panel production a reasonable cost. Both issues are closely connected as long as a multipurpose robot could work almost non-stop in very different tasks (cutting, milling, printing, etc.), on different materials, thus allowing for low cost fares while still making initial tool investment worthy and attractive.

Façade envelopes require sturdy and durable materials that can withstand weather conditions for years. Some of them above described could be successfully employed at a content price if construction industry can find the way of cutting costs by using new CNC tools.

6 Conclusions

After the discussion of the information reviewed several conclusions can be drawn:

- Prefabricated free-form architectural envelopes are currently possible both using transparent or opaque materials. Digital control of forms plays a major role in the design stage. Nevertheless seamless flow from digital design to digital fabrication has not yet been achieved.
- 3D software for creating solid forms are broadly available for architectural purposes, but panel division of big sized forms are not yet completely automated though several research attempts are on the way.
- CNC 2D cutting of sheet metal, wood and other materials has become a very extended, easy, relatively cheap and useful method to achieve both 2D and 3D free-form panels. CNC 3D milling is also an available method to make moulds out of soft materials.
- Flexible roll bending, incremental forming or multipoint forming are still in an early stage but they are very well suited methods for efficient fabrication of double curved panels in small batches.
- Double curved glass panels have been already thermoformed even for double glass insulated units, at an expensive cost, using an expendable glass pane as a sacrifice first molding layer.

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Estimation of the Probability of Biological Colonization on Etics

F. Re-Cecconi, G. Pergola and A. Redaelli

Abstract Due to the raising of building thermal performance requirements by energy regulations, there has been an increase of thermal insulation thickness in ETICS (External Thermal Insulation Composite Systems). The configuration of these multilayered walls has unfortunately promoted the risk of growth of biological organisms on the outer side of the façade.

There are many tools to be used for predicting biological growth risk but they are either too complex to be used or unreliable. The aim of the research work is to provide building designer an easy, but reliable, tool (a probabilistic neural network) to compute the probability of biological colonization on the external surface of ETICS.

The primary step consists in the formulation of a risk index, based on both technological and climatic parameters, which provides the growth probability of biological agents in different climate conditions when using different materials for ETICS.

The next step is to create, and to verify, a neural network to compute the risk index. To optimize neural net predictions a large dataset has to be created with parameters as inputs and the risk index quantified through numerical simulations as outputs.

Keywords ETICS • Biological colonization • Neural networks

1 Introduction

The damage caused by the formation of an organic coating on external surfaces of buildings vertical enclosures is one of the most common and recently it has begun to occur frequently also on ETICS. Due to the raising of building thermal performance requirements by energy regulations, there has been an increase of thermal insulation thickness and consequently there has been separation between internal and external temperature variations. So during nighttimes the external surface of insulation layer is subject to condensation due to high drop of its temperature [1].

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Numerous studies have shown that the climatic factors that favour biological organisms establishment and growth on building materials in general are suitable values of relative humidity and temperature [2]. In addition to these it is necessary to consider substrate morphological characteristics, such as roughness and the presence of bumps and recesses, in order to check the appearance of the four phases of biological attack: surface contamination, proliferation, development in depth, colonization [3].

The present research identifies significant technological and climatic parameters for biological growth in order to create a risk index that provides the growth probability in different climate conditions when using different materials for ETICS. Then, through the processing of data obtained from 5200 simulations, a forecasting tool (a neural network) is created. This tool is able to quantify quickly the risk starting from a small number of input parameters without additional complex simulations.

2 Physical and Chemical Environmental Factors

Bacteria, lichens, algae, mosses and mould proliferate on the facades if there are suitable environmental conditions to their growth and if these conditions last enough. Even if these biological organisms are generally very different, they need very similar environmental conditions, so they cohabit on the same surfaces.

Hud [4] indicate that the temperature has a big influence on the metabolism of biological species. In particular Baugham e Arens [5] said that most of considered species survived in a temperature range between −10 and +50 °C. Although this temperature interval is very wide, it is well-known that metabolism of biological organisms is accelerated if the temperature is near the optimum value and slowed down if the temperature is near the maximum or the minimum value of the interval.

Water, in liquid or vapour phase, is also a necessary precondition for biological growth [6], but all species which can be found on external surfaces are able to survive in dry condition in European climates. The absence of relative humidity causes an arrest of biological development that starts again only when a sufficient level of relative humidity appears. The minimal acceptable level of relative humidity on the external surfaces is between 65 and 70 %, it is also possible identify the optimal condition around 75 %.

The roughness of the substrate is another important factor, if it increases there could be a bigger probability of pollutants or other nourishments accumulation [4]. Roughness increase makes also easier the engraftment of the species that have filament or ife [7]. Sedlbauer [7] claims that substratum pH is a basic factor to determine the possibility of biological proliferation. It is nevertheless true that the acceptable range of pH suitable to microorganisms growth is very wide: for the great majority of species pH is between 2 and 11 is not a dangerous environment. Exterior surfaces of ETICS considered have basic pH that is always lower than 11. In particular it has valour between 8 and 9.5. Consequently pH is not a significant parameter that has to be considered for the analyzed cases.

It is well-known that saline content of the substrate is a factor the influences the growth of biological microorganisms. It is nevertheless true that variations of saline content cause very low changes of biological activity. So this factor is not considered in the analysis because it is less important than other factors.

Light is a necessary factor to photosynthetic organisms [7] while is useless for others like mould fungus. This factor is not considered because organisms need diffuse light, always present on external surfaces, and not direct light, that sometimes can be dangerous too.

Oxygen in dry air is around 21 %. All biological species require an oxygen availability between 14 and 25 % to survive [4] and this condition is always satisfied on the external surface.

All the above listed favourable conditions should last for at least a minimum period of time. Biological microorganisms can generally survive for a long time without acceptable levels of temperature and relative humidity, but in these conditions their biological activity stops. It is known that after a biological species has been exposed to adverse condition like drying or high temperatures it does take some time for it to recover the activity it had before the exposure [7]. So time has to be considered as a factor in biological growth risk assessment.

In conclusion, it is possible identify temperature, relative humidity, roughness and time like factors that affect more significantly biological growth on ETICS.

3 Risk Index

Even if there are many risk index to measure the probability of biological growth [8], the one proposed here is based on the isoplethic system. Johansson [3] says that isoplethic system define conditions of temperature and relative humidity on the external surface needed to biological microorganisms colonization and consequently he puts forward an index that depends on both façade RH and temperature:

$$I_z = \int_{t=t_0}^{t_1} f_{T(t)}\ f_{\varphi(t)}\ dt \cdot$$

Functions f_T and f_φ separately express the biological growth reliance on temperature and on relative humidity of the external surface. The curves used in this article are only the ones describing Cladosporium species growth because these are the most frequently found on building façades, and moreover Cladosporium species can proliferate in extreme environmental conditions compared to other species whose data are known [7].

Once chosen f_T and f_φ it is possible to set up a family of curves, called isopleths, as a function of plaster features like roughness and porosity. The first graph Fig. 1 corresponds to a plaster with low roughness and 12 % porosity, the second one to a plaster with higher roughness and porosity equal to 36 %. Curve named "LIM I" (the dashed one) shows environmental conditions that spores need to germinate,

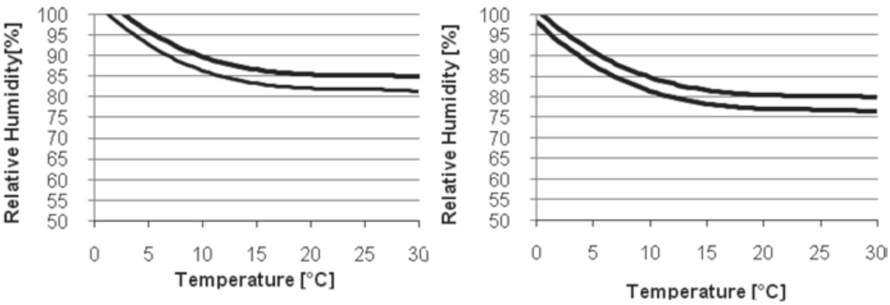

Fig. 1 Isoplethic system curves related to 12 % porosity substrate (lower roughness) and to a 36 % substrate (higher roughness)

while the curve named "LIM II" (the continuous one) refers to the necessary condition to mycelium development.

In this article hygrothermal conditions are considered dangerous if they can be represented by a point in the region of space above the lowest curve (LIM I).

Then actual values of temperature and relative humidity on the external surface as a function of time have to be computed. This can be done by simulations using WUFI® PRO version 5.1, a software, developed by Fraunhofer Institute for Building Physics. WUFI® is able to provide hourly values of temperature and relative humidity during a reference year starting from some inputs like the definition of external climate, the features of the wall and internal conditions.

WUFI® simulations were made under the following hypothesis:

- The wall is exposed on north-west, the most favourable exposure to biological growth;
- The wall is considered installed in a halfway floor to have not significant results variations due to some overhangs;
- There aren't external elements that could reduce daily hour sunshine;
- Humidity conditions of every layer are those that can be found after the evaporation of construction water;

ETICS investigated are made by the following layers (from internal to external): internal finish; support layer; thermal insulation, base and top coat. The internal finish was never changed in all the simulations. It is made by plaster (thickness 1.5 cm). Also the support layer is always the same and is made by alveolar brick (thickness 25 cm).

The simulations were made using different thicknesses (4, 8, 10, 14, 20 cm) of insulation and two different types of insulating board: one made by mineral wool and the other one by polystyrene. Different types of base and top coat, characterized by different porosities (12 or 36 %) and different colours (absorbance SW: 0.2, 0.4, 0.6 or 0.8), were used. As a result of all possible layers combinations 80 technical solutions were considered.

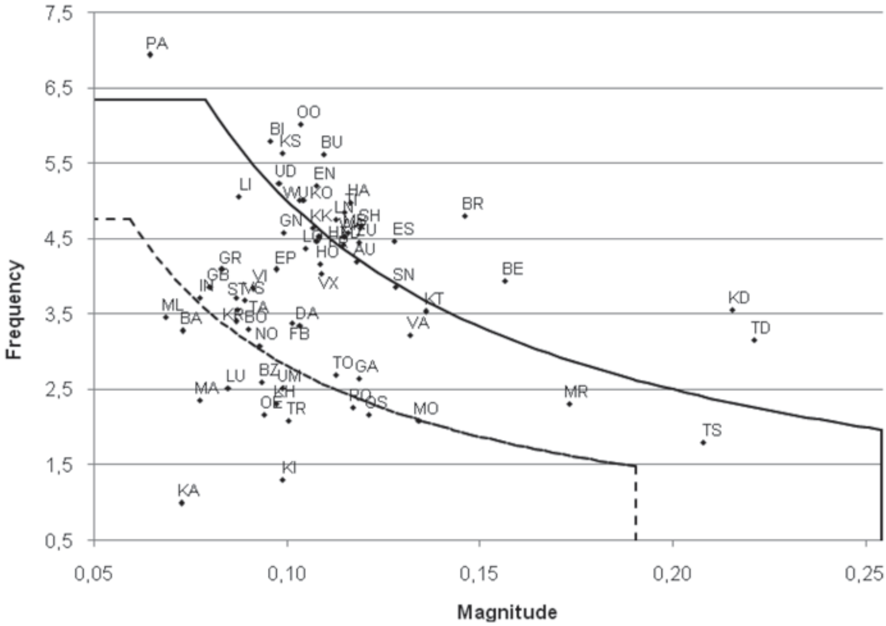

Fig. 2 Example of Cartesian risk graph

Internal conditions are defined according to EN 15026: 2007:

- In wintry period: temperature 20 °C; relative humidity 30 %;
- In summer period: temperature 26 °C; relative humidity 60 %.

The external weather is defined by WUFI® climatic data. The simulations were made by using data of 65 European cities. Data obtained by the program can be plotted in the isopleths graph in order to find periods when there are favourable conditions to biological colonization on the external surface. If frequency is the number of favourable periods during a year, when surface RH% and temperature are above limit curves, and magnitude is the average duration of these periods, it is possible to define a risk index as the product of frequency and magnitude: $RI = F \cdot M$.

Periods shorter than 4 h are not considered because after biological agents have been exposed to adverse conditions, it does take some times for them to recover their activity.

For each technological solution a Cartesian graph where the x-axis corresponds to magnitude and the y-axis corresponds to frequency is drawn (Fig. 2), every point of the graph corresponds to a couple of frequency and magnitude values referred to a city.

Using data obtain from simulations it is also possible to draw on each graph two curves that divide the plane in three different regions characterized by different probability of biological colonization. These curves are rectangular hyperbolas with the coordinates axes parallel to their asymptotes and two straight lines. The straight lines are useful to “cut” the regions to have not too low probability with very high frequency or magnitude.

If the probability of biological colonization in a city is defined as the distance between the origin and the hyperbola through the point representing the city, than the graph can be scaled so that the curve corresponding to 100 % probability is distant 1 from the origin of the axis. In Fig. 2 the upper curve (continued line) represents the 100 % probability of biological growth, the lower curve (dotted line) represents the probability of 75 %. So three different regions that correspond to different risk probability are identified.

If the distance between the origin and the hyperbola through the point representing the city is bigger than 1 then the probability of biological growth is assumed to be 100 %.

4 Probabilistic Neural Network

It may be useful to define a method to compute the risk index without the need to find all the climatic data and detailed technical information about materials because not all the information needed for WUFI® simulations are often available. This method can be based on the database obtained by all the 5200 WUFI® simulations previously made. Neural networks seem to be the best tool, because relying on a mere interpolation may lead up to low accuracy of results. In this research a Generalized Regression Neural Net (GRNN) has been used. It is an artificial probabilistic strictly layered feed forward neural network that used the normal probability density function. The one used is composed of four layers: (a) one input layer formed by as many neurons as the number of inputs; (b) two hidden layers called pattern, consisting of one neuron for each training case, and summation, consisting of numerator and denominator nodes; (c) an output layer formed by a single neuron.

The dataset used to train and test the network consists of all the results obtained through 5200 simulations for all different stratigraphies in 65 different locations. The inputs of each training case are defined by 6 independent numeric values identifying the type of ETICS used and the climate of the city. The output of each training case is the biological growth risk index. The input parameters have been chosen according to the analysis of the phenomenon of biological growth on ETICS discussed in paragraph 2. Other climate data or others parameters related to the type of ETICS were not included because this did not entail an improvement in forecasting accuracy. Trained net forecast accuracy is very high, in the test phase the difference between the risk index value calculated through numerical simulations and the value estimated by the network is generally very low (Fig. 3). This difference is significant only for cases located in dataset peripheral areas and the average error is 0.12 %.

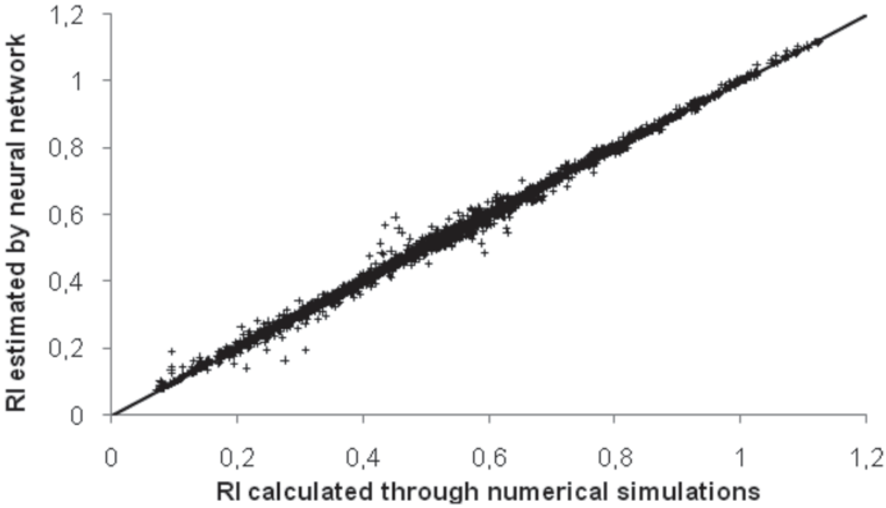

Fig. 3 Comparison between RI calculated through numerical simulations and RI estimated by neural network

5 Conclusions

An analysis of biological growth phenomenon on ETICS highlighted the influence of different wall or material. The influence of analyzed characteristics depends on external air temperature and relative humidity.

Although wall thermal resistance has a great influence on the biological growth phenomenon, all ETICSs considered have such a high resistance that internal temperature variations in winter times don't almost affect external surface temperature.

As regards water vapour resistance of the insulation layer, designers should be aware that:

- The characteristic has a low importance regardless of temperature and RH values;
- Above 10 °C (yearly average) it is advantageous to adopt technical solutions characterized by low water vapour resistance;
- If relative humidity yearly average is below 73 % it is again advantageous to have a low water vapour resistance.
- As regards porosity of base and top coat, designers should be aware that:
- The characteristic is always significant, and it is more important with increasing temperature and for a relative humidity yearly average between 73 and 77 %;
- Low porosity contrasts water evaporation on the surface favouring onset of biological agents.
- Furthermore as regards short waves absorbance of base and top coat, designers should be aware that:
- The characteristic is significant for temperature yearly average above 2 °C;

- The characteristic does not lead to sensible changes for relative humidity yearly average above 85 %;
- For the range of temperature and RH in which the characteristic is significant it is very advantageous to maximize the absorbance value using dark paints.

Accordingly to the analysis of the biological growth phenomenon and using WUFI® simulations tool a dataset to train and test a probabilistic predictive tool has been fully defined and created. This tool has been tested and its reliability is very high.

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SML Sistem: New Ways of Timber Construction

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Abstract Recently, technique and technology have made an effort to come back to attach importance to the timber construction as a primary structural material. The easy way to be assembled and the goodness of its mechanical properties have helped to increase the development and also the design of the most fashionable architecture. However, the lack of knowledge about it, either because of the little initiative of the universities or the lack of interest of students and professionals, have made a difficult way to be used by the architects at their projects. Nowadays there are many reasons to use it. We want to show how the use of the wood is changing the construction design through a project that our university (CEU-Cardenal Herrera) is developing with the support of several construction companies which are testing different applications of the wood in prefab housing in order to show its advantages and disadvantages.

Keywords Wood • Sustainability • Prefabrication • Construction

1 Introduction

It is known that wood has been a construction material present in the past and in the present, but scepticism about their possibilities in the future exists. The advantages and disadvantages in the use of wood as an structural element in the architecture are only too well tested since ancient times, being the unique material capable to support flexion efforts until the appearance of steel in 19th century, which gradually, was replacing wood[1] as a construction material and also with the introduction and development of concrete structures until the present.

[1] *In 1845 a strike of carpenters in France left without traditional frameworks to the housing constructors, which accelerated the process of substitution, appearing since this date new constructive solutions.*

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Determinants as fire resistance, dimension, maintenance or durability with the attack of insects and xylophages, has influenced to create a concept of wood as a material clearly in disadvantage in front of steel or reinforced concrete, having as a result that actually, almost all the building structures are solved with those materials.

But in last year's a revival of techniques and technologies around wood has been produced, bringing this material and their derivates as structural material of first order. Its easiness of being mechanized, its sustainability aspects, and the good performance to earthquakes, have helped to its introduction in the conception and development of the present architecture.

Examples that since not so far were impossible to be conceived, as height buildings totally solved in wood structure are a reality. A good example is the building made by the architect Kirsten Haggart in London in 2009 (Fig. 1), considered one of the first height building completely made in wood, not just walls and slabs, also staircases and lifts nucleus. Inside Spain, the use of wood has been specially attached to the architecture of wineries with high prestige architects, as the winery of "Usios" projected by Santiago Calatrava or the winery of "Señorío de Arínzano", projected by Rafael Moneo. This has allowed focusing the attention on this material, far away from the conventionality attached to its use until today, and introducing in a way an innovation in its construction use.

To this new re-emerging use of wood as a structural system, has been boosted also by another unexpected determinants; on one hand its properly performance to earthquakes, tested in a great visual example in the Center of Investigation of Seismic Engineering of Hyogo, in the real scale tests done over height buildings[2], where the optimums answer that structures made with structural wood panels have been checked. On the other hand, after the catastrophe generated by the earthquake in L'Aquila, Italy, other advantage in the use of prefabricated wood elements was shown in residential buildings construction for the accommodation of the people affected by the earthquake, allowing a fast execution of the building with optimums quality[3].

To all those advantages on performance and constructive process, other determinants which each day are becoming stronger are added, and that the own essence of wood solve perfectly. Those premises are concepts like sustainability, respect to the environment or recyclability. Those concepts are being token on account more and more, and will take place in a future European regulation on energy efficiency on buildings certification. Is in this reality where wood will get an advantage from its structural competitors.

Even with all the advantages, wood is actually a complete unknown material for technicians. The ignorance on its performance, the lack of instruction about its calculus or the perception as an archaic material caused by the little incitation of

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[2] *Seismic Test NEESWoodCapstone, realized by Colorado State University and Simpson Strong Tie, where reproduced many earthquakes in the biggest tremor platform in the world. The test where made on a residential building of 7 levels of height and dimensions in plan of 12 × 18 m.*

[3] *The italian company Sistem Construzioni, rebuilt during 2009 in the area affected by the earthquake in L'Aquila, Italy, a residential building in height solved with structure and closure of wood. Font: http://www.sistemiberica.es/.*

Fig. 1 Stadhaus building, London. Waugh Thistleton Architects. (Font: CTT)

formative organisms as by the innovation of these systems, have made that technicians and architects do not fell comfortable and safe with the adoption of this material as structural basis.

2 SMLsystem Proposal

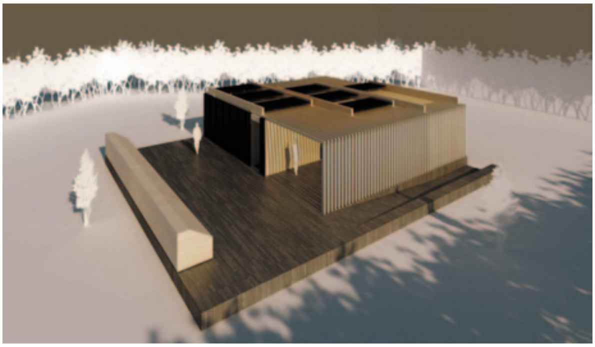
The special interest presented by these new products derived from the wood, and the curiosity of check in situ the performance and qualities, promoted that taking advantage of the participation in the international contest Solar Decathlon Europe 2012 which will take place in Madrid during September 2012, our proposal would be conceived in wood. Form University, a proposal of energetic efficiency and sustainable house was developed.

The adoption of wood as a structural system in the SMLsystem project developed for the contest, comes from the combination of diverse premises inherent to the concept of the own project, emphasizing being the wood a natural material, respectful with the environment, CO_2 collector, recyclable and reusable. Moreover, allows to give to the house a level of comfort higher that with other materials, in terms of control of interior humidity, maintaining the hygroscopic balance and reducing the energy consumption curbing thermal fluctuations in the interior, and having a better thermal insulation in comparison with the rest of constructive materials[4] (Fig. 2).

Attending to the main idea of efficiency and sustainability attached to the project, all the structural system of the house has been developed completely with CLT (cross laminated timber) elements. This system use prefabricated panels of wood (previously glued in transversal directions), adding clear advantages in the constructive

[4] *The CLT panel presents a level 5 times higher of thermal isolation compared to concrete, 10 times better than bricks and 350 times better than steel with a value of 0.13 W/mK.*

Fig. 2 SMLsystem proposal



planning, making possible to solve all the execution in dry construction, in a total prefabricated way and industrializing the mechanization of the panels according to the project, to develop an optimum and fast assembly of the elements, avoiding the remainder generation during works and saving time and costs. These CLT panels allow developing even vertical or horizontal structure elements, solving all the active elements of the structure with one product, and simplifying conceptually the house. Also, according to the strategy of flexibility and adaption to the necessities, we project a solution of modules addition, which will set the house, and simplifying one element which has one of the main problems of this type of architecture, the joint. The use of this material, erase in a big way the problem of the joint and the thermal bridges that usually appears in solutions with steel or concrete structure, allowing due to the easiness of the panel of being mechanized, design directly the joints.

The project is based in the fundamental premises of modularity, prefabrication, dry construction, simplification of the constructive process and optimization of the energetic balance.

The main module is composed by 2 CLT panels of 7,200 × 3,600 mm, which are used as floor and roof structure, and 4 columns in L form with dimensions of per side. The L form of the columns is the result of the aggregation process, trying to create, with the aggregation of 4 modules, decomposed columns with cross shape as a way to reduce the presence of the column in the space. On the CLT panel, 2 laminated wood beams are situated linking the head of the columns with a high resistance steel profile which is used to raise the module in the construction process. That beams set up 3 vessels which have a low slope to pick up the water in one of the short sides of the module. Also those beams help us to fix the solar systems avoiding problems of ruptures on the waterproof layer.

An interesting research from the construction perspective was the design of the knots, in wood, which were thought to be easily assembled between them and being executed like a meccano. There were many options to develop them, but at the end we decided to assemble them with metal elements trying to get a construction system similar to IKEA furniture, with the idea of making an instructions sheet where the steps for assembling the elements in the correct way would be explained (Fig. 3).

But in general terms, construction is placed in the origin of the SML system, trying to improve the construction process used in the SDE2010 edition with SML house.

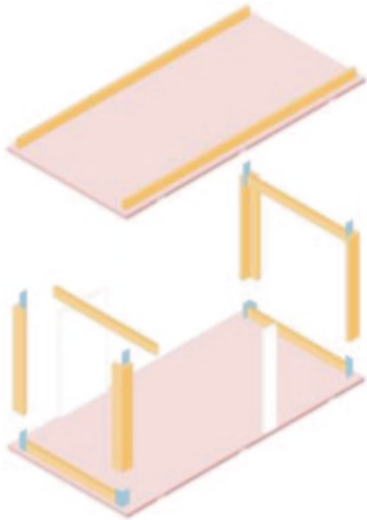


Fig. 3 Structure of the main SMLsystem module

Based in the modular system, we try to bring to the concrete the abstract concepts of efficiency and sustainability at the same time that we project a system which is easy to assemble and expand in the 3 dimensions with guarantee of creating habitable spaces with many options of customize.

The primitive concept is about continent and content. We conceive the module as a continent of habitable space perfectly assembled, where you can introduce prefabricated boxes, in order to be completely customizable. Those boxes contains the wet areas (kitchen, bathroom) chosen from a catalogue.

The module is formed by a laminated pine wood structure, ventilated facade in larch wood with composed closure (wood + isulation + wood + air camera + double gypsum board), and a vertical lattice system where larch wood and ceramics are used in order to get different thermal inertia and be able to use them depending on the external conditions. This system is dynamic, and allows the owner to create transition spaces between exterior and interior, just expanding them into the longitudinal module axis, at the same time that provides solar protection to the openings.

The foundations are a system of laminated pine wood beams, placed in the cross borders of each module, with stainless steel supports which transmit, across steel sheets of 1 m^2, the loads to the terrain (Fig. 4).

3 Conclusions

The development of the SMLsystem house for the Solar Decathlon Europe 2012 contest has allowed to technicians, teachers and students to get introduced in the use of CLT panels, checking the advantages, performance and singularities of this type of wood product as structural system. Its extraordinary performance, its easiness of

Fig. 4 Photos during the assembly of the SMLsystem modules

being mechanized, its industrializations and the possibility of organize all the construction process as a system totally prefabricated in dry, allows the adoption of this system to new premises from the future architecture, in the search for reducing costs and wastes without losing quality. The CO_2 footprint reduction and its optimum energetic balance, joined to premises like respect to the environment, recycling and sustainability, make from it a material with high value and which is anticipated that in a close future will have more and more impact on the structural and constructive systems in the architecture.

Part III
Energy and Sustainability

Andrea Salandín

Abstract On average, buildings consume 30-40% of energy in most countries. As the potential for energy saving is quite large, building energy efficiency has become an important issue in the drive to produce more sustainable buildings.

Sustainable buildings are designed and constructed to high environmental standards in order to reduce energy requirements, minimize water consumption, use materials with low environmental impact or low embodied energy, reduce wastage, protect the natural environment and human health.

By using adapted thermal insulation (in envelope) and energy savings techniques (in building systems), up to 80% of a building's total energy consumption can be saved. As energy costs rapidly increase, there must be a clear commitment to use renewable energy sources too and to apply energy management.

The chapter "Energy and Sustainability" looks at construction techniques, certification and assessment, energy consumption and thermal behaviour, passive bioclimatic conditions, envelope as energy factor, biomass system, eco-efficiency on façades, cogeneration, standards for green neighbourhoods, simulation and modelling of existing buildings.

Those contributions focus on the main issues while also providing a broad overview of this crucial topic.

The Use of Authentic Material and Construction Techniques in Historical Conservation: Orhaneli Stone School as a Case

M. B. Bagbanci

Abstract Most of the technological materials used in the building constructions have negative affects to ecological balance and human-nature-environment interactions. Being able to hand down today's resources to next generations is of great importance in terms of sustainability. For this reason, during construction, it is necessary to reduce costs of use, make use of natural, local, low maintenance, recyclable and eco-friendly building materials, create healthy, comfortable and livable environments and develop strategies intended for the protection of ecosystem.

In this article, the applications made during the restoration of the structure of Bursa Orhaneli Stone School will be examined in terms of sustainability, authentic materials and construction techniques. Exterior walls constructed by using masonry system and interior walls made by using the cob-filled timber structure system, timber trusses for roof system will be dealt with in detail and its construction stages will be explained. The characteristics of the cob material, mud plaster applications made on laths, fire-resistant for materials and the other application details will be shown. Moreover, suggestions will be proposed regarding the use, regular maintenance and repair following the restoration of the building and how to keep and hand down it to next generations with confidence.

Keywords Cob walls • Sustainability • Historical conservation

1 Introduction

Contemporary conservation principles is that the protection of authenticity of materials and construction techniques of Monuments and Sites. "Cultural heritage and authenticity" for the first time on the discussions at the international level was introduced in 1994 Conferences in Bergen and Nara (Nara Conference on Authenticity 1994). "Authenticity" or "originality" the most important criteria in determining the principles of architectural conservation and protection [1, 2].

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As the improvement in technology has positive effects on the construction material market, it also gives cause for the environmental pollution. The production of the modern construction materials, which are the products of advance technology, has great influence on the emergence of environmental problems. Not only in the production of these materials, but also during the usage and consumption and each stage of its lifecycle, these materials have an influence on the environment. In this case, it is inevitable to take precautions to avoid environmental pollution in order to leave a habitable domain for the next generations. As the traditional materials are abandoned and the usage of modern materials are popularized, the effects of these materials on the environment and human health should not be ignored. From the production to the usage and consumption phases, as a traditional material, cob and timber are ecological construction materials with least energy consumption and environment-friendly qualities.

The organisation of studies and step-by-step analyses -a multidisciplinary study- was required for the restoration work. No action was taken without a complete understanding of the benefit it would have or the harm it would cause to the building's architectural integrity. A full understanding of construction techniques and material properties of the building are important for any project related to the preservation of an architectural heritage.

The restoration of the building began in 2010 and was finished in 2012 under the control of the Bursa Special Provincial Administration and Bursa Orhaneli Municipality. The purpose of this article is to explain the restoration phases in details and to examine the construction techniques, authentic materials in terms of sustainable conservation.

2 Plan, Construction Techniques and Materials Used in the Building

Orhaneli Stone School is situated in the centre of the town. The construction of the school began in 1914, during the 1st World War the construction was stopped and remained incomplete. In 1927 it was finished and began to be used as a primary school [3].

The building, positioned in the direction of southwest and northeast, partly has a basement. Because the classrooms became insufficient in time, an additional structure with two classrooms, a short while after the main structure was built, was constructed adjoined to the northeast of the main building (Fig. 1).

There is a wide hall in the entrance of the school. The hallway is located in the entrance axis leading up to the garden. The first, second and third grade classrooms are on the main building. Director's room is located in the northeast of the hall. The school is accessed via an individual door located at the northeast part. In the southwest entrance, two rooms which are used as a laboratory room and staff room, and the hallway in the middle of these rooms also provide access to the basement. The basement of the building is situated below the teachers' and laboratory rooms.

Fig. 1 The ground floor of the school

The additional section was built further back from the main school building. One can arrive at the building by the stairs from the northwest direction. There is a room right across the entrance. There are two classroom doors openning to the entrance hallway. The fourth and the fifth graders were educated in this section.

The load-bearing walls of the building were rubble stone and at the corners of the building a well-treated marble was used. The interior walls of the main building were constructed with cob-filled timber structure system. Oak, which was a hardwood tree, was used as load bearing material. In order to apply plaster on the surface of the interior walls, timber lathes were nailed. Cob mortar was applied on the laths. The roof system of the building was collapsed in time.

The mud, prepared in advance in proper consistency for cob production, usually is shaped by pouring into the wooden moulds. The soil for the production of cob is mixed with water and hay is sprinkled in it and the mixture is trampled to form the mud. This procedure is called extraction of the mud. The extracted mud that has become cob in form is poured into the mould with wooden plates. After being poured into the mould, the mud is properly compressed. If this compression is not done, the adobe becomes weak. The surface of the compressed mud is properly smoothened with the help of a wooden piece and the extra mud is thrown away. The mud is left on a smooth surface after the mould is moved away. If possible, first the mud is set in the shadow and then left under the sun. In order to quickly dry the cob, the sides exposed to sun should be changed in process of time (Figs. 2 and 3). The inner size of the mould is kept larger than the determined size of the mould due to the shrink ratio. It is a material, which has survived from the old days until today, with high heat insulating value as well as having no need for a production facility, cost-efficient and specially irreplaceable for the rural areas. It provides the most convenient circumstances for the consumer in the building in all seasons. With this aspect, it provides economy without the need of another insulation material [4, 5].

3 Restoration Studies of the School

The restoration decisions regarding the building are considered within the frame of genuineness-authenticity, integrated protection and maintainability principles both institutional and scientific, relative to the national and international protection principles. The Project is considered according to Venice Charter (1964) with the international protection principles, The Declaration of Amsterdam (1975), the protection principles which are accepted in Nara Conference (1994) and within the frame of "Principles for the protection of the Historical Timber Structures" which is adopted by ICOMOS in 1999. As the intervention principles were being determined, the assurence of authenticity in material, labor and design was taken into consideration.

Since the building was assigned to Uludag University and kept within the boundaries of the campus, it was considered suitable to be functioned as Congress and Culture Center. The restoration project of the ground floor plan is shown in Fig. 4.

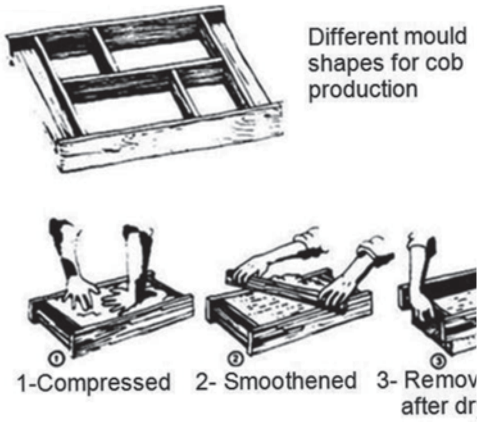

Fig. 2 Different mould spahes and production stages of cob material

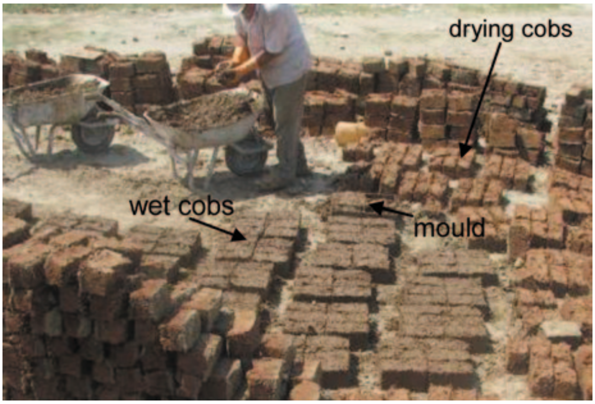

Fig. 3 The production of cob material with mould in-situ

In "maintainability and integrated protection" sense, the building, becoming integrated with the city, was utilized with a public function and in "authenticity-genuineness" regards the stabled structure elements were protected in-situ.

Below is the list of the things that are done during the restoration of the building in order:

- Since along with the whole roof, the floor covering and the ceiling coatings lost their quality to a large extend, it was not possible to preserve them. However, those timber ceiling and floor coatings which were stable set apart and those timber parts, which can be kept, were impregnated either by brushing on or atomizing system, whereas those newly produced materials were impregnated by dipping method.

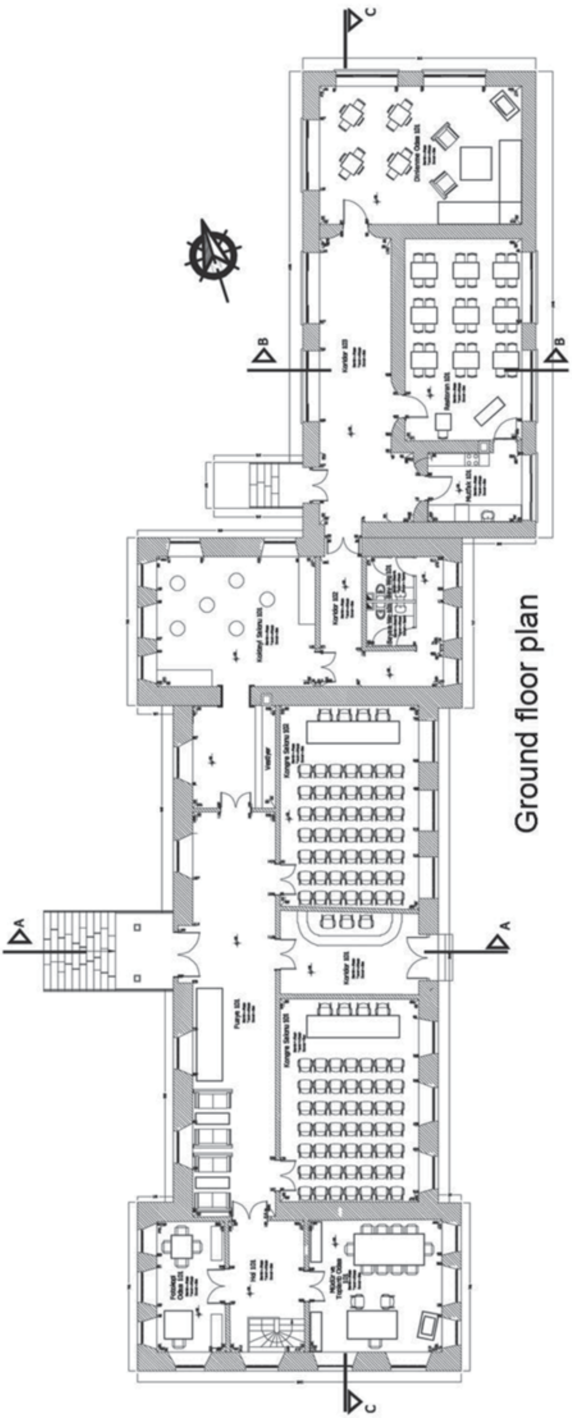

Fig. 4 The restoration project of ground floor

Fig. 5 The timber beam for supporting the trusses on stone walls

Fig. 6 Timber trusses constructed on the stone walls

- Load-bearing timber elements used in the building were chosen as oak material and ceiling and floor coverings were chosen in pine material as its original form.
- Roof trusses were formed and supported on the timber beams which were constructed on the stone walls (Figs. 5 and 6).

- The cob material placed between the timber structural system and timber laths were nailed (Figs. 7 and 8)
- Stable load-bearing elements were preserved.
- The physical and chemical qualities of the cob material used in the interior walls for filling, the clay and straw plaster and the lime mortar used on the outer walls

Fig. 7 The construction of the cob filled timber walls

Fig. 8 The cob filled timber structural system and the timber laths

were determined after laboratory studies and were reproduced according to those quantities.
- The protection of the timber material from fire was provided.

4 Conclusıons

Not for only the future of our country, but also for the future of the whole world, it is very important to generalize the usage of soil and timber which are the natural building materials in building systems. For leaving a habitable environment to the next generations, it is necessary to chose not only long-lasting materials, but also environment-friendly, recycable, energy saver and economic materials. These type of buildings can be considered as sustainable buildings because of their very low environmental impact, availability and the production of the materials easily, their good thermal performances, their sound insulation, and their potential cheapness. They also represent a cultural architectural heritage that presents the authentic architecture that must be preserved.

The properties, deterioration degrees and problems of the authentic building materials oriented to be used for the protection of the historical buildings in our country should be determined in detail. By protecting the distinctive specifications of each building, the transference of those cultural heritages to the next generations in security should be provided. In this project, the aim is determined as the protection of an old school building “Taş Mektep” (Stone School) and the medium is estimated as function.

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Certification and Assessment Method for Sustainable Communities

P. Pereiro-Villanueva

Abstract BREEAM ES *Urbanismo* (BREEAM for Communities) is the sustainability assessment and certification method for community planning projects. It focuses on fundamental environmental, social and economic sustainability criteria and any planning requirements with an impact on urban projects.

BREEAM ES *Urbanismo* assesses sustainability in accordance with the following categories: Climate and Energy, Community, Place Shaping, Ecology, Transport, Resources, Business and Building, and aims at mitigating the environmental, social and economic impacts of an urban development or renovation project.

During the process of adapting BREEAM ES *Urbanismo* to the particularities of Spain, this methodology was applied to three actual planning projects for the purpose of testing the method's specific applicability: "Parque Central de Valencia" (Nova Ingeniería y Gestión S.L.), "Marqués de la Ensenada" in Castile-León (Arnaiz Consultores S.L. and the Autonomous Government of Castile-León) and "La Rosilla" in Madrid (EMVS & Ezquiaga Arquitectura, Sociedad y Territorio S.L.).

This paper intends to explain the BREEAM ES *Urbanismo* methodology, as well as the case studies.

Keywords Urban development • Sustainability • Planning • Certification • Energy • Mobility

1 Introduction

The aim of BREEAM ES *Urbanismo* is to mitigate the impacts from urban projects; to enable said projects to be acknowledged based on their environmental, social and economic benefits for the local community; to provide a comprehensive, tried and tested certification of environmental, social and economic sustainability; to stimulate the demand for a more sustainable urban planning and to ensure the development of communities that are more sustainable.

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BREEAM ES *Urbanismo* makes it possible to minimise the contribution to global warming from development projects, guaranteeing these are appropriately adapted to the impacts resulting from present and future global warming. Additionally, this scheme contributes towards designing developments accommodating vibrant, new communities that can blend with the surrounding areas and the local context, respecting any existing heritage and preventing the creation of "gated" condominiums or communities that are perceived as such. The development's design shall provide an "actual" place with character, allowing people to move and manage their way around instinctively, and achieving the integration of the new development into the local context, respecting existing heritage. Likewise, the scheme takes into account aspects such as the efficient use of resources (water, materials) or providing alternatives other than private cars, encouraging cycling or walking for healthier lifestyles. It also takes into consideration financial sustainability, rewarding opportunities for establishing businesses, and for these businesses to service the local area and to provide job opportunities for local residents

The operation of the BREEAM ES *Urbanismo* methodology is based on awarding Credits for eight categories: Climate and Energy, Community, Place Shaping, Ecology, Transport, Resources, Business and Buildings. These credits are awarded in accordance with the planned or designed environmental performance, measured in relation to sustainability targets and the requirements of local, regional and national legislation. These Credits are then added up for a single score, which is translated into a rating of Pass, Good, Very Good, Excellent and Outstanding (Exceptional)

2 Methodology [1]

BREEAM ES *Urbanismo* can be used to assess the environmental impacts resulting from development, for both the planning stage (interim certificate) and the post-construction stage (final certificate).

The first step of a BREEAM ES *Urbanismo* assessment is defining a reference framework that will provide the basic foundations based on which specific sustainability targets will be defined. Once this framework is created, the BREEAM ES Assessor shall collect any required evidence and compose the appropriate assessment report detailing how targets are achieved by the developer. Finally, BREEAM ES shall verify the submitted report and, should everything be correct, the certificate for the relevant stage will be issued.

Project typology covers residential, mixed-use or non-residential developments, including both new build projects and urban renovations.

One of the specificities of BREEAM ES *Urbanismo* is that it defines seven zones based on climate, environmental, social and economic parameters.

The following describes the process for achieving a BREEAM ES *Urbanismo* rating (Fig. 1):

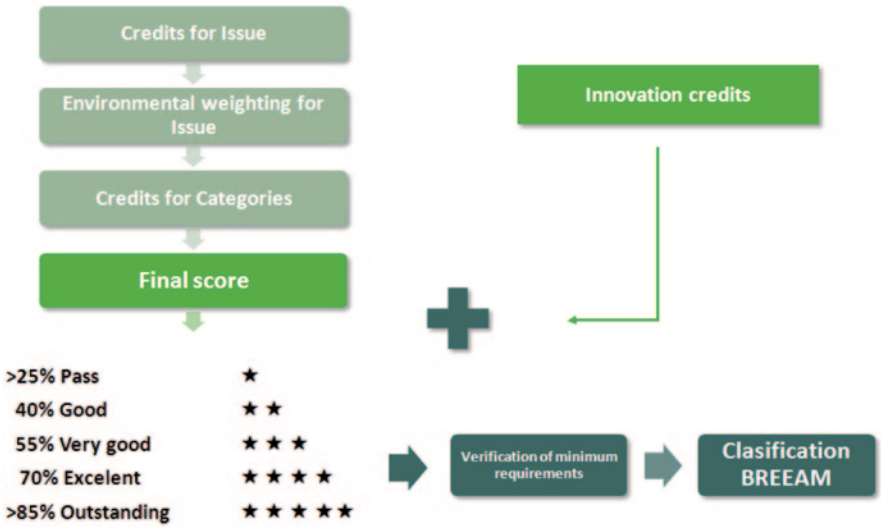

Fig. 1 Process for achieving

1. A maximum of three Credits can be awarded for each individual Issue can. The Assessor must appraise each Issue individually and evaluate the amount of credits awarded in accordance with the Manual. Each issue will be multiplied by the appropriate environmental weighting for the zone where the project is located.
2. Issue scores are added up, grouped by Category and these Category aggregate scores are then added together for a final score. Next, the final score is compared with the benchmarks and, provided that the basic requirements have been met, the relevant BREEAM ES *Urbanismo* rating is obtained: Pass, Good, Very Good, Excellent and Outstanding (Exceptional).

3 Issues Assessed Under Breeam Es Urbanismo [1]

Climate and Energy Reducing the proposed development's contribution to global warming, ensuring that developments are adapted to the impacts from current and future global warming. Issues: *Energy and Water management, Design principles, Infrastructure, Water resource management, Resilience/flexibility.*

Community Designing the development so that it supports a vibrant, new community that can blend with surrounding areas, preventing the creation of "gated" condominiums or communities perceived as such. Issues: *Social Impact Assessment, Community Participation, Sustainable Lifestyles, Management and Operation.*

Place Shaping Providing a framework for designing an "actual" place with an identity that ensures that people can move and find their way around instinctively, and guaranteeing that the new development is integrated into the local context, respecting existing heritage. Issues: *Site Selection, Site Design, Green Spaces, Housing Density, Affordable Housing, Security, Active Frontages, Local Architecture.*

Ecology Preserving the site's ecological richness. issues: *Habitat Enhancement, Biodiversity Action Plan, Green Corridors, Ground Pollution.*

Transport Enhancing personal mobility by providing alternatives other than private cars and encouraging walking or cycling. Issues: *Public Transport, Local Amenities, Cycle Networks, Traffic, Sustainable Travel Plans.*

Resources Designing for an efficient use of resources, including water, materials and waste in construction, operation and demolition. Minimising lifecycle impacts of materials chosen. Issues: *Material Selection, Land Use and Remediation, Waste Management, Water Resources.*

Business Providing opportunities for the establishment of businesses and for these to service the local area and to provide new job opportunities for local residents. Issues: *Investment, Local Employment, Sustainable Charters.*

Buildings Ensuring that the design of individual buildings contributes to the overall sustainability of the development through high environmental standards. Issues: *BREEAM ES Buildings, Sustainable Homes.*

4 Practical Application—Case Studies

4.1 Ecobarrio, La Rosilla—Vallecas (Ezquiaga Arquitectura, Sociedad y Territorio S.L., 2012) [2]

Design Team: **Ezquiaga Arquitectura, Sociedad y Territorio S.L.**

Developer: **Empresa Municipal de la Vivienda y Suelo (Municipal Housing and Land Development Company)**

Total scope area (m^2): **38,000** (Fig. 2)

"La Rosilla" is located South East from the Madrid city centre, supported by the Vallecas-Villaverde road and in the vicinity of the original settlement of "Pueblo de Vallecas".

Existing conditions make it possible to ensure that the works will contribute to sustainable urban development, as understood by the aggregate of three factors:

Economic sustainability, ensuring that specifications reduce the cost of the development, construction, maintenance and use of buildings, including the fit-out costs.

Environmental sustainability, setting out conditions that promote for the new development to produce less waste, emissions and discharges than other

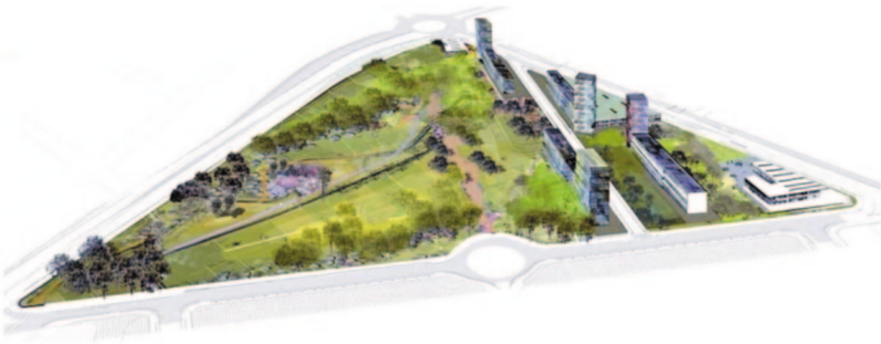

Fig. 2 Solution for "La Rosilla"

conventional developments and that, at the time of demolition, the waste generated can be recycled to the greatest possible extent. The development must be sited so that it takes the most advantage of sunlight; cross-ventilation is feasible for all dwellings; and for the generation and use of renewable energies to be possible and successful, both technically and aesthetically. Additionally, and for the purpose of preventing the heat-island effect, paving of the public realm must be limited. The design of in—building parking facilities must make an adequate provision for bicycles and motorcycle spaces. The development project must allow for the eventual installation of a pneumatic waste collection system and district heating systems.

Social sustainability, enabling different and assorted dwelling types in terms of size and layout and introducing a classification of uses that facilitates the implementation of auxiliary activities, such as retail.

4.2 Marqués De La Ensenada—Castile-León (Arnaiz Consultores, 2012) [3]

Design Team: **Arnaiz Consultores S.L.**

Developer: **Consejería de Fomento y Medio Ambiente de la Junta de Castilla y León—Department of Public Works and the Environment of the Regional Government of Castile-León**

Total scope area (m^2): **105,803 m^2**

The "Marqués de la Ensenada" Regional Urban Development Action Plan ("PRAU") falls within the Regional Urban Development Actions Programme, a public development strategy for the construction of social housing, endorsed by the Department of Public Works of the Regional Government of Castile-León.

The Regional Plan's proposal is set in a highly singular place in Medina, the former Artillery Barracks "Marqués de la Ensenada", with no current military use and designed by the architect Ventura Rodríguez (Fig. 3).

Fig. 3 Solution for "Marqués de la Ensenada"

A number of design strategies have been defined for the new proposal to blend into its surroundings, minimising its impact on existing elements, at both the urban and landscape, natural level:

- Topographical adaptation, visual integration into the landscape and consideration of climate particularities will set the foundations for a higher bioclimatic comfort.
- Producing a large public space enveloping the barracks building, providing a higher level of singularity to the environment. Creating public-realm continuity, connecting existing green spaces with the proposed free public spaces through free, public transition areas. This free public realm will be fluid, continuous and easy to navigate, a cohesive area unifying history, culture, society and urban space, favouring pedestrians, bicycles and alternative transport.
- A perimeter and functional mobility system, with a demand-based hierarchy. Safe streets and public spaces, creating perspectives and connections. Controlled access routes, guided through shared roads.
- Integration with the existing irregular urban grid. Absence of boundaries.
- Small-, medium- and large-scale identity, generating a space with a new centrality.
- Diverse Supply of Programmes (R&D+C; Cultural, Social, Knowledge Tourism), promoting the barracks building "Marqués de la Ensenada" as a symbolic, singular space.

- A residential urban development comprising mainly social housing in a semi-enclosed block.
- Encouraging plant life in both the public realm and in buildings in order to control wind, sunlight and acoustics.
- Using filtering and permeable materials to control surface run-offs.

4.3 Parque Central De Valencia (Nova Ingeniería, 2012) [4]

Design Team: **UTE Gustafson Porter—Borgos Pieper—Grupotec—Nova Ingenieria.**

Developer: **Valencia Parque Central Alta Velocidad 2003 Gestiona Para El Ayuntamiento De Valencia**

Total scope area (m^2): **656.624 m^2**

The "Parque Central de Valencia" community represents a historic opportunity for integrating a brownfield area currently occupied with railway facilities and obsolete industrial areas into the city's urban fabric. This is significant because of its large area, its location in the city centre, its close proximity to important transport nodes, the presence within or in its surrounding area of elements with a relevant historical, social and artistic value, the opportunity it provides to resolve the final integration of neighbourhoods which are actually close but clearly segregated due to railway lines, the enhancement of amenities and, particularly, of green areas to be provided for these deep-rooted neighbourhoods, the occasion to develop a new community the standards of which comply with future requirements, such as sustainability and quality of living (Fig. 4).

Finally it offers the opportunity to develop the Central Park of Valencia, a 23 Ha. urban park, designed to represent a new milestone for the city and change its appearance, improving both the standards of living of its residents and the outward image that the renovated city will project into the future.

The project develops the landscaping and urban design in two different levels: the Parque Central (Central Park) itself and the design of the new South neighbourhood.

The "Parque Central", together with the high-quality public realm within the Barrio Sur (South Neighbourhood), will act as a catalyst for the development of the surrounding land, providing not only an added retail value, but also a new character and new qualities that will improve their users' life standards.

The design has been developed as a coherent piece, susceptible of phased development in order to react to the construction programme for the railway line and the current financial climate. The Barrio Sur is connected to the Parque Central through a new, one-kilometre long boulevard. This "Gran Vía" (Broadway, High Street), will not only join the "Barrio Sur" with the Park and the historical city centre, but will also be a destination on its own right, with markets, playgrounds and water in a leading role.

Fig. 4 Solution for “Parque Central de Valencia”

In broad terms, the park’s design is a curved-trait design seeking to blend into the new, rich topography of the “Parque Central de Valencia”. The shapes of all hills, undulations and any ground unevenness shaping this city-centre Park have been defined and polished. Gentle slopes, easily passable by all, will connect all the Park’s spaces. Stairways have also been added to create direct access routes and to dramatise certain views.

5 Conclusions

This methodology, BREEAM ES *Urbanismo*, allows:

1. Seeks to create awareness in planners, developers, users, consultants and policy makers about the benefits of sustainable projects.
2. Ensures that recommended practices are incorporated into urban development projects in order to increase their sustainability.
3. Sets out requirements that are above those required by regulations and challenge the market to provide innovative solutions that comply with the sustainability targets of urban development projects.
4. Cost savings are achieved by refocusing the design team to consider site-wide solutions and building sustainability into designs from the earliest possible stages.

5. Planning applications move through the system more efficiently as developers work with the community, local authority and other stakeholders to agree what can be achieved on the site in a transparent and focussed process.
6. Consultants save time by using the studies produced for other legislative requirements (e.g. environmental impact assessment) to satisfy evidence requirements in this scheme
7. Buildings on the site are able to achieve a higher sustainability level.
8. Politicians and planners involved in making decisions on planning applications understand the development's sustainability credentials.
9. Local and strategic needs of the area are addressed through surveys and assessments that reach beyond the development boundary.
10. The needs of existing communities are built into development proposals through consultation and engagement activities.

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Energy Consumption and Thermal Behavior of a Light Construction Room-Sized Test Cell

J. M. Lirola-Pérez, B. Lauret-Aguirregabiria, M. Khayet, L. J. Claros-Marfil, B. Perez-Pujazón and G. Ovando-Vacarezza

Abstract A new room-sized test cell is being monitored in the Faculty of Architecture of the Technical University of Madrid (UPM), to achieve a forthcoming zero-energy test cell. This small building located at the outer parking of the faculty, has the typical light construction of a building site office, with very poor insulation and almost no thermal inertia. These features make it very suitable for testing any thermal improvement. Initial measurements of its thermal behavior both in winter (cold spring) and summer (hot spring) cycles together with computer simulations have been performed. Both testing results and computer simulation are reported and discussed.

Keywords Cell • Zero-energy • Consumption • Thermal • Simulation

1 Introduction

In Europe, directive 2010/31/UE [1] states that from 2020 on the buildings have to be almost zero consumption. In Spain, the Código Técnico de la Edificación (CTE), which rules the technical aspects of construction, still should achieve these energy efficiency requirements. A "zero net energy" building produces at least as much energy as it consumes over the course of a year, regardless of the time and form of energy (e.g., electricity, gas or fuel) consumed or produced [2]. In this way, it is interesting to study thermal behaviour and energy demand of a room-sized test cell, to first estimate and then measure actual performance of modifications made to achieve a net zero-energy cell. Building simulations were done previously [3] as well as exploration of the improvements to achieve a net zero energy building [4].

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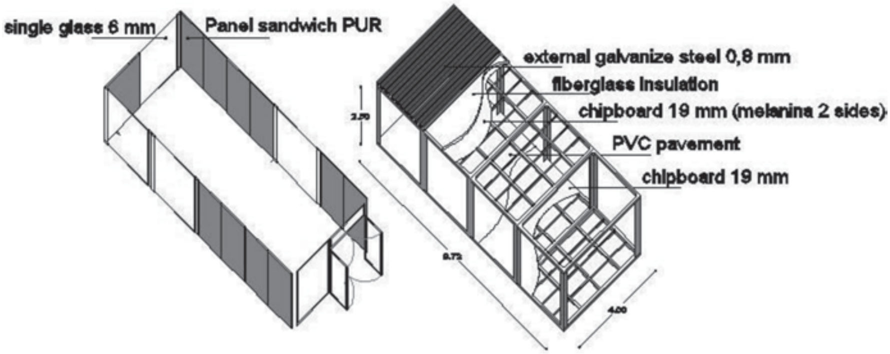

Fig. 1 Constructive scheme of the tested cell.

2 Test Cell Description

General dimensions of the test-cell are 9.72 m long, 4 m wide and 2.5 m high (Fig. 1). The floor is made of water-proof chipboard 19 mm thick; walls are standard PUR sandwich panel with 40 mm sheet of pre-painted galvanized steel and white micro-surface 0.4 mm thick on both sides with polyurethane insulation of 40 kg/m^3 density.

The flat roof is made of particle 19 mm chipboard, coated on both sides with white melamine and 80 mm thick fiberglass felt insulation, including vapor barrier paper and external galvanized steel profiled microwave sheet 0.8 mm thick. Glass panes are 8 mm single glazing and carpentry without thermal break. The test-cell has a standard HVAC system equipped with a heat pump.

3 Experimental Results

Two periods have been chosen to measure the inner and outer temperatures as well as energy consumption to maintain comfort conditions. Because the test cell has been built recently, it is not possible yet to study its performance during winter and summer weather conditions. Therefore, cold spring time and hot spring time, are considered as representative for winter and summer weather conditions, respectively. In each period two tests have been performed: with and without heating/cooling supports and without any ventilation.

Two temperatures data loggers (Hobo) have been used to register the temperatures and an energy meter has been used to measure the heat pump consumption. Data loggers are placed at approximately 1.5 m height in interior and at shade conditions at exterior.

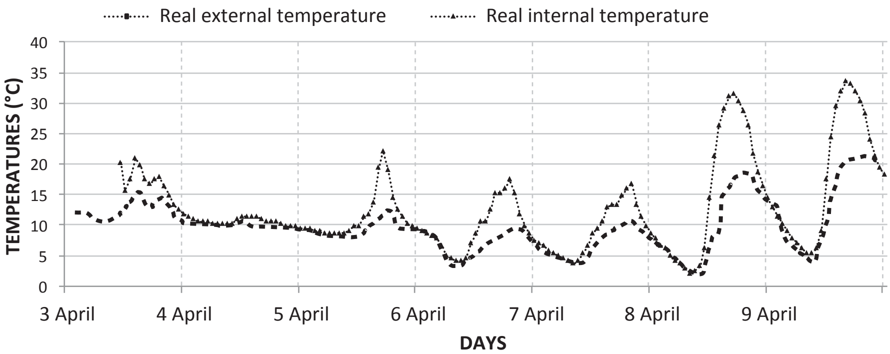

Fig. 2 Comparison between real internal and external temperatures from 3rd to 9th April 2012

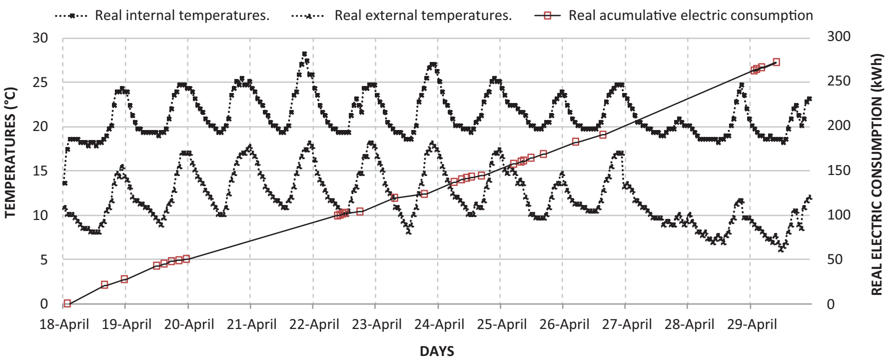

Fig. 3 Real internal temperatures with heating and external temperatures compared with real accumulative electric consumption from 18th to 29th April 2012

3.1 First Spring Period (No Heating or Cooling) FROM 3rd to 9th April, 2012 (Fig. 2).

Firstly it is necessary to know the test cell as a passive construction, so it is tested with no HVAC system. In Fig. 2 it can be noted the extreme sensibility to external conditions. Actually it almost matches outside temperature at night while getting extremely hot at central hours of day, showing a wide thermal oscillation of about 40 °C.

3.2 Second Spring Period (with Heating) FROM 18th to 29th April, 2012

In this case, due to special cold period, heating were set at 23 °C temperature (Fig. 3). There is no constant temperature at 23 °C because the internal space must readjust its own temperature to external changes, for this reason, the internal temperature oscillates around the main temperature of 23 °C.

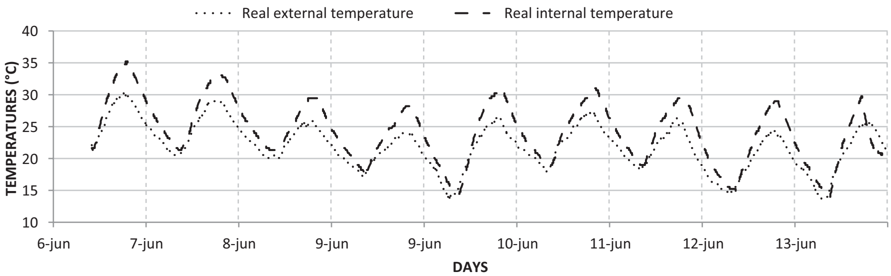

Fig. 4 Comparison between internal and external temperature from 6th to 13th June 2012

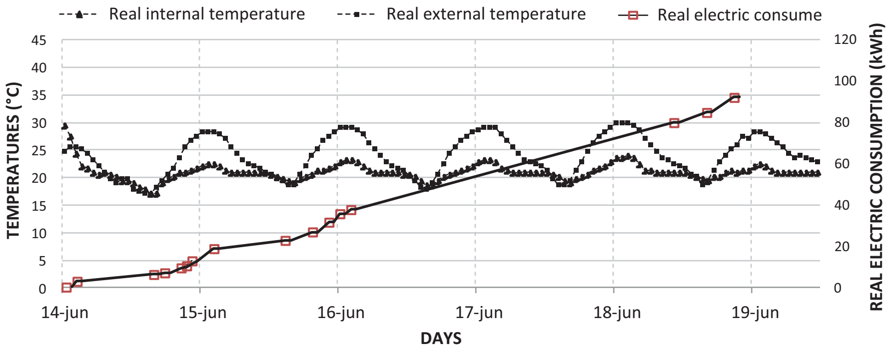

Fig. 5 Real internal temperatures with air-conditioning and real external temperatures compared with the electric consumption from 14th to 19th June 2012

As can be seen in Fig. 3 the inner temperatures are kept in the 20–25 °C range due to the heating system. The total electric consumption in this period is 419 kWh, what means an average of 35 kWh/day.

3.3 First Summer Period Without Heating/Cooling from 6th to 13th June, 2012

In this case no air conditioning or heating were used (Fig. 4).

3.4 Second Summer Period with Air-conditioning from 14th to 19th June, 2012 (Fig. 5)

In this last case, air conditioning was set at 22 °C temperature. As can be seen in Fig. 5 the inner temperature does not increase significantly above 22 °C due to the cooling system. Total electric consumption in this period is 102.8 kWh, what means an average figure of 20.56 kWh/day.

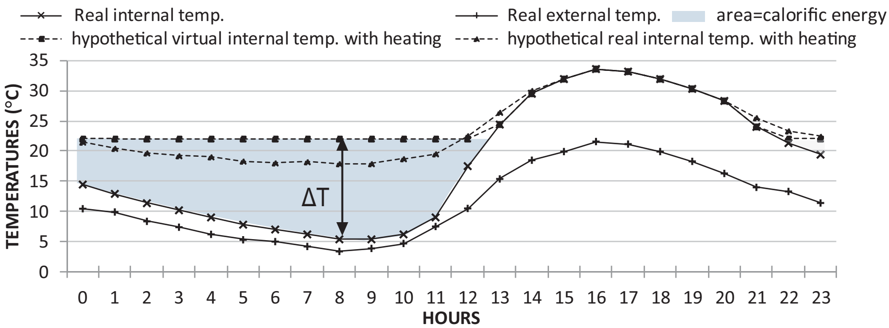

Fig. 6 Comparative real temperature without heating and hypothetical temperature curves with heating the day 9th April 2012

3.5 One-day-cycle Analysis Period and Estimation of Electric Consumption.

We analyze one-day-cycle as an electric consumption estimation example with only inner and outer temperatures. In Fig. 6 it can be observed the outer temperatures vary from 4 °C to 20 °C, while the inner temperature of the test cell climbs up to 34 °C.

The energy balance of the test-cell is the sum of the energy provided by HVAC and energy losses (or gains) through the cell walls. Both energies are affected by temperature differences: first between test-cell with and without heating (or cooling) machine and the other between internal and external temperatures.

At the peak curve position, differences between these intervals of temperatures are very small. This occurs especially in low inertia constructions. With this concept we can suppose that they reach same value. At this point, we can assume that the required thermal energy is proportional to the same temperature difference. The proportional value between the thermal energy and temperature difference will include all parameters involved in heat transfer by conduction, convection and radiation phenomena.

By knowing the total electric consumption and the efficiency of the HVAC system, through its COP value and ERR coefficients, we can determine the electric energy consumption curve from the temperature difference of reference because it is proportional to this value (Fig. 7).

Following the same procedure, we are able to get the energy demand in winter (cold spring) for 24 h cycle. The results are plotted in Fig. 7.

In Fig. 8 it can be observed the thermal behavior of the cell during 24 h cycle in a typical hot night and a sunny spring day, where the outer temperatures vary from 20 °C to 28 °C, while the inner temperature of the test cell increases up to 34 °C. Both the simulated and registered inner temperature have been plotted in order to understand the heating power needed and energy demands distribution throughout the day.

As explained previously, the same procedure was followed to obtain the energy demand in summer (hot spring) for 24 h cycle (Fig. 9).

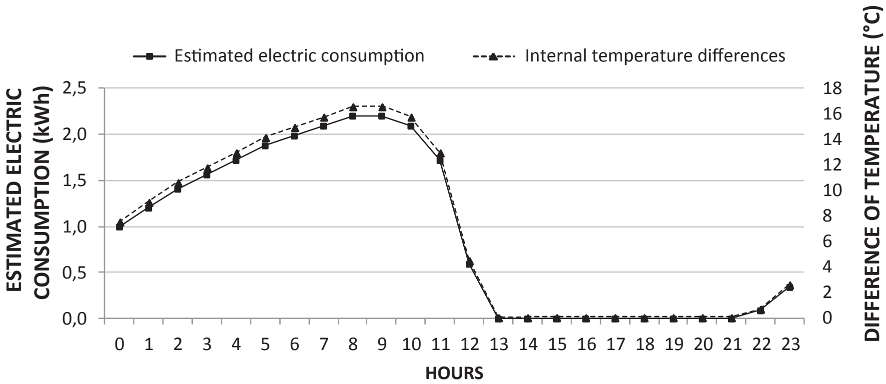

Fig. 7 Difference of temperatures and estimated electric consumption of the day 9th April 2012

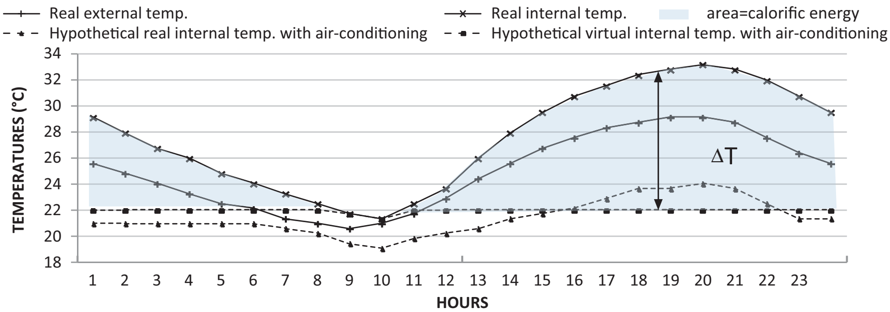

Fig. 8 Comparative real temperature air-conditioning and hypothetical temperature curves with air-conditioning for the day of 6th June 2012

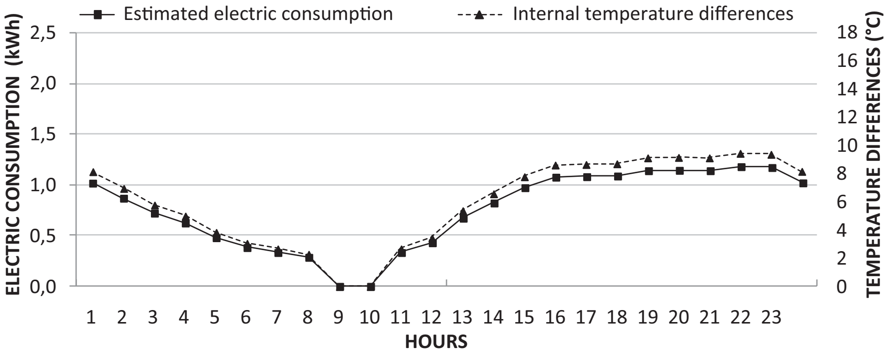

Fig. 9 Difference of temperatures and estimated electric consumption of the day 6th June 2012

Fig. 10 Comparison between studied real test cell and Ecotect software simulation image

4 Simulation Results

By comparing the electric consumption of the studied periods of the real test cell and simulations (Fig. 10) relevant differences are observed in some cases. For example, in cooling period simulated with Ecotect it is obtained a 42 % more electric consumption. On the other hand, in heating conditions Designbuilder results showed a 37 % less electric consumption comparing with the real electric consumption in same period. These differences are due to climate differences. By comparing the *standard* registered day in simulation programs with the real climate period we find that they do not match.

5 Discussion

Winter-cycle-type testing shows that the bulk of energy demand concentrates during night hours due to the beneficial effect of glazed surfaces during day hours. The peak electricity demand of around 2.2 kw is assumed to occur at 8 h am. Summer cycle type testing shows that energy demands are more uniform along the day. The peak electricity demand of around 1.2 kw is assumed to occur at 20 h.

Initial testing results allow to estimate an average wintertime daily electricity needed of 21.96 kWh and In the same way the average summertime daily need is estimated to be 14.4 kWh, what means an estimated yearly total needed of 6,596.22 kWh. These energy demand figures could be supplied by a rooftop 36 m^2 PV standard system, which produces an average annual energy of 5,792 kWh, and passive simple improvements of the envelope.

Performed Simulations were not able to reach the desired accuracy when compared with the testing real results. Probably, one of the main barriers has been not to perform the simulations with real weather conditions files but using software own climatic files instead.

6 Conclusions

After analyzing the thermal performance of the test cell, the following conclusions can be drawn:

- Average energy demand of a test cell as described to get comfort conditions using a regular split heat pump HAVC system is 419 kWh (0.61 kWh/m^2 day) in winter and 102.8 kWh (0.40 kWh/m^2 day) in summer. The estimated annual demand could be set to 6,596.22 kWh (0.51 kWh/m^2 day).
- Annual demands could be supplied both improving insulation and using solar PV panels. Passive measures are insulation improvement and double-glass at windows. These passive measures suppose 36 % saving in electric energy. Additionally 36 m^2 of rooftop solar panels would meet full energy needs at an estimated cost without grants of 17,290 € (480.28 €/m^2). Required additional investment accounts for an additional 57.63.% over initial costs and its return has been calculated in 30 years (possibility of 7 years with grants).
- Due to the poor energy efficiency of the test cell, it can be found that any single storey building can reach net zero energy consumption by improving insulation and using full rooftop PV panels, in a climate similar to Madrid.
- Estimations made by using computer simulation have reached in electric energy demands with an accuracy in Ecotect of 70 % at heating conditions and 42 % at cooling conditions. In DesignBuilder has reached 37 % of accuracy at heating conditions and 100 % of accuracy at cooling conditions.
- Further tests would be necessary to evaluate different energy efficiency improvement options looking for the contribution in energy savings.

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On Passive Bioclimatic Conditions at Cabanyal Neighbourhood, a Sustainable Model on the Shores of the Mediterranean Sea

R. Pastor-Vila and J. L. Higón-Calvet

Abstract The Cabanyal neighbourhood, along with Grao, Nazareth and Malvarrosa, constitute the eastern boundary of Valencia with the Mediterranean Sea. Its proper location in the area led to its morpho-typological development and unique landscape, giving an additional condition as a urban waterfront. The district sets up an urban piece with specific qualities different from the rest of the city, these are: the bioclimatic characteristics, traditional culture, socio-economic performance and natural resources such sun, sea and winds.

In the present study has been analyzed in depth the bioclimatic conditions of urban environment. For this purpose has been used Givoni's Bioclimatic Chart to determine which passive strategies are suitable. The analysis shows excellent conditions set in its response to climate.

Keywords Passive bioclimatic conditions • Urban sustainability

1 Introduction

The location of Valencia city center, away from the sea, led to the autonomous growth of the Cabanyal,[1] The Grao, and Nazareth Malvarrosa, settlements emerged around the fishing port activity and the eastern boundary of the city with the Mediterranean Sea. It represents the joint area between the city and the sea (Fig. 1).

[1] The three fishing settlements Cabanyal, Canyamelar and Cap de França, from its origins relatively uncertain, until 1837, were neighborhoods of Santo Tomas de Valencia. From this date until June 7, 1897, which were annexed to the city, formed a commune called Pueblo Nuevo del Mar. From 1897 until nowadays, Pueblo Nuevo del Mar, now called the Cabanyal, is part of the city of Valencia (Pastor 1995).

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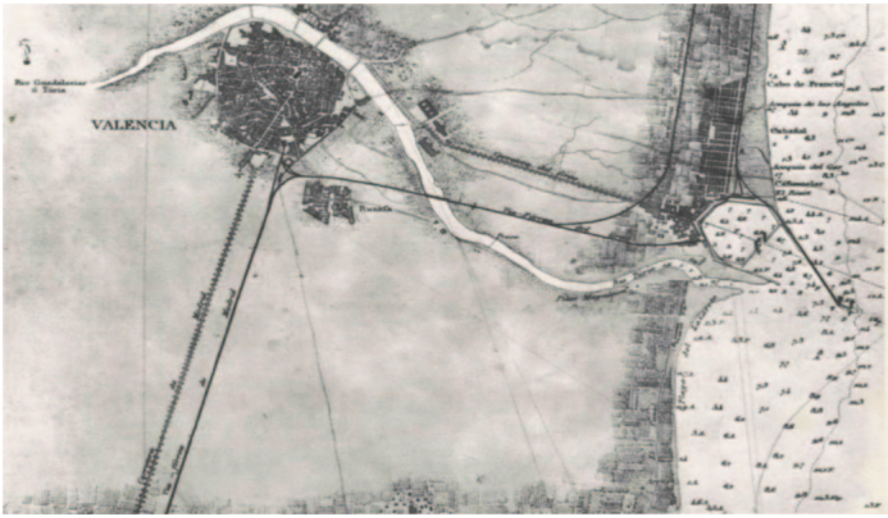

Fig. 1 Eastern Mediterranean Coast of Spain from Cape Cullera to Grao Valencia (1877). [6, p. 36]

The Cabanyal, as an independent municipality with the name of Pueblo Nuevo del Mar, until 1897 when it was annexed to Valencia, has followed a particular growth and differentiated with respect to the city, with residential use which a leading part in this process.

The territory where the settlement of El Cabanyal was done, had some previous conditions to the action of man, the natural characteristics represented by the morphological features and climate of each place such as relief, hydrographic network, weather conditions, the characteristics of soil and productivity [1] and according to them, man made the first anthropic structuring of space in relation to nature.

The place was originally a swamp of possible lacustrine origin. The beach consisted of sand washed small that the wind carried inwards forming low-lying dunes and the rest was marl land cultivation [2], their habitat are characterized by the abundance of canals roads and trails that crossed the field, indispensable for the vital development, also had well water for domestic use.

The presence of the settlement in the territory came about thanks to the exploitation of primary production structure as was fishing and it grew as suburb of Villanueva del Grao (now El Grao); urban consolidated core provided with water supply and road links with the city across three ways called New Path (Camino Nuevo), Old Path (Camino Viejo) and Deep Path (Camino Hondo) [3].

Men took a number of premises to occupy the territory of El Cabanyal: the capacity of the sea as a resource for subsistence, settlement security against natural disasters or geographic processes active, and the optimal conditions of temperature and humidity and use allowing good land management. Their settlement configured habitat in a progressive manner, in a process of constant balance with nature.

Regional planning was composed by adding block row plots grouped back to back, focusing on housing orientation east-west and its accessibility from the sea.

Fig. 2 Geographical overview of the village of the beach of Valencia (1736). [7, p. 402]

Fig. 3 The traditional houses at Cabanyal neighborhood. (Pastor 2010)

The corners are finished off with a house without any special treatment, modest opening holes in the ends without any accorded rhythm. Blocks were strips of elongated proportions with constant depth, equal to the sum of the depth of the plots, with a road scheme composed of parallel main streets to the sea in north-south streets and others of second order, called crossings, in perpendicular to the above. The possibility of unlimited growth was limited by the various water canals running through the territory (Fig. 2).

The initial settlement directly linked to livelihood related to the sea, became the support of a traditional architectural style whose idiosyncrasies produced a vernacular architecture [4] (Fig. 3).

Vernacular architecture emerges as a response to the needs of satisfaction of a man with their habitat, conditioned by a socioeconomic and cultural components that represent the features and characters of their own, distinctive of a community. Constructive and formal solutions and materials were related to the site implantation in harmony with the bioclimatic environment.

According to Rapoport [5] the characteristics of the vernacular are: "no theoretical or aesthetic claims, working with the right location and with the micro-climate, respect for other people and their homes and thus to the total environment natural or man-made."

Fig. 4 Detail plot plan and façades of the Cabanyal. (Ord. PEPRI Canyamelar Cabanyal-T 1, p. 27)

2 Bioclimatical Behavior

The study of the site bioclimatic conditions appears as resulting from the interaction between two types of factors: climate data on the location and geometric and formal configuration of buildings. Bioclimatic aspects that characterize the neighborhood of Cabanyal are its proximity to the sea, the direction of the urban pattern, the density of the building and the shape of street section (Fig. 4).

Regarding climate data, records has been based on the 'Average Weather of Valencia' in the 1971–2000 Period, obtained from the website of the State Meteorological Agency AEMET [8]. The data thus obtained has been plotted on a graphical representation (Fig. 5).

The graphical representation of statistical data on monthly average weather values shown on Givoni's diagram [9] allow us evaluate the range of minimum and maximum values reached in both temperature and relative humidity. The graphical representation of the twelve months of the year on the diagram, allow us also characterize the annual behavior of the studied site from a bioclimatic viewpoint.

In the case of the data available to the neighborhood of Cabanyal, the Givoni's diagram obtained is as follows (Fig. 6):

For the purposes of interpreting the Bioclimatical Givoni Chart, each segment representing a month is divided into as many days in the month are, assigning to each day the strategies where the segment running on. By applying this procedure to all months of the year can deduct the periods of the year in which certain strategies must be implemented to achieve the status of comfort.

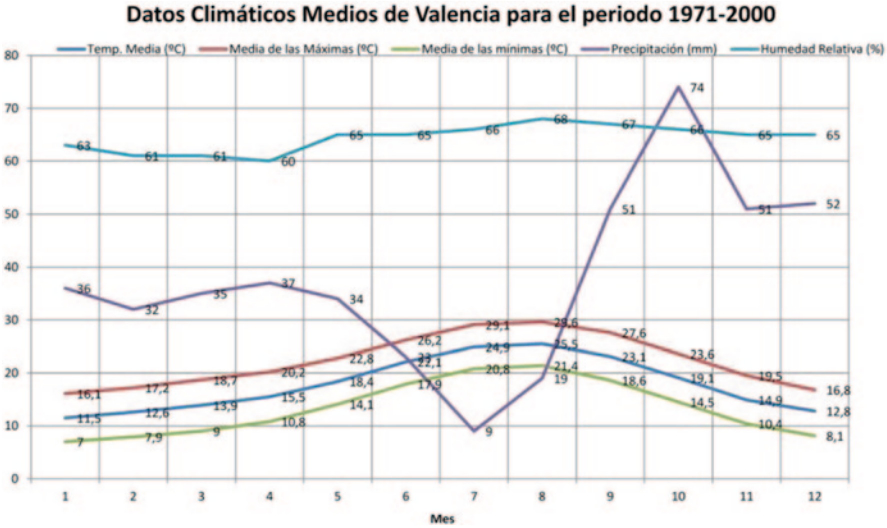

Fig. 5 Graphical representation of mean climatic data of Valencia. (AEMET 2011)

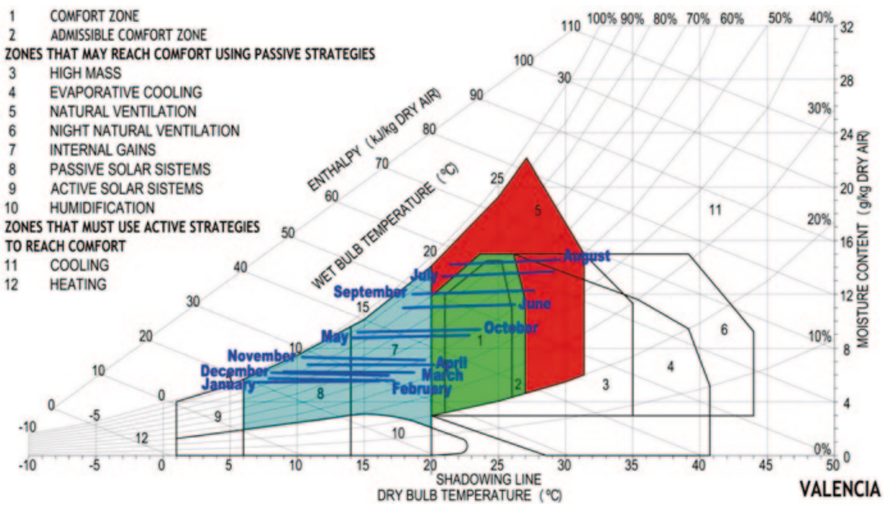

Fig. 6 Bioclimatical Givoni chart for Valencia. (Higón 2011)

Table 1 Monthly distribution of the most common strategies

	Solar Protection	Summer strategies	Confort	Winter strategies
Jan				31
Feb				28
Mar				31
Apr	1		1	29
May	10		10	21
Jun	22		22	8
Jul	31	13	18	
Aug	31	18	13	
Sep	25	3	22	5
Oct	12		12	19
Nov				30
Dec				31
365	132	34	98	233
	36,16%	9,31%	26,85%	63,84%

Most Common Strategy		
8D		Passive Solar Sistems
8D		
8D		
7D	Solar Protection	Internal Gains
7D		
1D		Confort
5-6D		Natural. Nightly Ventilation
5-6D		
1D		Confort
7D		Internal Gains
7D		
8D		Passive Solar Sistems

From the averaged weight of the segments that represent full year for climate data from Valencia, has been constructed the following Table 1:

Based on the strategies identified, the bioclimatical diagnosis of Cabanyal Neighborhood is as follows:

- December, January, February and March: Passive Solar Systems are recommended.
- November: Internal Gains are recommended.
- April, May and October: Internal Gains are recommended with Solar protection.
- June and September: Comfort. Solar protection is recommended.
- July and August: Natural permanent and Nightly Ventilation, with Solar protection.

3 Conclusions

The Cabanyal Neighbourhood, for the climatic conditions of its geographical location, the geometry of its urban pattern and its component typologies has suitable conditions for the use of passive bioclimatic strategies in order to obtain comfort conditions inside buildings with no other external energy input than that provided by solar radiation in order to get enough heat in winter and natural ventilation in order to cool the interior of the buildings during the summer.

The optimal characteristics of the Cabanyal neighborhood for the purposes of the application of passive strategies, and issues that can be improved are described as follows:

Favorable aspects:

- The typical Mediterranean climate, optimum for use passive cooling strategies, makes not necessary at any time of year the use of active strategies (heating or air conditioning).

- The shape and the orientation of the urban pattern and the geometric relation between street width and the height of the buildings are in favor of the application of solar passive systems. The width of the streets in direction N-S ranges between 7.50 and 18 m, with a height of cornice ranged between 6 and 9.5 m. The above mentioned geometric shape, orientation and dimensions turn out to be specially favorable to the capture of solar radiation from the East from the first hours of the day during December, January, February and March, which allows to reach the conditions of comfort exclusively by means of the application of passive strategies such Internal Gains and Solar Passive Systems.
- The used typology and its consequently urban morphology, mainly double oriented in the E-W direction, with the same direction of predominant breezes during the last hours of the evening and the first hours of the night, turn out to be specially favorable to the application of the passive strategies of natural permanent ventilation and natural night ventilation during July and August, producing thus the dissipation of the heat caught by the building during the day.

Areas for improvement:

- All West facing façades must have sun protection mechanisms in order to minimize overheating during the period between April and October,
- In general, given the age of the building, it is recommended to improve the thermal insulation, in order to take advantage of internal gains during periods of April-May and October-November.

Should also be noted that favorable conditions regarding the use of passive strategies in the neighborhood of Cabanyal are conditioned largely by the shape, dimension and orientation of the urban pattern. Any change in the urban pattern, whether tending to alter the relationship between road width and height of the building, or on the orientation of the plot, would only worsen a sustainable urban model, whose current form is the result of the Mediterranean tradition and common sense.

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Architecture as an Energy Factory: Pushing the Envelope

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Abstract There is an increasing energy scarcity in global terms. Global energy production is, not taking dreams on account, stationary (International Energy Agency. World Energy Outlook 2011. ISBN:978-92-64-12413-4), while population demands are increasing. The centers for energy dissipation are today the cities. In the near future energy will be collected and used locally, instead in big producing centers. The proposal presented here has therefore a considerable impact in the way we must design our buildings and cities. There is an increasing need to gain self sufficiency in architecture and cities in order to move on from "cities that consume" to "cities that produce". The search for innovative alternatives is on, and includes the emerging technology of microalgae cultivated via photo-bioreactors. Architecture has become susceptible of taking on the role of a Bio-Factory for energy and food and other products. In this paper we develop a variety of proposals that involve introducing algae photo-bioreactors within architecture, which are capable of producing various amounts of bio-fuel and medicines, food and various other products, and that present an alternative to existing solar panels and photovoltaic cells.

Keywords Cities • Architecture • Energy factories • Envelope • Integration

1 Introduction: Cities as Wealth (Energy) Factories

We want to present the following idea: to view cities as "Energy Factories", i.e., places that produce more energy than they actually use by exploiting all resources available in their physical structure (buildings, urban spaces, infrastructure).This model of urban planning redefines the current city and allows to redistribute energy and produce wealth for all in reasonable timescales.

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Prior to the 1800s wealth (that is, energy) was obtained from the fields via photosynthesis and yielded poor results. During the nineteenth and twentieth centuries energy flowed from concentrated sources like mines or wells. In the course of time, the number of people needed to generate wealth in the fields decreased by 90 %, while the number of people able to enjoy and distribute that wealth concentrated in the cities that had grown immensely as the sink necessary to run the economic machinery.

During the twenty-first century it is expected that the current concentrated sources of wealth will disappear as an economic meaningful system, that is, with energy returns of the order 50:1. In our proposal we use cities as the new sources of extended wealth that can now yield 10 times more energy than that obtained in the old agricultural fields. Until today the system has been very much concerned with wealth distribution and wealth dissipation. Cities have acted like energy (wealth) drains with no concern whatsoever for wealth generation.

Redefining what is possible in the places we live and work and play, Energy Factories suggest a timely holistic approach that defies the detrimental belief in continuously consuming the new and discarding the old, which rates so high in economic costs.

Energy Factories present us with an example of a pioneering, globally viable, financially attractive and self-reliant positive solution for the city and its architecture.

In addition to that the city could also function as the perfect example of a fresh approach to producing wealth. Investors would be drawn by the reliability of their financial returns, thus generating new businesses. Further benefits would include the reduction of CO_2 emissions. Globally speaking, it would contribute towards achieving existing international sustainability targets.

The innovative designs of both architecture and urban elements that use up to date technology of photo-bioreactors and solar energies, combined with energy storage strategies and energy distribution schemes, would allow for this new concept of the city as “Energy (wealth) Factory” to become a tangible reality.

2 Introducing Energy Generating Algae into the Bio-City

Reliance on energy is at the core of twenty-first century society. There is a steady increase in demand and a foreseeable shortage of supply set to worsen as existing resources continue to be drained. Consequently new habitat models are important in the design of human living places.

We have grown accustomed to seeing buildings designed to obtain energy through solar panels and photovoltaics (PVCs) built within them, even if only on a small scale and not as widely used as would be desirable. Only the occasional theoretical proposal is found regarding the production of bio-fuel, food or other products from microalgae cultivation in photo-reactors installed within architecture, and this is a path that is now ready to walk upon.

Our firm Cervera & Pioz Architects belongs to a consortium that won the Ministry of Industry bid CENIT 2010 with the project entitled “VIDA-BIOCAS, A

Self-Sufficient City Using Algae". As a member of this research group, our firm is developing highly groundbreaking proposals that integrate photo-bioreactors into architecture and the city. The aim is to transform currently vacant and/or underused surfaces and areas into "Energy Factories". In our proposals we make use of the city by taking advantage of all available architectonic and urban surfaces. A variety of scenarios offer opportunities for the integration of energy production, medical products, food, cosmetics and others, from algae cultivation. The biggest potential for photo-bioreactor integration lies in built constructions, however the urban scenario also offers interesting opportunities as we will discuss further on.

3 Main Characteristics of Microalgae Cultivation Using Photo-Bioreactors

Algae use the sunlight by capturing its energy by means of photosynthesis process which enables the conversion of inorganic matter into simple sugars. There are two main methods followed for its cultivation: ponds and photo-bioreactors [1]. Cultivation in ponds is the cheapest although less efficient and difficult to control. In both cases algae need is sunlight, water with nutrients and CO_2. When using photo-bioreactors the plants are grown in a controlled environment. For maximum efficiency photo-bioreactors need to be cleaned from time to time, which means that a thorough distribution divided by sectors or modules that can be easily maintained is in place [2]. Algae are harvested when fully grown by separating the slurry parts from the water, then pressing them, and following this by centrifugation. As a result of this process products like algae oil and biomass are produced [3].

One of the main advantages that algae present is a speedy growth rate that generates a full crop cycle every 24 h. The biomass it produces can truly become a valuable alternative to that of cereals or other products used for feeding people. Even though things are slowly improving, the current production cost for oil and bio-fuel is still too high, so economically speaking it can hardly stand as a competitive fuel option. The area where microalgae cultivation is most widely developed is that of highly valued pharmaceutical products, foods and cosmetics, all of which offer excellent value for money [4].

4 Pushing the Envelope: Integrating Photo-Bioreactor Crops into Buildings

Algae, the base of life in our planet, can transform landscapes and environments [5]. We are discovering visions and tracing plans for restoring and regenerating natural environments, transforming and greening urban landscapes through the use of algae[1].

[1] There is a global challenge to design visionary algae systems introducing algae in architecture and landscape design. Experimental projects are trying to find out a combination between engi-

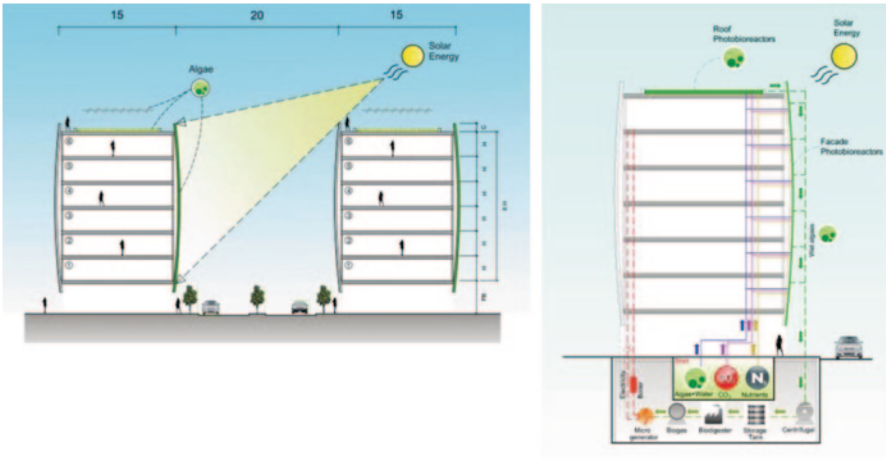

Fig. 1 Photo bioreactors vertically integrated in facades. Pipes and storage

Building envelope structures are increasingly being considered versatile places compatible in their function as enclosure with that of energy capturing areas. Thanks to this, moving from existing photovoltaic panels placed on facades to the incorporation of photo-bioreactors within buildings is currently a relatively easy step to take (Fig. 1).

The diversity of construction typologies requires specific planning proposals for each kind [6, 7]. However photo-bioreactors are suited to be integrated into window surfaces of residential and tertiary sector buildings alike without interfering with day to day usage. The typology characteristic of the industrial sector buildings include large hangars and warehouses that allow for a more intense use of the envelope structure [8].

In a hypothetical case study, we look at an area of 400 ha that presents the following urban distribution: the residential and tertiary sectors each occupy 33 % of the total, and a further 33 % is shared between public and green spaces (20 %) and the street and road network (13 %). If an optimum output was to be obtained using existing photo-bioreactor crop technology of 0,02 kw/m^2, a total ranging around 12 kw/h per day could be obtained from 100 m^2 of façade, depending on façade and roof surface usage, in addition to other possible areas in the urban fabric.

For the time being, we are making some attempts and experimental approaches about the best use of photo-bioreactors in the city. We started with a calculation of potential areas and an optimum coefficient of algae crop, as follows (Fig. 2):

Also, we are researching in energy use of micro generation closed-system for buildings, developing together with "CT Ingenieros" and through which it reaches 10 % of the energy savings in buildings.

neering and design. The main aim is to produce energy systems inside the urban landscape: http://www.domusweb.it/en/architecture/algae-farm/; http://www.algaetecture.com/; http://www.algaecompetition.com/; http://www.bartlett.ucl.ac.uk/architecture/partnerships/installations-for-london-2012/algaezebo; http://www.amazon.com/Imagine-Our-Algae-Future-Architecture/dp/1475128185.

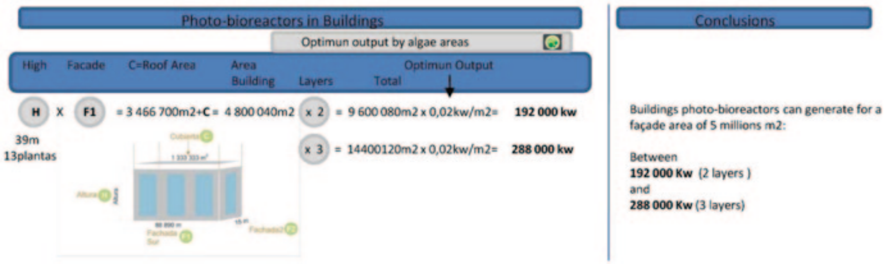

Fig. 2 Preliminary estimates of potential building areas

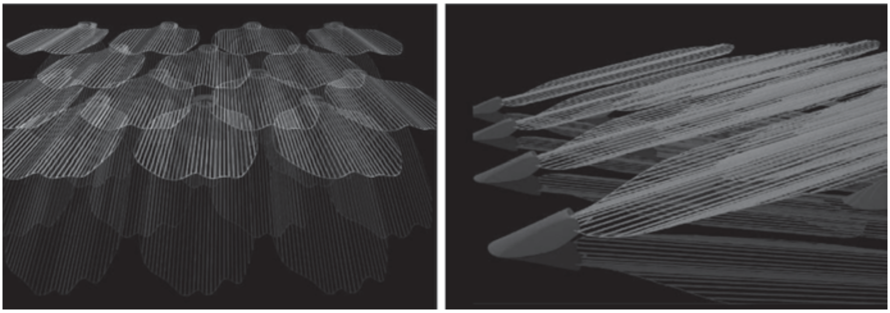

Fig. 3 Natural reference of the silk of a butterfly's wing

4.1 *Example of a Design for a Vertical Photo-Bioreactor*

Working within the previously mentioned VIDA-BIOCAS project framework, the authors' current research into bionics relating to bio-construction has resulted in the design of a photo-bioreactor inspired on the silk of a butterfly's wing, (Fig. 3). Butterflies shape their wings surface by means of extremely thin silk scales positioned like tiles that generate a very light fabric with the velvety and beautifully drawn appearance that we can all appreciate in them. These scales fasten themselves to an end of the butterfly's wing structure functioning as a projecting or jutting out. The photo-bioreactor design mimics this arrangement generating a fickle structure that is able to lay over any surface or facade. A series of horizontal bars conform the primary structure that holds together the microalgae modules.

The modules' suspension pieces allow these to be articulated so that they can be positioned at will for maintenance, design or user convenience. They can be of a tubular shape or located within a "glass like sandwich" with all microalgae fluids running inside (Fig. 4).

Some other designs for façades and roofs are been produced acting simultaneously as place for algae culture and as louvers, producing shadows and reducing the solar radiation impact (Fig. 5).

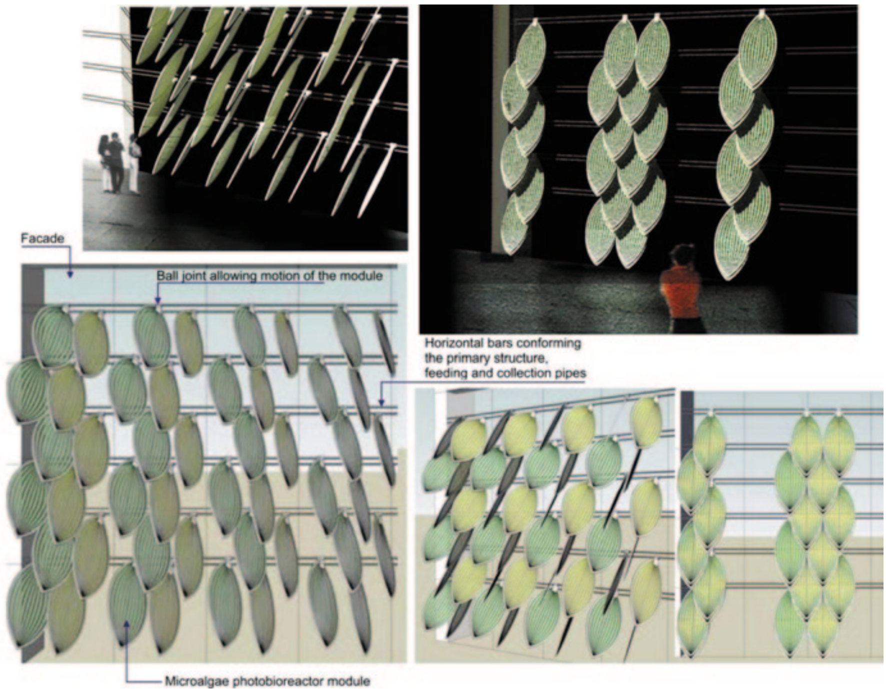

Fig. 4 Photo-bioreactor design example for vertical surfaces

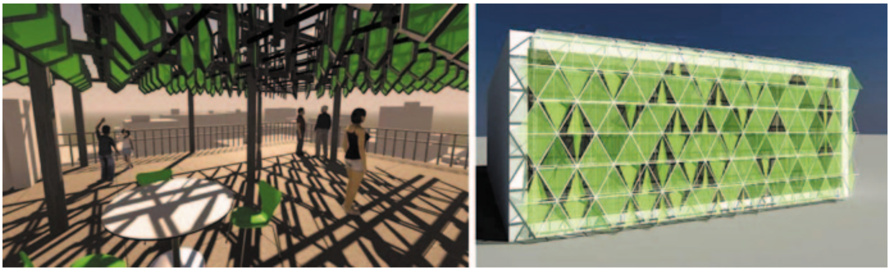

Fig. 5 Vertical and horizontal photo-bioreactors designs for "envelopes"

5 Incorporation of Photo-Bioreactors into the Urban Fabric

The urban scenario offers a myriad of chances to introduce photo-bioreactors, from large scale, "artificial" urban parks, to smaller scale usage of urban furnishing. Here we introduce some examples that the authors are currently working on.

We have named our first example the "artificial woodland". They are of variable scale, spread from urban marquee to a piece of park, and are formed by trees

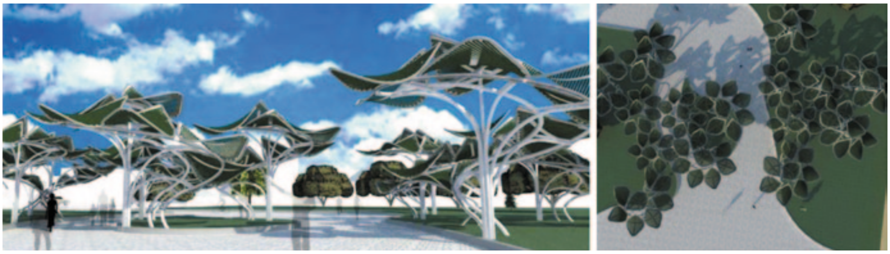

Fig. 6 Factory—Forest of algae: Trees "that function as photo-bioreactors of microalgae"

which are in reality microalgae photo-bioreactors. They have been designed under the geometrical laws followed by real trees, which enables sunlight to reach them in optimum conditions. This tree ensemble could form a little algae woodland-factory, with all production being collected and directed towards a centrally connected biomass base (Figs. 6 and 7).

The second takes outdoors parking shed or canopy that has been designed to convert the covers into areas for algae crops (Fig. 8). These sheds present an alternative to conventional parking by searching for the versatility of surfaces.

Our first estimation of potential crop areas are as follows (Fig. 9):

6 Conclusions

Through our research works, we want to change the ideology or concept of "consuming cities" to "self producing cities", developing a variety of proposals which introduces algae in architecture and urbanism.

Further from our lecture we are offering a new vision to the city as for 'Energy Generation', in which architectural envelopes are also used as a novel technology for growing algae and generating energy like biodiesel and biomass.

Until now, these envelopes were just considered as a sheer protecting cover/envelope for the buildings from the outside environment, but now we take a step further in converting them into energy producing envelopes which can be used for the services or self energy consumption of the building itself, having minimum impact on the environment.

By exploiting the facades, enough renewable energy taken from a combination of sources can be produced to supply the city's own needs. Added value would derive from the zero cost of energy transportation. Further environmental benefits would include the reduction of CO_2 emissions. Globally speaking, it would contribute towards achieving existing international sustainability targets. Finally investors would be drawn by the reliability of their financial returns, thus generating new businesses.

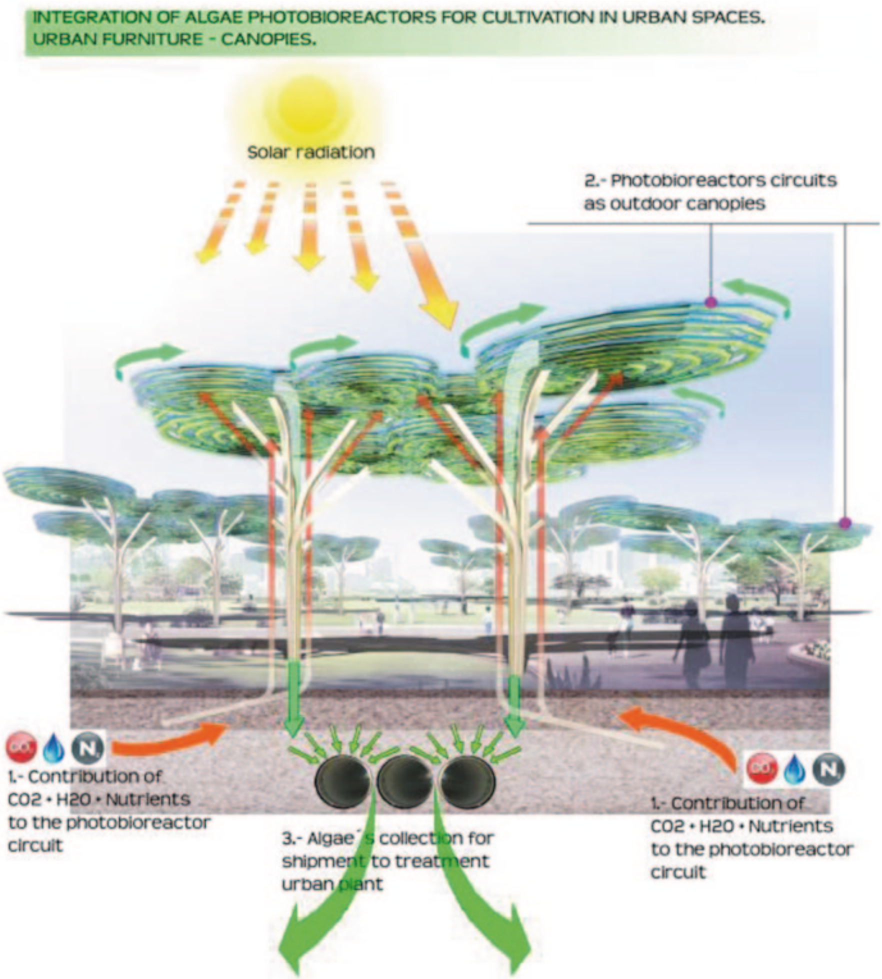

Fig. 7 Factory—Forest of algae

Fig. 8 Parking sheds

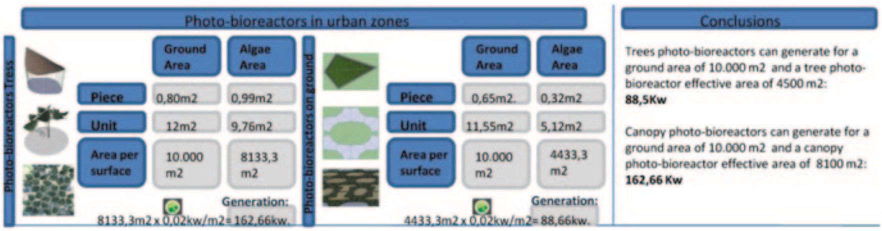

Fig. 9 Preliminary estimate of potential urban areas and photo-bioreactors urban furniture's

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The Use of Unconventional Fuel to Build "Biomass System"

Juan Martínez-Portilla

Abstract Nowadays, our Society keeps on demanding an increasement of Energy, but at the same time, we find a more respectful society, which cares about the environment, reacting against its problems. As everybody knows, the Greenhouse Effect is one of the main worries. It is provoked by the emission of pollutant gases which come from fossil fuels as coal, petroleum and combustible fumes.

According to this situation, different "Renewable Energies" are presented to us. I consider really relevant to focus in one of these energies: Biomass.

I would like to explain the reasons why:

When Biomass is used to build, it is a reliable technology with competitive costs, and these features get from Biomass a high rival against natural gas and petroleum products.

So, with this Biomass energy we could cover a great part of the building demand (hot water, Heating); we will get a lower economical cost and even more important, the reduction of the emission of CO_2.

If the amount of CO_2 is reduced the building will get a better energetic qualification, therefore it will gain a better position in the property market, as a better quality product.

Keywords Sustainability • Energy efficiency and efficient technology

1 Background

Introduction From the period of the prehistory, the utilization of the fire represented the most important advance, before it was learning to realize it, the alone man could obtain fire of the spontaneous fires, the beams that were falling down during the storms, the volcanic eruptions ect.

The fire was giving light and heat, working as source of energy to warm the caves and the cold zones, both cavern as favoring the meeting of people around meeting the needs of cooking and heating.

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DOI 10.1007/978-94-007-7790-3_28,

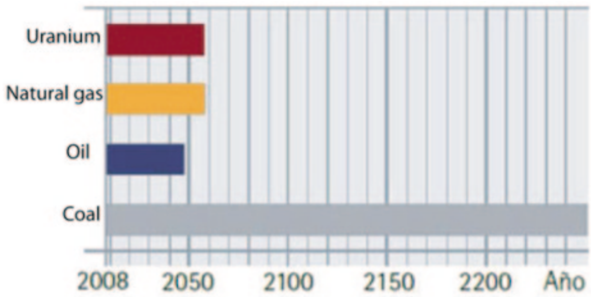

Fig. 1 Availability of fossil fuels, module biomass, master project manager and energy facilities, Energy Technology Institute (ITE) page 14

Fig. 2 Fuel for use in the building, book Biohome, Institute for Diversification and Saving of Energy (IDEA), page 7

With the advent of fossil fuels, coal becomes the primary source of energy used in buildings, industry and transport.

To increase demand for energy, environmental problems arise in cities as greenhouse gases or climate change issues. Given this situation with urban environmental problems, renewable energy are presented and in this case the energy of biomass as an environmentally friendly energy.

Description Biomass means all "**set of renewable organic matter, plant, animal, or its natural or artificial transformation**".

Types of biomass (Fig. 1):

Forest waste (pruning and cleaning of mountains).
Wastes from wood (straw, cereals, etc).
Solid waste and sewage.
Livestock wastes.
Crops energticos (of sugar cane, sunflower, corn etc).

Throughout last decade, in Spain one has been employed at the facilities of biomass developing an experience and professionalism, allowed that the boilers of biomass adapt to buildings and housings

The utilization of the biomass as energetics is considered to be specially beneficial, since the forest residues exist and the forest residues elimination is necessary for a good preservation of the environment (Fig. 2).

Fuel for use in the building The types of fuel for heating and plumbing systems in buildings biomass are:

1. Wood.
2. Wood chips.
3. Pellets

Gas oil	Pellets	Wood chips	Natural gas	Propano	Electricity
0,7 €/L 0,07 €/Kwh	0,2 €/kg 0,0408 €/Kwh	0,06 €/kg 0,0162 €/Kwh	0,5348 €/m3 0,050 €/Kwh	0,703 €/kg 0,055 €/Kwh	0,11248 €/Kwh
					
9,98 Kwh/L	4,9 Kwh/kg	3,7 Kwh/kg	10,69 Kwh/m3	12,88 Kwh/Kg	
1 m3 700 €	3,13 m3 407 €	7,7 m3 162 €	934 m3 499 €	371 m3 545 €	9980 Kwh 1123 €

Fig. 3 Fuel types in building, biomass module, master in project management and energy facilities. (Energy Technology Institute ITE)

The pellets are the fuel most used in the biomass is a bio combustible standardized worldwide.

The pellets are one small cylinders proceeding from the compaction of sawdust and shavings.

To produce the same heat, the stored pellet occupies some three times less in volume that the massive fuel wood and scarcely the pellets produces smoke.

The pellets can manage of form similar to a liquid; it is possible to automate totally, so much in his transport and filling deposit, since in the combustion and cleanliness.

The pellets are the cheapest medium-term solution in facilities of heating. The pellet is not subject to so many variations of prices as the rest of the fuels.

Fuels used to produce hot water and heating (Fig. 3).

Comparison with other fuels:

2 kg Pellets = 1 l diesel fuel = 1m^3 gas
1m^3 Pellets = 320 l diesel fuel aprox.

Price of the consumption of one month that use 1000 kWh:

Electricity: 112.5 €
Pellets: 40 € (0.25 €/kg)
Natural gas: 50 €

Biomass is significantly more profitable than fossil fuels, but uses more fuel volume for the same power output. This is because the calorific value of the biomass is less than fossil fuels.

The combustion of biomass boilers does not contribute to the greenhouse effect. The carbon emitted is zero and CO_2 emitted close the carbon cycle (“photosynthesis”) (Fig. 4).

The emission of the biofuels (pellets, splinter, fuelwood), they fulfill the limits of CO_2 emissions and CO. The emission of the biofuels is mas low that the boilers of diesel oil but higher than in the gas boilers.

It is fundamental does a study of the energetic demand (annual hours of functioning) that has the one-family housing or the building to fit the power of the boiler of biomass.

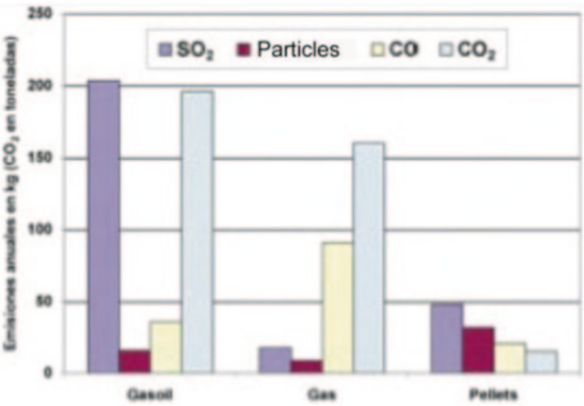

Fig. 4 Comparison of the emission for the different fuels, Book Biofuels for residential buildings, Institute for Diversification and Saving of Energy (IDEA), page 11

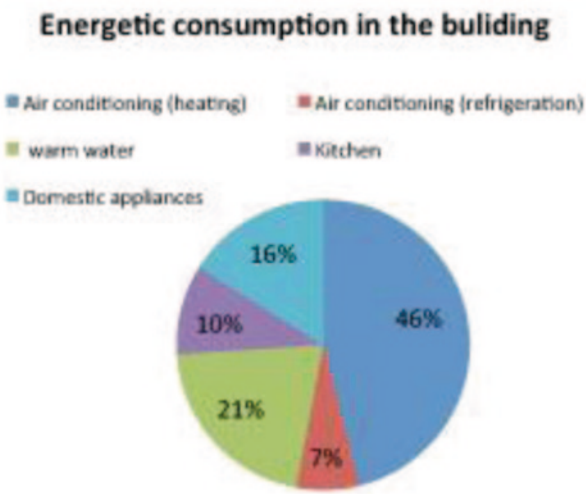

Fig. 5 Energetic consumption in the building, own image.

In the study it is necessary to know the average temperature of the water and the maximum power demanded by the system of heating.

This in the end we can provide a more cost-effective installation, both in initial investment and in consumption over the life of the installation.

According to the energy demand for detached house used a low-power biomass boilers (< 50 kW).

To flats building is used a centralized biomass boiler medium power (< 500 kW).

The houses or buildings consume 40–60 % of energy, with the tendency to increase in coming years (Fig. 5).

The biomass boilers is a strong competitor of natural gas and petroleum products, boilers have energy efficiency between 85-92 %.

The energetic qualification of a housing depends basically on the design, on the closing and the thermal facilities. The closing of the building limits the quantity of energy that will be necessary to come to the conditions of comfort.

The thermal facilities are very important in the energetic qualification more efficient be fewer CO_2 emissions. The biomass is considered as emission zero and it obtains the maximum energetic qualification.

If the amount of CO_2 is reduced the building will get a better energetic qualification, therefore it will gain a better position in the property market, as a better quality product.

2 Economic Study

Bases of the economic study The biomass is an energy that has a cost of implantation is superior to that of other conventional sources.

Biomass facilities have a fast payback thanks to the low price of fuels used. The initial investment costs (on the 450 €/kW).

Studies of return on initial investment raised based on the life of the installation of 20 years.

The study is based on the price of other fuels, the price and the same allowable increase in the coming years.

Example for a house of 200 m^2 the thermal energy of heating and plumbing.

As can be seen in Table 1 reversing the installation of a boiler is higher initially Biomass. The amortization period of the facility has a period of 6 or 7 years for the Installation of Biomass pellets and the use of other fuels as chips smaller, about 5 years.

3 Conclusions

Fossil fuels are priced variable high and is a resource with an expiration date.

The low price of biofuel versus fossil fuel allows the installation profitable quickly (4–6 years).

Biomass energy is an environmentally friendly, natural cycle of CO_2.

In the building allows us to cover much of the building’s energy demand, reducing CO_2 emissions.

The improvement in CO_2 emissions of the building entitles you to a better energy rating.

Table 1 Amortization of the different fuels, own image.

Years	Pellets	Wood chips	Natural gas	Propane	Gas oil	Electricity
0	8,375.00	10,575.00	4,000.00	6,500.00	4,700.00	5,380.00
1	10,199.00	11,369.89	6,206.45	8,944.40	8,052.94	10,404.94
2	12,086.84	12,192.61	8,633.55	11,633.24	11,707.65	16,183.62
3	14,038.52	13,043.14	11,281.29	14,566.53	15,664.12	22,716.05
4	16,054.04	13,921.50	14,149.68	17,744.25	19,922.35	30,002.21
5	18,133.40	14,827.67	17,238.71	21,166.41	24,482.35	38,042.12
6	20,276.60	15,761.67	20,548.39	24,833.02	29,344.12	46,835.76
7	22,483.64	16,723.49	24,078.71	28,744.06	34,507.65	56,383.15
8	24,754.52	17,713.13	27,829.68	32,899.54	39,972.94	66,684.28
9	27,089.24	18,730.60	31,801.29	37,299.47	45,740.00	77,739.15
10	29,487.80	19,775.88	35,993.55	41,943.83	51,808.82	89,547.76
11	31,950.20	20,848.98	40,406.45	46,832.64	58,179.41	102,110.12
12	34,476.44	21,949.91	45,040.00	51,965.88	64,851.76	115,426.21
13	37,066.52	23,078.66	49,894.19	57,343.57	71,825.88	129,496.05
14	39,720.44	24,235.23	54,969.03	62,965.69	79,101.76	144,319.62
15	42,438.20	25,419.62	60,264.52	68,832.26	86,679.41	159,896.94
16	45,219.80	26,631.83	65,780.65	74,943.26	94,558.82	176,228.00
17	48,065.24	27,871.86	71,517.42	81,298.71	102,740.00	193,312.80
18	50,974.52	29,139.71	77,474.84	87,898.60	111,222.94	211,151.34
19	53,947.64	30,435.39	83,652.90	94,742.92	120,007.65	229,743.62
20	56,984.60	31,758.88	90,051.61	101,831.69	129,094.12	249,089.65
Save of pellets	0.00	*−25,225.72*	33,067.01	44,847.09	72,109.52	192,105.05
Save of Wood chips	25,225.72	0.00	58,292.73	70,072.81	97,335.24	217,330.76

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Ecoefficient Façades for Office Buildings

O. Irulegi, A. Serra and R. Hernández

Abstract This paper analyses the energy efficiency of a Ventilated Active Façade—*VAF*—applied to office buildings in Spain. The studied *VAF* was developed in the "Ventilated Active Façade" project financed by the Spanish National Plan for Research and finished in December 2009. This façade system consists of an outer layer element of 2 mm galvanized steel panels and a 3 cm air cavity where the ventilation air is preheated in winter and exhausted in summer. After defining 8 typical office typologies in Spain, 192 study cases are obtained where different parameters like the percentage of glass in façade, the orientation and the climatic zone of the buildings are considered. The energy demand of all these study cases is obtained using the official simulation tool of the *CTE* called *LIDER*. The results, in terms of energy saving, are presented in comparison with the minimum energetic requirements of the Spanish Technical Building Regulation (*Código Técnico de la Edificación—CTE).*

Keywords Efficiency • Heating • Façades • Offices

1 Introduction

Europe is dealing with a radical change in the energy efficiency of buildings. The construction of buildings with low, almost zero, energy consumption is one of the most ambitious objectives set out in the recently approved DIRECTIVE 2010/31/UE. Because of this, the targets set in the earlier Directive 2002/91/EC and in its transposition in Spain in the Technical Building Regulation got outdated. The case of Spain has some peculiarities that need to be mentioned and not doing it, a complete understanding of the gravity of the current situation could be not correct. While the rest of states of the European Union were concentrating their efforts on defining new effective strategies to reduce their energy consumption, the entry into force[1] of the Spanish Technical Code—*CTE* (March 2006) was, in contradiction,

[1] *CTE* is the transposition of the Directive 2002/91/EC, EPBD: Energy Performance of Building Directive.

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accompanied by a frenzied construction activity in Spain. *According to the number of construction permits registered in the Spanish Architect Association in 2006,* 113.041 permits for new buildings were registered. This figure has dramatically decreased ever since, in 2011 a total of 24.285 permits were counted, this decrease has been undoubtedly influenced by the gravity of the economical crisis in Spain.

Thus, when new strategies are to define, it is important to consider that almost all the existing buildings in Spain do not comply the minimum requirements established by the *CTE*, which means that in the near future, a great account of recently constructed buildings should be refurbish to fulfill the new European requirements. Moreover, the imminent entry into force of the energy labeling for existing buildings will highlight, even more, the necessity to act on them. Since 1990 the energy consumption in office buildings has increased by 300 % becoming the responsible for the 47.84 % of energy consumption in the service sector in 2008 (6 % of the total energy consumption in Spain) [1]. Furthermore, the energy impact of this sector is expected to increase considering the proliferation of squanderer glass buildings in the last decade, since concepts related to modernity, technology and transparency are playing a predominant role in their design [2]. Office buildings are going to be one of the most important typologies of the next decade in Spain but they need, in turn, to be redesigned to get adapted to the new energy frame. With this target, the envelope cannot play only a decorative role [3].

Under all these considerations it seems clear that industrialized energy saving systems integrated into the envelope of the buildings [4], as the *VAF*, will proliferate in the near future[2].

2 Objective

This article is part of a PhD research [5] linked to the project called "Ventilated Active Façade" financed by the Spanish National Plan for Research[3]. Its aim was the development of opaque façade elements that manage the energy flows between the interior and exterior of buildings [6]. The research project ended in December 2009 and was conducted by the *University of the Basque Country, the University of Seville* and *the University of Cordoba* of Spain. The Ventilated Active Façade—*VAF*—is a Double Skin Façade [7. 8] and in this project is defined as a parieto-dynamic wall with an opaque exterior layer [9, 10]. In the parieto-dynamic wall [11] ventilation air is taken from outside by forced ventilation, preheated in the air cavity and led inside the building when heating is required. When the building does not need heating, the air of the cavity is directly exhausted outdoors (Fig. 1).

A first prototype (Fig. 1), made of an outer layer element of 2 mm galvanized steel panels and a 3 cm air cavity, was built and tested in the Construction Quality

[2] *SolarWall* ® is an example of this type of technologies produced by the Energy Department of USA, the National Renewable Energy Laboratory and Conserval Engineering Inc.

[3] Ref. BIA2006-15398-C04-02.

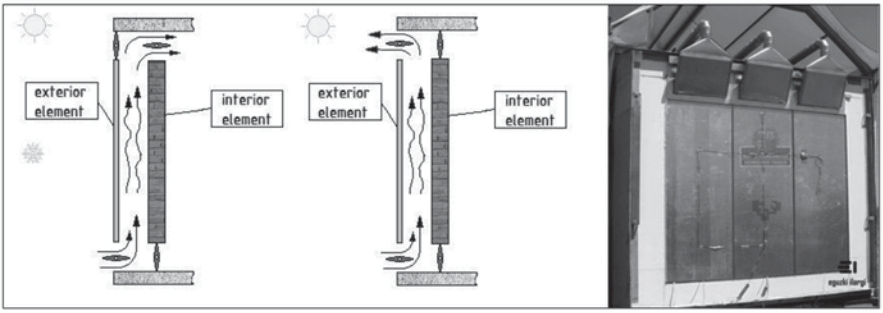
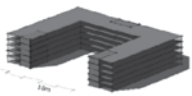
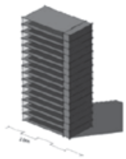
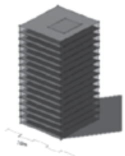
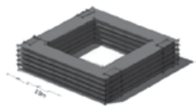
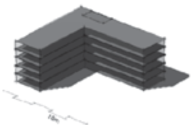
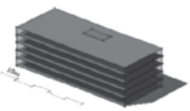
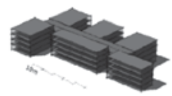
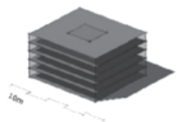


Fig. 1 *VAF* in winter and summer operational mode and test of the first prototype

Table 1 Typical typologies of office buildings

U typology	Tower building with communications core in the façade	Tower building with central communications core	Ring typology
			
L typology	Linear typology	Disperse typology	Compact typology
			

Control Laboratory of the Basque Government in Spain (*Laboratorio de Control de Calidad en la Edificación del Gobierno Vasco)* following the Paslink procedure. The main objective of this paper is to quantify the energy efficiency of a *VAF* applied to office buildings in Spain, and to determine whether or not it is capable of achieving the new targets set by DIRECTIVE 2010/31/EU. The *VAF* used to conduct this analysis is the first prototype developed by the co-ordinated Ventilated Active Facade project. Firstly, a study was made to determine the typical characteristics of office buildings in Spain (Table 1). This analysis has made it possible to define a series of building types that represent the most common characteristics [12–14]. Subsequently, the *LIDER* program was used to obtain reference building models: a reference building comply with the minimum energy demand require-

Table 2 Maximum and minimum heating demand of reference buildings by typology

Typology	Maximum [kWh/m2y]	Climate zone	Minimum [kWh/m2y]	Climate zone
U typology	77.29	Soria (E1)	2.84	Almeria (A4)
Tower 1[a]	57.13	Soria (E1)	0.17	Almeria (A4)
Tower 2[b]	50.09	Soria (E1)	1.23	Almeria (A4)
Ring typology	79.62	Soria (E1)	4.28	Almeria (A4)
L typology	66.71	Soria (E1)	1.62	Almeria (A4)
Linear typology	54.36	Soria (E1)	1.84	Almeria (A4)
Disperse typology	71.94	Soria (E1)	4.60	Almeria (A4)
Compact typology	60.78	Soria (E1)	2.10	Almeria (A4)

Tower 1[a]): Tower building with communications core in the façade
Tower 2[b]): Tower building with central communications core

ments indicated in the *CTE* for each of the established climate zones. A total of 192 study cases were thus obtained.

Finally, the 192 reference buildings were used to determine the energy efficiency of the system by adding a *VAF* on the opaque part of the south façade. The 192 study cases are not intended to simplify the complexity and specific nature of actual projects, for this it would be necessary to conduct a more detailed study. The key objective of this present work is to provide an initial estimated quantification of the influence of certain parameters on the energy performance of office buildings in Spain, with and without the use of a *VAF*.

3 Heating Demand of Reference Buildings

The calculation of the heating demand of the reference buildings is conducted by considering different parameters former mentioned: the typology, the percentage of glass in façade and the climate zone. After an individual analysis of every typology general conclusions will be given. The maximum and minimum values for each typology are collected in the Table 2.

With regard to all the cases studied, it can be concluded that the heating demand is greater for a 30 % glazed façade than for a 60 % one (Table 3). This is due to the fact that, with a larger glazed area, it is possible to absorb a greater amount of solar energy. Furthermore, it should be emphasised that the façade properties vary according to the percentage of glazing. The Spanish Technical Building Code requires less thermal transmittance for a greater glazed surface area.

On the other hand, a considerable difference can be observed between the heating demand in the coldest climate zones (D2, D1 and E1) and the hottest zones (A3, A4 and B4). The values vary between a maximum of 79.62 kWh/m^{2}y and a minimum of 0.17 kWh/m^{2}y.

Table 3 Heating demand for reference buildings for each climate zone [kWh/m^{2}y]

Tipology of building		Climate zones in *CTE*											
		A3	A4	B3	B4	C1	C2	C3	C4	D1	D2	D3	E1
U typology	30%	<30	<30	<30	<30	<30	30–60	30–60	<30	60–90	60–90	30–60	60–90
	60%	<30	<30	<30	<30	<30	30–60	<30	<30	60–90	30–60	30–60	60–90
Tower 1 (*)	30%	<30	<30	<30	<30	<30	30–60	<30	<30	30–60	30–60	30–60	30–60
	60%	<30	<30	<30	<30	<30	<30	<30	<30	30–60	30–60	<30	30–60
Tower 1 (*)	30%	<30	<30	<30	<30	<30	<30	<30	<30	30–60	30–60	<30	30–60
	60%	<30	<30	<30	<30	<30	<30	<30	<30	30–60	30–60	<30	30–60
Ring typology	30%	<30	<30	<30	<30	<30	30–60	30–60	<30	60–90	60–90	30–60	60–90
	60%	<30	<30	<30	<30	<30	30–60	<30	<30	60–90	30–60	30–60	60–90
L typology	30%	<30	<30	<30	<30	<30	30–60	30–60	<30	60–90	30–60	30–60	60–90
	60%	<30	<30	<30	<30	<30	30–60	<30	<30	30–60	30–60	30–60	60–90
Lineal typology	30%	<30	<30	<30	<30	<30	30–60	<30	<30	30–60	30–60	30–60	30–60
	60%	<30	<30	<30	<30	<30	<30	<30	<30	30–60	30–60	<30	30–60
Disperse typology	30%	<30	<30	<30	<30	<30	30–60	30–60	<30	60–90	60–90	30–60	60–90
	60%	<30	<30	<30	<30	<30	30–60	<30	<30	60–90	30–60	30–60	60–90
Compact typology	30%	<30	<30	<30	<30	<30	30–60	<30	<30	30–60	30–60	30–60	60–90
	60%	<30	<30	<30	<30	<30	<30	<30	<30	30–60	30–60	30–60	30–60

(light)	Energy demand < 30 kwh/m^{2}y
(medium)	Energy demand between 30-60 kwh/m^{2}y
(dark)	Energy demand between 60-90 kwh/m^{2}y

In general, it can be seen that the s/v shape factor has an impact on the heating demand: the greater the shape factor (the greater the surface area over volume) the greater the heating demand. Therefore the heating demand simultaneously depends on many factors: the percentage of building façade glazing, the characteristics of the glass, orientation, shape factor, typology and climate zone. The following Table 3 shows the heating demand based on the façade glazing percentage, typology and climate zone. From this table it can be concluded that the heating demand for the majority of cases studied, is less than 30 kWh/m^{2}y. The heating demand is greatest in the coldest climate zones (D1, D2, D3 and E1), where the majority of cases have a heating demand ranging from 30–60 kWh/m^{2}y to 60–90 kWh/m^{2}y. All the cases studied comply with the minimum requirements established by the *CTE* by climate zone. This means that the *CTE* tolerates the presence of buildings with a high heating demand. This fact contradicts the zero energy consumption target established in the European Directive and must be studied more closely.

4 Heating Demand of Buildings with *VAF*

The estimation of the energy efficiency of the *VAF,* is based on the 192 reference buildings mentioned above. The opaque surfaces of the optimally oriented facades were subsequently replaced by the *VAF.* These buildings with *VAF* were simulated with the *LIDER* program in order to determine their energy demand. To conclude, the results are presented and compared with the values of their corresponding reference buildings (Table 4). In this way, it is possible to assess the energy efficiency offered by the *VAF* in each of the cases presented.

Table 4 Energy saving allowed by the Ventilated Active Facade respect to reference value. (Percentage)

Tipology of building		Climate zones in *CTE*											
		A3	A4	B3	B4	C1	C2	C3	C4	D1	D2	D3	E1
U typology	30%	> 40 %	> 40 %	20–40 %	20–40 %	20–40 %	10–20 %	10–20 %	20–40 %	10–20 %	< 10 %	10–20 %	< 10 %
	60%	> 40 %	> 40 %	20–40 %	> 40 %	20–40 %	10–20 %	10–20 %	20–40 %	< 10 %	< 10 %	10–20 %	< 10 %
Tower 1 (*)	30%	> 40 %	> 40 %	> 40 %	> 40 %	> 40 %	20–40 %	20–40 %	20–40 %	10–20 %	10–20 %	10–20 %	10–20 %
	60%	> 40 %	> 40 %	> 40 %	> 40 %	> 40 %	20–40 %	20–40 %	20–40 %	10–20 %	10–20 %	10–20 %	< 10 %
Tower 1 (*)	30%	> 40 %	20–40 %	20–40 %	> 40 %	20–40 %	10–20 %	10–20 %	20–40 %	< 10 %	< 10 %	10–20 %	< 10 %
	60%	10–20 %	10–20 %	20–40 %	20–40 %	20–40 %	10–20 %	10–20 %	10–20 %	< 10 %	< 10 %	10–20 %	< 10 %
Ring typology	30%	10–20 %	10–20 %	10–20 %	10–20 %	10–20 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %
	60%	10–20 %	10–20 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %
L typology	30%	> 40 %	> 40 %	> 40 %	> 40 %	20–40 %	20–40 %	20–40 %	20–40 %	10–20 %	10–20 %	10–20 %	10–20 %
	60%	> 40 %	> 40 %	20–40 %	> 40 %	20–40 %	10–20 %	10–20 %	10–20 %	< 10 %	< 10 %	10–20 %	< 10 %
Lineal typology	30%	> 40 %	> 40 %	20–40 %	> 40 %	> 40 %	> 40 %	> 40 %	> 40 %	< 10 %	< 10 %	20–40 %	< 10 %
	60%	> 40 %	> 40 %	20–40 %	20–40 %	10–20 %	< 10 %	< 10 %	10–20 %	< 10 %	< 10 %	< 10 %	< 10 %
Disperse typology	30%	20–40 %	20–40 %	10–20 %	20–40 %	10–20 %	10–20 %	10–20 %	10–20 %	< 10 %	< 10 %	10–20 %	< 10 %
	60%	10–20 %	< 10 %	10–20 %	10–20 %	10–20 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %	< 10 %
Compact typology	30%	> 40 %	> 40 %	20–40 %	> 40 %	20–40 %	10–20 %	10–20 %	20–40 %	10–20 %	10–20 %	10–20 %	< 10 %
	60%	20–40 %	20–40 %	20–40 %	> 40 %	20–40 %	10–20 %	10–20 %	20–40 %	< 10 %	< 10 %	10–20 %	< 10 %

(darkest)	Energy saving < 10 %
(dark grey)	Energy saving between 10 – 20 %
(light grey)	Energy saving between 20 – 40 %
(white)	Energy saving > 40 %

In general, it can be concluded that the use of a Ventilated Active Façade improves the energy efficiency of the buildings in relation to the reference values. This is confirmed in all the climate zones. Therefore, the performance of the *VAF* is optimal in those climate zones with milder winters. The Table 4 shows that an energy saving of more than 20 % is achieved for most of the cases studied. Analysing the different typologies, in the case of buildings with 30 % of glazed façades, the L-type building is the one in which the *VAF* is most effective.

In all the climate zones, with the exception of zones D1, D2 and E1, there is a saving of more than 40 %. Furthermore, in the case of buildings with 60 % of glazed façades, the Tower building with communications core in the façade is the one in which the *VAF* is most effective presenting an energy saving is of around 20–40 %, even reaching a 40 % in some cases. In all the climate zones, with the exception of zones D1, D2 and E1, there is a saving of more than 40 %.

5 Conclusions

Meeting the *CTE* requests does not guarantee to obtain energy efficient buildings in Spain, moreover, the Spanish Code allows the construction of office buildings with high energy consumption (over 100 kWh/m²y in some cases). It means that most of the buildings recently constructed would need a rehabilitation to improve their energy performances. Heating is an important factor of the total energy consumption of office buildings and depending on the zone, its significance becomes even higher. The heating demand of office buildings that comply the *CTE* varies between a maximum of 79.69 kWh/m²y (for a Ring-type building located in Soria, Climate zone E1) and a minimum of 0.17 kWh/m²y (for a Tower building with communications core in the façade located in Almeria, Climate zone A4).

In all the studied cases, the heating demand in buildings with 30 % glazed façade is higher than in the cases of 60 % glazed façade. This is due to the fact that the incident radiation trough glazed surfaces allow to take advantage of the solar gains. Moreover, it has to be highlighted hat the higher the percentage of glass in façade, the lower thermal transmittance is required by the *CTE*.

After running the simulations by *LIDER*, it is possible to establish that with the us of the *VAF* system it is possible to achieve over a 40 % reduction in heating demand in the most of the cases. In climate zones with mild winters, for instance, in a U-type building with 30 % glazed façade, the heating demand decreases from 10.35 kWh/m²y to 5.46 kWh/m²y. In temperate climate zones as C1, C2 and C3, on average the potential energy saving is around 10–20 %. But this value could be improved as in the case of C1 where the heating demand decreases from 17.23 kWh/m²y to 6.77 kWh/m²y. Finally, in zones with severe winters, the energy saving situates around 10 %, but could be improved in the case of a Linear-type building with 30 % glazed façade situated in D3, where the heating demand decreases form 30.80 kWh/m²y to 19.39 kWh/m²y. The Ventilated Active Façade—*VAF*, with a gap thickness less than 5 cm, is an interesting alternative for the rehabilitation.

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Cogeneration (Chp) as Alternative Energy Production To Ecological Neighborhoods

I. Calama

Abstract At present, the power generation systems based on cogeneration are in process of evolutionary development. The projects proposed are applied to small power plants for industries, hospitals, office buildings, etc., and systems are being considered to serve entire neighborhoods associated with the transformation of cities. These cogeneration projects are presented as a viable alternative to offer a whole district the energy produced in its own sector, as it has been done with other technologies such as solar. The implement of cogeneration in a neighborhood means improving the efficiency of local energy production to avoid losses that may occur in transport. Moreover, cogeneration plants that use biogas digestion of waste generated in the neighborhood could be used in the same neighborhood, closing the energy cycle.

Keywords Cogeneration • Ecological neighborhoods • Sustainable energy

1 Introduction

Cogeneration is a heat technology which allows obtaining electricity and useful thermal energy in the form of steam or hot water. When cold is also generated (ice, cold water or cold air), is called trigeneration.

This is a technology that applies the concept of high efficiency in electricity production, because, while large power plants from distribution companies only pursue the generation of electricity and dissipates heat to the environment, cogeneration presents the advantage that heat is used both as mechanical or electrical energy in a single process. Its design is based on using the heat that inevitably occurs when fuel energy is converted into electricity, in the production center or future users. For this reason, cogeneration plants, as they take into advantage this heat, they get a much higher overall efficiency.

The procedure is simple, since the electricity is generated by a generator or alternator, thanks to a heat engine or a turbine, the harnessing of the chemical energy from used fuel is between 25–46 % (on the lower heating value) and the rest is

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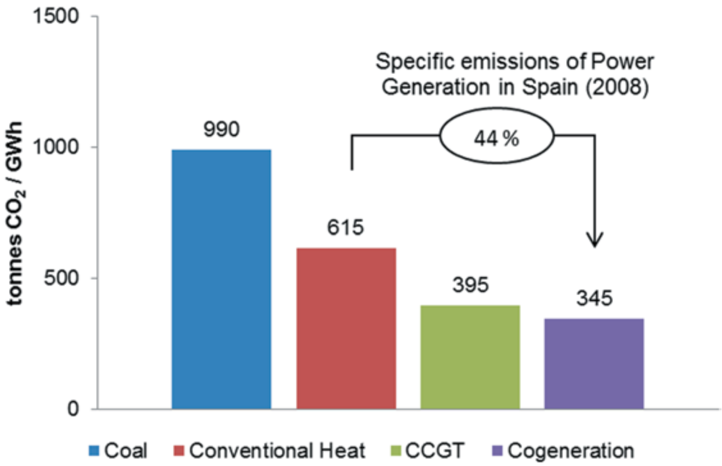

Fig. 1 Cogeneration reduces emissions in electricity and heat generation

dissipated to the air or water as heat. Cogeneration takes advantage of an important part of this thermal energy and, moreover, avoids the problems caused by the heat that is not used in a conventional power plant.

The procedure is simple, since the electricity is generated by a generator or alternator, thanks to a heat engine or a turbine, the harnessing of the chemical energy from used fuel is between 25–46 % (on the lower heating value) and the rest is dissipated to the air or water as heat. Cogeneration takes advantage of an important part of this thermal energy and, moreover, avoids the problems caused by the heat that is not used in a conventional power plant.

In a cogeneration process, heat is represented as water vapor at high pressure or as hot water. This way you can use the hot water vapor obtained from the electric power turbine to supply energy for other uses, obtaining high levels of energy savings and a significant decrease in the energy bill, without changing the production process. Furthermore, if energy is generated in the same place where it will be used, it decreases as well energy losses during its transport, which can be quantified between 10 and 15 % [1], which also improves the quality of the energy supply.

In addition to this, CHP is the key to reducing emissions. According to the *Boston Consulting Group (BCG)* [2], cogeneration saved over 13 million t of CO_2 in Spain in 2008, which represents 3.2 % of national emissions. However, if we compare the data of specific emission electricity generation, the percentage reduction would be 44 % (see Fig. 1), which shows its efficiency compared to conventional electricity generation and turns into a key tool in the fight against climate change.

In this respect, cogeneration is considered an optimum environmental energy production system, which also provides safety to the electrical system. Nevertheless, in Spain, despite the energy savings of cogeneration, this technology has only installed 6,000 MW (2010), when its potential, according to the Institute for Diversification and Saving of Energy IDEA [3], could reach 20,000 MW. In other words, there's only a 29 % possible technological potential. As accurate data of this type of energy production, we have that since 2002–2009, the cogeneration in Spain grew by 9 % while the European average was at 21 %. Thus, despite the energy savings and the reduction of the emissions which provides this technology, cogeneration does not quite takes off.

Therefore, cogeneration can be considered as an essential tool against climate change because it is a power generation system more sustainable than the traditional power generation, to save primary energy, avoiding emissions.

2 Urban Planning of the District Level Co-generation

One of the basic design principles of an ecological neighborhood planning is the generation, distribution and consumption of the energy [4]. From a building scale, low consumptions can be achieved with bioclimatic designs, but consumption depends more on the users. However, from a neighborhood scale, the energy management can be raised even from the analysis of generation and supply systems with a central character. This, in addition to allowing better performance and efficiency in the management system, allows the installation of telecommunication and energy management systems by providing information directly to users to propose appropriate control systems and processes to implement best energy practices.

Therefore, this communication is intended to expose some of the advantages patents that, from a standpoint of sustainability, show the production of energy from a cogeneration plant at the neighborhood level.

2.1 Basic Principles of A Cogeneration System for Green Neighborhood

As it was mentioned above, nowadays, power generation systems for cogeneration are undergoing evolutionary development. In the case of industries, many examples can be cited, among them hospitals where it is being used with success in performance of small power plants. The current pulse passes through design cogeneration plants which can provide service to neighborhoods and transform cities.

In Spain we have some examples of its application to neighborhoods, such as the new district of La Marina in the Port of Barcelona [5], which uses the old trigeneration plants, which were the SEAT factory, in order to feed a network of air conditioning offices, homes and shopping centers in the area. At the Expo Zaragoza, we constructed a trigeneration plant to power the enclosure and all the new adjacent urban area.

These micro-cogeneration projects are presented as a viable alternative to provide a whole districts and neighborhoods with energy produced in their own sector, just as they have been doing with other technologies, like the solar.

Implement cogeneration in a neighborhood means improving the efficiency of local production of energy by avoiding unnecessary losses of energy transport. In addition, the districts could be used for micro-generation plants that harness the biogas digestion of waste generated in the neighborhood, closing the energy cycle. For example, in the Wastewater Treatment Plants (EDARES), the heat generated by the plant is used to provide heat to the digesters and even office buildings, making it a renewable cogeneration criterion.

The idea of a twofold basis: first of all, it generates the necessary electricity for a neighborhood, at the same place of the consumption, eliminating energy losses in transportation and the disadvantages of the market production cost. And secondly, it is about designing a system of domestic hot water (DHW) and central heating at the neighborhood level. Energy and heat production is due to a cogeneration system using biogas boilers, biomass and even municipal solid waste. This system of generating electricity, hot water and heat production produces electricity and heat through a central close to consumers. The electricity generated would be more economic, as it wouldn't have losses in its transport, and for hot water production, it would be installed a system of properly insulated pipes, preferably buried or underground, so that hot water is distributed to all the buildings in the neighborhood that are part of the network. The most common means to distribute the heat is water, but steam can be also used.

The cogeneration plant is estimated to generate electricity that the neighborhood will consume and in case of excess energy, you can sell it to the overall distribution network. In the case of hot water production for more intense demand situations, it can be installed storage systems which store energy during times of lower consumption. For a better performance, the heat which is distributed can not only be used for DHW heating, but heating in winter and in summer.

Nevertheless, it should be taken into account that one of the drawbacks of this system is that the implementation of heat-producing plant and pipeline network requires a large initial investment, so its design should look for a performance that allows amortization to medium term. For this reason, it is not advised to neighborhoods with low population density or single-family homes.

2.2 The Keys in the Ecological Neighborhoods Project

Based on the principles of eco-neighborhood, where the sustainable approach must be comprehensive, so as to integrate all environmental issues: waste, water, energy, landscape, etc., it seems that this is an appropriate scale urban unit for using the cogeneration.

Another aspect to consider in our proposal is that ecological neighborhoods provide the city's commitment to sustainability, so that its principles contain basic design approaches such as: the search for savings in floor building that offers a high density to the whole; good communications networks for non-motorized (bicycle and pedestrian), greater accessibility to public transport, buildings with lower energy consumption, a minimization of the effects of urbanization on the natural water cycle, easy access from the housing to open spaces.

In this respect, an eco-neighborhood should be favored by the City Council itself so that you are provided with tools to favorably affect these aspects of sustainability. In the case of energy production by the cogeneration system, the initial investment is considerable and, no doubt, necessary measures of support from local government. But we must not forget that an ecological neighborhood should comply with energy standards for "low consumption", which means that this is the latest figures that should be of the order of 55 kW/h per square meter. If we transfer this information to homes, their consumption should be around 15–30 % less than the required standards of the current energy legislation [5]. Therefore, over-the initial cost of installing a cogeneration plant could be assumed by the municipality itself, as it will be the beneficiary of the energy savings to be generated during use. Furthermore, in the scope of these actions, it may even be necessary the assistance of the City Council for the issuance of municipal ordinances that include specific clauses which allow the design of eco-neighborhood, as is the case, for example, that on the issue of waste collection the developers must set aside specific spaces on the outside of buildings, for the collection and for the self-composting.

Based on the previous approaches, a project for the installation of a cogeneration plant to serve an eco-neighborhood requires local authorities to get involved in the process. First of all, you need to carry out preliminary studies and environmental impact assessments. You also should set environmental objectives related to energy, water, materials and waste, urban greenery and connection to the environment and social objectives. At this stage, contributions of the project writing team with the work units of the City Council are very important.

In addition, generally, for the construction of a neighborhood we have count on an indefinite number of different promoters. The specific needs of an ecological neighborhood might require that the technicians in the City Hall become the project managers to coordinate the diversity of formal concepts and solutions in innovative ecological criteria.

Moreover, these pilot projects should be kept tracked during the use in order to facilitate behavioral patterns towards sustainability focus. For example, it may be necessary to establish grants to encourage residents to purchase energy-efficient appliances or give advice on sustainable consumption and energy efficiency to residents so they can apply them as a daily practice.

2.3 Some Practical Proposals for Eco-neighborhoods

To check the contributions of energy savings that can be obtained with an installation of a cogeneration plant in a neighborhood, our research group is conduct-

Fig. 2 Neighborhood Los Bermejales (Seville)

ing pilot studies for energy rehabilitation activities of neighborhoods of the City of Seville. In the case of cogeneration, we have chosen the neighborhood of Los Bermejales (Fig. 2), which, although it is not a neighborhood conceived from the ecological point of view, its houses comply with the basic principles of energy efficiency and the first studies allow us to assert that some proposals of sustainable urban development could turn it into an environmentally efficient neighborhood.

For the study of energy management, in a first approximation, we have selected a block of the district (Fig. 3), installing in a free space inside of it a cogeneration plant to produce electricity and hot water. It has been estimated that it provides serve to 204 three-bedroom homes, with an output of 4 kW and services over five blocks of eight floors and four apartments per floor and three eight-storey blocks and six apartments per floor, over 288 homes of four bedrooms, with an output of 8 kW service, nine blocks spread over eight floors and four apartments per floor. They have also included 6250 m^2 for shops and an indoor garden with private pool and street lighting for the block, about 125×130 m. For this, it has been estimated that energy requirement is 1.5 MW, so the plant design includes three electric motors of 3.5 MW cogeneration total powers, which will allows an excess production for sale to the network.

This is a pilot project, which is currently under review and discussion; as the idea is to study the global needs from a neighborhood point of view and propose a global project. In this first development, we have focused on the design for a cogeneration micro scale for heating and hot water production for fuel cells. From the plant building center, the distribution network reaches the substations located in the basement of the houses.

The first theoretical calculations [6], compared with the energy from the general network, show that our central neighborhood get up to 23 % more energy efficiency in the production of heat and hot water, due to the factor of centralization/simultaneity. Furthermore, the first data provides us an energy efficiency of around 53.5 %,

Fig. 3 Block under study

which means that to produce a kWh in the cogeneration plant, it will be consumed 40 % less fuel than when it is compared to the traditional thermal systems used for distribution through overall network [7]. This first data let us know that cogeneration is essential for reducing energy dependence in terms of efficiency.

Furthermore, using natural gas in our plants (alternatively, biodiesel or biomass), CO_2 emissions are greatly reduced. Firstly, because the *CHP* is more energy efficient, but also because it is associated with cleaner fuels [8]. In the project, we have calculated a decrease of the emissions of around 56.1 % [9].

As an alternative to the minimum solar contribution to the production of DHW required by the Technical Building Code (CTE) in its Article 11.2 (DB HE-4), and to remove the solar panels which are normally installed for this concept, the study project would require the installation of six fuel cells, thus it could cover 86 % of the energy needed for hot water consumption, compared with 70 % required by the CTE.

Although the data provided, we are currently developing the project, so we have considered obtaining efficiency results, in other words, what is the proper size of the eco-neighborhood to achieve the efficiency of the project and, consequently, the optimum size of the plant for the production of cogeneration.

Another element that is under consideration and that we have already mentioned is that one of the main problems of this type of installation has is that they require high investment. However, the first calculation results average the cost of kW/h produced rounds 11.8 cents, when the average market price is not below 50 € cents [10], which, in terms of consumption, implies a saving of 75 %.

We are also studying the possibility of including absorption refrigerating machines. That is, producing cooling from a heat source basing on chemical principles that take place inside heat engines under very low pressure and that cool the water circulating through the cooling network using the heat from electric motors. The first results, although it is not confirmed, would allow us to cool the water which returns to the homes at 12–5 °C by this residual energy, allowing, in addition to heating, cooling the households in summer.

3 Conclusions

The study process of the project to implement a cogeneration plant at a neighborhood is still at its initial phase. However, from our research we can advance some general conclusions about the system itself, and some particular ones about the success of this project:

a. *General conclusions:*
   - Our country has a high dependence on foreign energy markets; therefore, any action to improve energy efficiency is always positive. In this aspect, the energy approaches that are made from a global concept, such as the planning of district heating and/or cooling, are a clear example of how to optimize energy resources at the level of an urban area.
   - Cogeneration projects for energy production at neighborhood level, as basic urban units, facilitate energy management and control, as measurement and control systems may be provided to improve consumer habits and production efficiency.
   - In these systems there is no loss of energy transport as the production occurs in the same place of the consumption. Furthermore, besides saving energy, they avoid emissions from 25 to 50 % of CO_2, so they are systems to be considered as sustainable generation.
   - En estos sistemas no se producen pérdidas por transporte de la energía al producirse en el mismo lugar de su consumo y ahorran energía primaria, evitando emisiones de entre un 25 a un 50 % de CO_2, por lo que son sistemas que pueden ser considerados como de generación sostenible.
   - According to the requirements of the *CTE* (*Building Technical Code*) related to the minimum solar contribution in *ACS (Sanitary Hot Water*), it may be replaced by cogeneration systems, so the production would not depend on whether it is a sunny or a cloudy day, but only on the demand of use.

b. *Successful key factors*
   - The success of the implementation of a cogeneration plant at a neighborhood level, should part from the basis that each and every one of the participants of the project, would perceive benefits. The features of its implementation involve an important consumption of capital and a long term business approach, so an institutional backing is strictly necessary, especially in the construction phase of the network.
   - If the urban area chosen must be transformed, the support of the public administration to carry out the project is essential. Ideally, the administration should be the initial developer of such projects. It is therefore important to make an environmentally efficient solution (emissions reduction, revaluation of waste,

greater energy efficiency, reduced number of cooling towers, lower overall water consumption, water treatment products,…), improving the environment (no impact on the landscape) and, ultimately, the improvement should be perceived by citizens. Furthermore, by participating in the project, problems can be identified and solved; even the development of standards for their solution can be encouraged.

- The developer or project concessionaire (*ESCO*), as for its private character, must obtain adequate financial returns within the parameters that its members consider acceptable. Furthermore, brand awareness and market leadership can be strategic objectives.
- Finally, note that the user is the most sensitive, as it is the ultimate recipient of the service and the one permanently coexisting with the system. The user should receive benefits from a wide range of the system advantages: savings in energy costs (for lower cost electricity in hiring, and real higher coefficient of performance *(COP)* against individual facilities); savings in exploitation costs (easier technical maintenance); will not require future reinvestments for replacement of production equipment; more comfort by absence of noise, increased security of supply (the system must be robust and redundant), more usable space available, eliminating risks (legionella, combustion,…), better anticipation of their energy costs, availability of power, etc. [11].

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Standars for Development of Green Neighborhoods

J. M. Calama and M. López

Abstract In this communication, the concept of "ecological neighborhood" been based on consideration of the urban neighborhood as a planned urban unit from sustainably, ecological and bioclimatic and are included in addition to economic criteria and social relations. For this reason, in what follows, our aim has been directed to establish a number of standards from the study of the relationships that develop in an urban neighborhood and have been analyzed from the perspective of habitability, the medium environment and energy consumption, and that we consider basic to catalog the neighborhood as ecological.

Keywords Ecological-neighborhood • Urban indicators • Sustainable planning

1 Introduction

The "ecological-neighborhoods" are units of urban planning, with its own character and are based on sustainable development from what has been called "bioclimatic urbanism" [1], whose main objective is to reduce CO_2 emissions by efficiency in energy consumption, use of renewable energy and transport models. But in addition, a specific aspect to be considered in its development, the socio-economic, integrating in this way: diversity and participation, public management, local development, lifestyles and consumption, etc. And all this while maintaining the level of quality of life of its citizens arise from principles of efficiency, equity and diversity.

2 Approach to the Topic

One of the problems raised by the concept of green neighborhood or eco-neighborhood is that it has agreed a formal definition. The variety and models show the breadth of this concept. According to some authors [2], the green neighborhood builds its concept from their own development. Therefore, we will leave to consider

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an eco-neighborhood as an urban fragment that should be designed with energy efficiency, which takes conditioning systems active and passive, establishing an appropriate relationship with their environment and improve social relations of its residents.

In any case it is important to make clear that the concept of eco-neighborhood is referred to the term "sustainable urban neighborhood" [3]. That is, the idea would be that of a sustainable built environment, which is part of a city and that the proceedings relate to the scale of neighborhood and are situated within those limits. An ecological neighborhood would, therefore, an environment sufficiently large to undertake extensive changes and small enough for its inhabitants to feel involved in them.

3 Basic Principles of Design of a Green Neighborhood

The criteria set out in the previous section lead us to propose that a neighborhood to be considered ecological, must answer the following elements of planning:

a. Urban structure, such as physical reality of the neighborhood and its connection to the city.
b. Transport and mobility, both for the movement of people and goods within the neighborhood and outside.
c. Flows of energy and materials through the various physical and urban systems.
d. Study of socio-economic aspects that determine the quality of life for its residents.

Therefore, in a fairly comprehensive approach, we dare to emphasize some basic principles to be met by developing an eco-neighborhood and we state briefly in terms of their relationship with:

a. The structure and urban morphology
b. Public space and biodiversity
c. Mobility and transport
d. Flows of energy, materials and waste
e. Socio-economic aspects

3.1 Principles Related to the Structure and Urban Morphology

One of the principles of the eco-neighborhood is that this area is included in the structure of the city, ingress zones do not nurture urban links, that could compromise the efficiency. To do this, the structure of green-neighborhood should facilitate contact, exchange and communication of its inhabitants, at two basic levels: the external relationship with the core area of the city and among the parties from the own area. To achieve the first level, the area should be integrated into the communications

Fig. 1 The Quarter Bermejales Seville, despite being on the outskirts of the city has a good network connection to the historic center

network of the city, while achieving the objectives of the second level, involves a series of relationships that have to do with the compactness and density appropriate to the space [4], which could be the combination of the types of morphologies urban areas discarding mono-functional. Therefore, a project of eco-barrio must consider the structural and morphological interrelationships with a minimum requirement, which we state below:

A) Integration of the urban neighborhood in the city

- The ecological neighborhood must be integrated into the city and other centers with which it interacts (Fig. 1).
- This integration must occur through an appropriate linkage to existing public transport networks to access central services and facilities.
- Public transport should be quality and connection nodes being located at a distance that can be traveled on foot or by bicycle by the inhabitants of the neighborhood.

B) Integration of the urban neighborhood in the city

The compactness must attend not only the gross density but also net, so that should be a mix of types and urban morphologies, discarding the mono-functional character areas (zones exclusively residential, industrial, business park…) (Fig. 2).

In terms of density, its quantification is complex, especially when we talk about sustainable urbanism. However, from an ecological perspective, it is necessary that in each case thresholds are set so that if you pass or if they fall below the reference level, it lost much of the values of sustainability and the tissue becomes much more expensive from the environmental point of view. In this sense, the

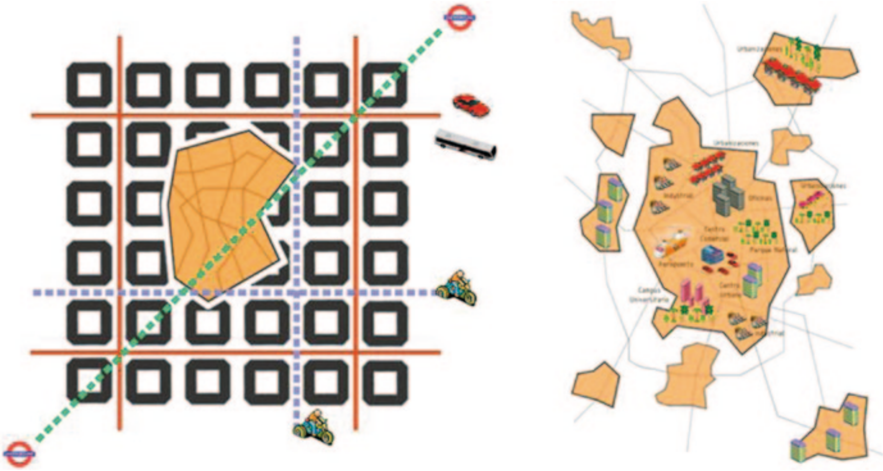

Fig. 2 Schemes compact city (London) and diffuse city (Los Angeles California)

density and size determine the number of residents and users of a neighborhood. In our case we are agree with the authors of project ECOCITY [5]. They consider most appropriate for the ecological neighborhood:

- Buildability index: 0.8–0.3 m^2/m^2
- Ocupation index: 0.35–0.70 m^2/m^2

C) Mixture of uses balanced

The mix of uses (residential, productive, educational, commercial and leisure facilities dedicated to administrative, social and health) should be considered in so far as it will provide access to equipments, facilities and workplaces and, consequently will be getting a global reduction in travel needs (Fig. 3).

To optimize the structure a way functional, should be based the relation on three concepts: a mix of uses, balance and accessibility [6]:

a. Distribution and appropriate mix of uses, combining residential with commercial and tertiary uses at all scales: apples and buildings.
b. The overall balance of all existing uses in the area, combining residential, educational and productive with leisure facilities. Without creating areas for housing only, retail or offices.
c. Adequate accessibility to all facilities, organizing activities around public transport nodes in urban centers, the local pockets of activity and public spaces.

D) Sustainable building

It is appropriate that the building of eco neighborhood respond also to ecological principles. The correct orientation of buildings, to get more light, two facades available to improve ventilation, open spaces a stipulated minimum size, the use of materials that the environment respected and implementation of panels PV are

Fig. 3 Spaces as "Ramblas", in Barcelona, are clear samples of mixture usage

a bioclimatic architecture will allow to reduce energy demand. If these principles are added others for reduce dependence on nonrenewable resources betting on alternative energy, we will getting a eco-efficient solutions.

E) Equipment and development must be concentrated in suitable areas.

An eco neighborhood should contain the basic equipment: schools, retail, healthcare and entertainment and all easily accessible.

3.2 Principles Related to Public Space and Biodiversity

Another of the elements that give character to the eco-neighborhood is the proper conception of public spaces and green areas as privileged scenarios for the life of citizens [5]. Attractive and safe elements should be designed, with diversity and variety and protected from inclement weather. Actions related to the integration of the neighborhood with nature are valued positively, through the design of river beds or green areas planned for environmental education (Fig. 4).

A) Public spaces and green areas.

Public spaces should be at the service of its inhabitants, shaping and organizing the network in primary and secondary spaces, adapting them to the public and how they become structural elements of social life.

Among the strategic objectives in the town of Pintana, in Santiago de Chile (Fig. 4), one approach to neighborhood improvement project taken from Vallecas boulevard of Madrid, has been the relationship between housing and space public reassessing morphological quality of public spaces and areas intended for increasing green areas. Emphasizes the neighborhood landscape attributes and reinforces your identity.

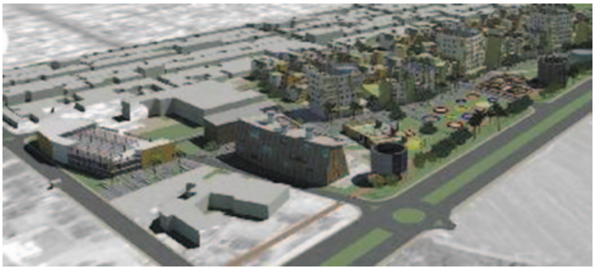

Fig. 4 Neighborhood of Pintana in Santiago

B) Trees in streets and squares.

Open spaces and green areas in addition to creating quality urban environments, interacting with other aspects of eco-neighborhood, become control elements of the cycles of energy, transport and infrastructure [7]. The trees on the streets can help the formation and creation of microclimates, regulating temperature, humidity and air quality, provide habitat for a diversity of plant life and animals and provide sensory perceptions (light, color, sound…).

3.3 Principles Related to Mobility and Transport

The activity often forces people to travel, these being the result of combining land use and transportation system characteristics. From an ecological perspective the priority is to minimize transportation needs, in the second site bet on non-motorized transport modes (including bicycle), third public transport systems and within these sustainable transport.

A) Accessibility for all, with short distances.

Returning to the principles of a sustainable approach in green neighborhoods must be created sheltered areas of road traffic and pedestrian character. Must to make a plan for parking, especially at the entrances to education areas, health and trade [8].

To achieve adequate accessibility should establish a spatial distribution of road traffic and pedestrian. For a model of mobility based on pedestrian and bicycle accessibility, it is necessary that urban design provides for a reduction of the distances through the diversity of uses and pedestrian road comfortable and safe. Pedestrian mobility requires a public space in which the scale and proportions of streets, buildings and places provide a human-scale character, and a high density which together with the mix of uses makes possible the close of office, retail, equipment, etc.

B) Lanes for pedestrians, bicycles and public transport.

In planning a neighborhood with ecological criteria, transport priorities tend to what is called "car-free spaces".This concept is used when the area set aside for parking of private vehicles does not exceed 20 % of users and residents. In these

Fig. 5 Bike lane

areas, parking is usually limited to the distribution of goods and emergency services. Priority is given to pedestrians and cyclists (Fig. 5) and car parks for users are at the edges of the neighborhood.

There are also so-called "limited traffic zones" and "traffic calming areas." In the first, reserve up to 60 % space for users, so there are not only restricted traffic to motorized users but also for residents, there are residential streets with limited speed and other traffic and no parking spaces are distributed in the district and its periphery. While in the second, all the streets are accessible to vehicles but limited speed, not being suitable for through traffic. The parking spaces are distributed, under a coat of ground or surface and at least one vehicle per household residents.

3.4 Principles Related to the Flow of Energy and Materials

Regarding the urban metabolism, the scale of the neighborhood is particularly appropriate to address resource management, which is one of the fundamental criteria of sustainable urbanism. In the neighborhood scale can be applied systems more controlled energy saving and renewable energy, water management and waste management and would enhance aspects of network maintenance. This management should introduce criteria savings and demand reduction, and ensure efficiency in distribution.

Unlike what happens in the buildings, which are more dependent on consumption by the users, the result values that are handled at neighborhood, have a decisive influence on the overall performance, especially in energy consumption.

To evaluate these aspects, the basic design principles should aim to bioclimatic aspects, energy management, water management and waste management.

A) A comfortable bioclimatically neighborhood.

To get a bioclimatic neighborhood is essential to integrate green areas and sports facilities including some agricultural areas.

And as for the aspects of proper management of energy, with proposals to increase the efficiency and integration of systems that would reduce electricity

Fig. 6 "Clovers"solar energy production in places of Seville

Fig. 7 Pipes for district heating cooling

consumption, and the use of renewable energy in urban facilities (Fig. 6), are basic elements for an ecological neighborhood

B) Planning the generation, distribution and energy consumption

A neighborhood scale energy management can arise even from the analysis of the generation and supply systems with a central character. The idea is that the neighborhood has a system of self-management in energy production.

In our studies we are investigating the possibility of creating networks of ecological energy production through micro generators, connected to multipurpose buildings (homes, offices and culture) so that the district is self-sufficient (Fig. 7).

For example, cogeneration is a technology that explains the concept of the high efficiency in the production of electricity and heating hot water and health [7]. It is also very interesting experience to have some ecological neighborhood integrated control network to control the consumption of all supply networks, in order to manage and meet ordinary consumption and analyze incidents and eventualities arising from such networks.

C) Reducing, reusing and recycling waste.

From the viewpoint of development, the waste management prioritizes the reduction thereof. The second step is the reuse or recycling, this second aspect requires consideration of the residue as a useful resource and we must encourage this attitude in the eco-neighborhood. In any case, good management of waste requires provide the necessary infrastructure, identifying the different types of waste and anticipate their possible uses.

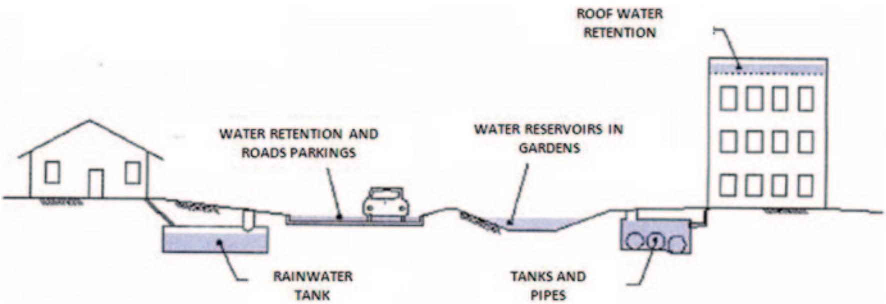

Fig. 8 Rainwater harvesting systems from integrated urban

D) Closed water cycle.

The available amount of water suitable for human consumption is limited still further distribution, very uneven. Therefore water must be rigorously managed and used effectively, especially in arid areas (Fig. 8).

Water management should include a series of concrete measures from natural water cycle in each geographic area: [9, 10]

- Measures taken to reduce consumption of natural cycle.
- Measures of treatment of waste water to re-enter the natural cycle.
- Measures to minimize disturbance of the natural cycle (keeping the levels of infiltration of rainwater into aquifers, using rainwater for use, etc.).

3.5 Socio-economic Principles

The green neighborhood implies a new relationship between citizens and their environment, both the responsibility and knowledge of the functioning of ecological systems and cycles, and especially in their decision to form a community, which implies an increase in their autonomy and probably a transfer of power by the administration. In any case, this transformation of the relationship between citizens and their environment will not occur spontaneously, so eco-neighborhood projects must include a plan for environmental education and encouraging participation. In this respect the eco-neighborhood, should be a model of sustainable habitat and cultural identity [11].

A) Neighborhood healthy, safe and sustainable lifestyle

For a socially sustainable urban neighborhood is necessary to improve the quality of life of its inhabitants, and that the environment is pleasant to live and visit. Could be necessary create programs of environmental sensitization to show of the characteristics of the management plan between the eco-neighborhood residents and obtain their cooperation to achieve compliance with the objectives stated therein [12].

Fig. 9 Socio-cultural activities in the neighborhood Los Bermejales (Sevilla)

B) Cultural identity and social diversity

Increasing opportunities for social contact and communication, and therefore the sense of identity with respect to urban space, creating the potential for organized social fabric and the exchange of information for decision-making, are necessarily aspects integrated into the concept of quality of life.

A neighborhood model as we are defining should facilitate social interactions, generating an increase in communication, which would facilitate an awareness of the community and the environment inhabited. This will create a community structure with its own identity and possible joint action. Also in an eco-neighborhood should promote direct participation of people in managing the environment through different mechanisms of participation, that the neighbors know what your neighborhood and how they can improve it (Fig. 9).

4 Conclusions

The proposed eco-neighborhood we have presented has been raised trying to expand the technical vision of planning to make it closer to citizens who feel the need to inhabit. In this regard we have considered the ecological neighborhood as existing city development and understanding your project with participation of the citizens who inhabit it.

From this perspective we believe that the eco-neighborhood can be an extension of rights and duties of citizenship, to include environmental responsibility and the necessary participation of citizens in their design and management.

Although the model we have proposed urban unit can theoretically be said already raised and know how to deal with emerging dichotomies to which we have referred, still lacking truly involving pragmatic developments administrations, researchers and professionals, as much remains to be done in the field of reality constructed and would be naive to circumvent it.

Although we are aware that eco-neighborhood bring technological innovations, we wanted to make clear his character transformer in the system of production and consumption and because existing urban developments that enable the generation of cities that must adjust their status through the recovery of the local versus metropolitan of organic versus the technocratic, participation against the will of others. In summary, ecological neighborhood should not be the exception in the city, but should be the model for the necessary transformation.

Therefore, our patent remains firmly in the immediate future goes through the transformation of cities from eco-neighborhood projects that as urban centers, is where the logic of the urban phenomenon. In a context of globalization, the process may seem the most relevant aspects of dealing metropolis, but in a vague and nameless field, environmental solutions must solve everyday problems of consolidated cities. In any case, there is a mechanical application of the principles we have stated and defended and, based on the eco-neighborhood, could generate ecoCities with a similar theory subsequently generating practical application. The challenge is to follow the map drawing among all urban sustainability to encompass the entire territory.

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Simulation of Energy Performance of Buildings: A Case Study in Prague

A. Martínez, I. Tort and J. Llinares

Abstract Energy used in buildings represents the largest contribution in Europe of fossil fuel use and emissions of carbon dioxide. For these reasons, and to demonstrate the need for sustainable design buildings, a study of a building has been made to analyze its original state (with no energy saving design taken into account), and to arrive to possible improvements to improve the energy efficiency. The objective is also to show the possibility to achieve comfortable buildings with a reduced amount of energy. To do that, the DesignBuilder software has been used to analyze a kindergarten located near Prague, Czech Republic. To begin, the building is sketched and simulated according to the current situation. Results show that the building needs to be modified to improve its thermal performance, because the indoor temperature should be higher in winter and lower in summer. Then, new solutions are needed to reach this objective, and a 2nd simulation is performed, which shows that the changes to the temperature control devices have worked perfectly, but the consumption is too high. In order to reduce it, the objective of the 3rd simulation is to prevent heat losses in the building.

Keywords Energy • Sustainability • Building Simulation

1 Introduction

The 160 million buildings in the European Union are the 40 % of primary energy consumption in Europe. Therefore, energy used in buildings represents the largest contribution of fossil fuel use and emissions of carbon dioxide. The building design must consider the energy saving aspects, for instance, by large windows facing to south (in the northern hemisphere and middle and high latitudes) for winter days the solar radiation heating spaces, using a thermal insulation into building surfaces, especially those parts of the thermal envelope of the building (roofs, walls,

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floors, etc.) to reduce heat losses, or installing solar panels to increase the independence of the electricity [4].

For these reasons, and to demonstrate the need for sustainable design buildings, a study of a building has been made to analyze its original state (with no energy saving design taken into account), and to arrive to possible improvements to improve the energy efficiency. To do that, the DesignBuilder software has been used.

2 Descriptive Report of the Building

The building is in Ruzyne, 17 km from the centre of Prague (Czech Republic), with average annual temperatures around 8–9 °C and continental climate. Winters are hard, with average temperatures around 0 °C.

The building is used as a kindergarten for 40 children. There is a big corridor with two elements at both sides, containing the classrooms, toilets, kitchen, teachers' area, etc. It also has a small basement with a laundry, storage, toilet and technical room.

2.1 Constructive Report of the Building

Table 1 Constructive description

Building units	Layers
External wall	Prefabricated concrete wall.150 mm
	Glass wool insulation. 180 mm
	Fixing metal element. 93 mm
	External ceramic panels. 30mm
Ground floor	Gravel. 150 mm
	Hard thermal insulation. 125 mm
	Waterproof layer
	Polystyrene layer
	In situ concrete slab. 180 mm
	Hard thermal insulation. 40 mm
	Mortar and Ceramic paving stone
	Plaster
Glazing	Double-glazing. 6 mm/13 mm Air
Flat roof	Gravel. 32 mm
	Filter fabric. 20 mm
	Roofing membrane.5 mm
	Light concrete min 2 %. 40 mm
	Two layers of Glass wool thermal insulation. 150 and 180 mm
	Steam insulation
	Roof structure

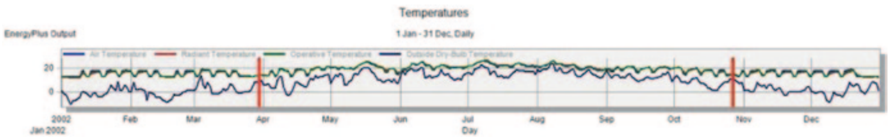

Fig. 1 Temperature results first simulation

2.2 Installations

The building is fully heated, with hot-water radiators in every room (37) and a piping system that starts at the shaft to rise to the ground floor and it's distributed to reach all the hot spots, with return path. There's no cooling system in this building, but a ventilation system is necessary to ensure air renewal, because natural ventilation is not sufficient. The pipelines begin in the basement and go up through the shaft being distributed along the ceiling too.

3 Energy Performance Simulations. Current situation

DesignBuilder is a software tool for high performance building design, simulation and visualization. It is useful for checking the building energy and comfort performance and delivers results on time and on budget [1].

3.1 First Simulation (Current Situation)

To begin, the building is sketched and simulated according to the current situation. Figure 1 shows the results of the simulation on annual temperatures, where inner temperatures appear to be too low: most of the year they are below 20 °C, and the average value is 18 °C, which is not acceptable at all as a comfort temperature inside the building.

Figure 2 shows the global consumption, divided into the different contributions, being the heat generation the greater value (105 MWh).

3.2 Discussion of Results (Current Situation)

Results show that the building needs to be modified to improve its thermal performance. The temperature inside the building should be higher in winter and lower in summer. Then, new solutions are needed to reach this objective.

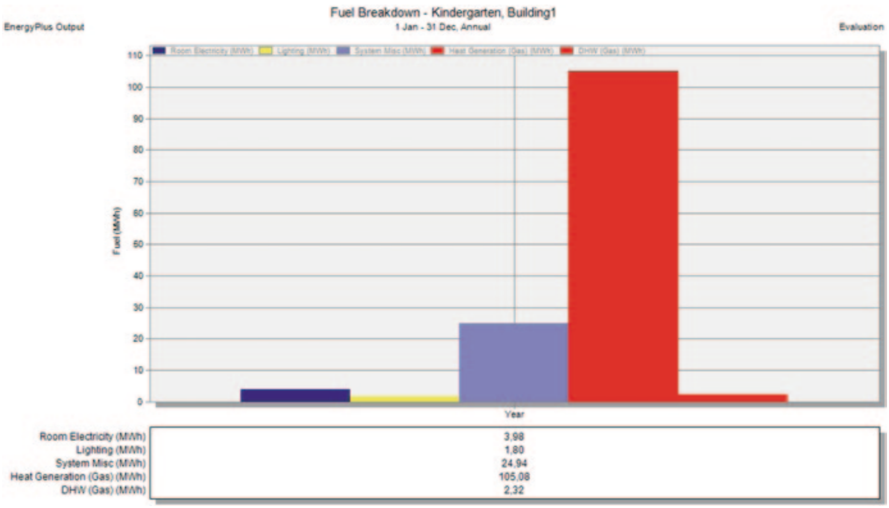

Fig. 2 Global results of consumption first simulation

Table 2 Changes in 2nd simulation

Simulation 1 (current situation)	Simulation 2
Wrong temperatures	Change inner control temperatures
Insulation of MW glass wool	Insulation of MW glass wool
Double blue glazing 6 mm/13 mm air	Double blue glazing 6 mm/13 mm air
Without cooling	With cooling

Table 3 Heating and cooling temperatures

Title	Simulation 1 (°C)	Simulation 2 (°C)
Heating	22	22
Heating set back	18	20
Cooling	26	26
Cooling set back	26	28

4 Energy Performance Simulation to Improve the Comfort

In the second simulation, the inside temperatures are changed and also a cooling system has been introduced (Table 2).

Changes made in temperatures are shown in Table 3. With these modifications in the control system, the building will have higher temperatures in winter and lower in summer, and also smaller variations between low and high temperatures. Obviously, the cooling system has been placed at this stage in order to resolve the issue of higher temperatures.

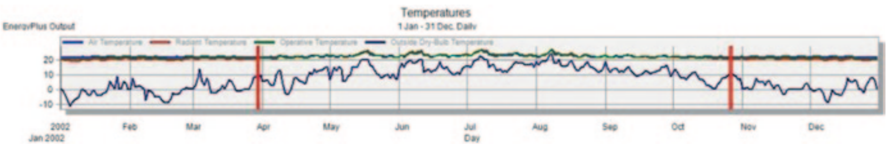

Fig. 3 Temperature results 2nd simulation

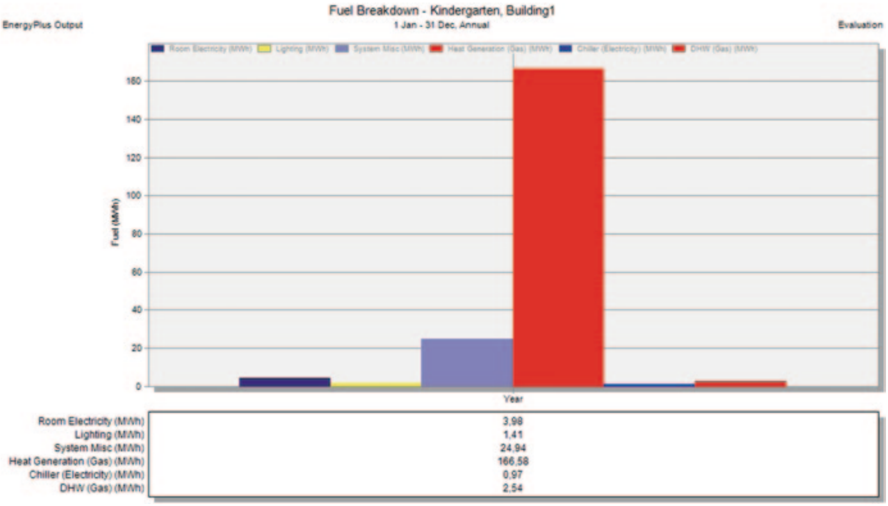

Fig. 4 Global results of consumption stage 2

4.1 Second Simulation

Figure 3 shows that, due to the new controlled temperatures, the variations in the inside temperature values have been reduced, and temperature stays around 22 °C during all the year despite the outside temperature is higher or lower. Regarding the energy consumption, Fig. 4 shows, as expected, that the heat generation requires more energy now than in the 1st simulation. Electricity consumption has also appeared in Fig. 4, due to the cooling system incorporation, but the cost is low because cooling is used only for a few days.

4.2 Discussion of Results. Second Simulation

The changes to the temperature control devices have worked perfectly: the inside temperature has been stabilized around 22 °C no matter the outside temperature. There are only a few days when the temperature is higher, but the range of variation is acceptable. The only drawback is the increased energy consumption due to the

Table 4 Consumption on simulations 1 and 2

Simulation	1	2
Consumption	105.08 MWh	166.58 MWh

Table 5 Changes on simulation 3

	Stage 2	Stage 3
Insulation	MW Glass wool 0.036 W/m.k	XPS Extruded polystyrene 0.030 W/m.k
Glazing	Double Blue 6/13 mm Air 2.665 W/m.k	Triple Clear glazing 3/13 mm Ar 1.62 W/m.k

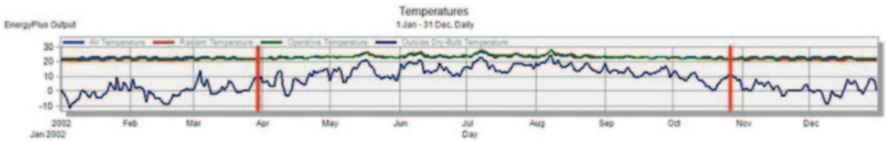

Fig. 5 Temperature results 3rd simulation

heat generation needs (see Table 4). Then, in order to reduce this consumption, the objective of the 3rd simulation is to prevent heat losses in the building.

4.3 *Third Simulation*

Suggested changes for this simulation are shown in Table 5.

Figure 5 shows that the comfort data are virtually identical to those calculated in the previous simulation, as expected, because parameters of temperature control haven't been changed.

Figure 6 shows that the amount of energy used for heat generation is much lower than on the previous phase: while in the two previous phases the energy for heat generation was over 100 MWh, this solution is around the 36 MWh.

4.4 *Discussion of Results. Stage 3*

The objective of this simulation was to reduce as much energy consumption as possible without losing the comfort parameters achieved in the previous phases. That was achieved improving the thermal insulation, reducing the thermal transmittance of glazing. Thus, heat loss of the building has been considerably reduced and the objective has been achieved.

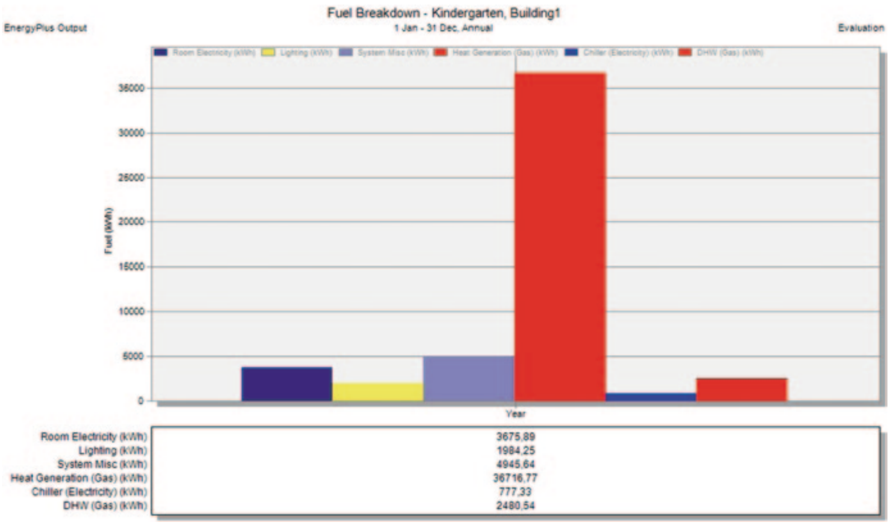

Fig. 6 Global results of consumption stage 3

Table 6 Annual energy cost

	Simulation 1	Simulation 2	Simulation 3
Gas consumption (KWh)	107,400	169,120	39,197
Gas cost (€)	4,436.37	6,985.84	1,619.11
Electricity consumption (KWh)	30,720	31,310	11,383
Electricity cost (€)	3.844.88	3,918.72	1,424.68

To sum up the results, Table 6 shows the annual energy expenses in the three simulations.

5 Conclusions

Comfort conditions are not guaranteed in the current state of the building. The 2nd simulation, then, showed an improvement in the indoor temperatures through the year. However, the building hasn't been design to keep these constant temperatures, so the heat losses were too high and consequently, the energy consumption as well. Changes in isolation are suggested in the 3rd simulation, and the energy consumption (and then, the cost) is reduced very considerably.

The objective of this study was to show the possibility to achieve comfortable buildings with a reduced amount of energy. According to the results obtained in a real building, this possibility is ensured, and we conclude that energy costs can be reduced keeping comfort, if buildings are constructed accordingly, and thermal conditioning systems are used responsibly.

The economic expenses are tremendously reduced when the thermal isolation is appropriate to keep the desired indoor temperatures, and this fact justifies in itself this type of interventions in existing buildings.

The experience of last years demonstrates that is not easy to change the building construction systems and its functioning. Routine and wrong habits regarding natural resources should be broken to achieve sustainable constructions [2, 3]

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Modeling and Simulation of History Museum of Valencia

A. Martínez Molina, I. Tort Ausina and J.L. Vivancos

Abstract This study reports the analysis of energy consumption of a historic building under a modeling program of Heating, Ventilation and Air Conditioning system (HVAC) to improve the energy efficiency of the building.

The building is a Museum located in Valencia (Spain), called "Museum of History of Valencia". It was built in 1850, constructed as a water deposit.

There is a need of maintaining the historical pieces under precise temperatures for proper maintenance regardless of the public who visit the building. In order to check the Museum's thermal behavior, the thermal characteristics have been analysed for a full year. The results show that the building behaves perfectly in winter and there are some too warm days in summer exceeding temperatures over 25 °C. In addition, the consumption data for the Museum's installations have been obtained and its analysis is shown.

Keywords Energy efficiency • Historical buildings • Simulation • Thermal comfort

1 Introduction

Often historic buildings have interesting and fascinating ancient technology, which is convincing by its simplicity. There are simple technologies like historic "box windows" which were opening towards the outside and allowing a natural ventilation when it is not windy outside, through the gaps of the window. Some researchers [1–3] have investigated an ancient natural ventilation system inside a historical building and have analysed the efficiency of this simple cooling technique, using a Computational Fluid Dynamics (CFD) transient simulation of the three-dimensional

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(3D) model of the building. One of the advantages of the 3D simulation model is the capability to analyse the development of the thermal characteristics of the building studied.

Maintaining thermal comfort is one of the most important aims of Heating, Ventilation and Air Conditioning (HVAC) systems. There are a large number of physical variables that influence thermal comfort. These variables include the temperature of the surrounding air, the radiant field around the person, the velocity of the air over the person, the humidity of the surrounding air, the clothing worn on the body and the activity of the person [4]. Therefore, thermal comfort evaluation has always been a difficult issue and is attractive to researchers. Thermal comfort models for the human body have been available for over 30 years as a result of considerable efforts in the 1960s and earlier to develop such models for military and aerospace applications. Currently, the most frequently cited thermal comfort standards: ASHRAE 55-2004 [5] and ISO 7730 [6] are both based on Fanger model, which solves the heat balance equations between human body and its surroundings represented as a uniform environment. On the other hand, for the purpose of improving energy efficiency and thermal comfort, asymmetrical thermal environments, such as formed by displacement ventilation (DV) or personalized ventilation (PV), have been developed in recent decades [7] and [8]. The distributions of the human body's skin temperature and sensible heat gain and loss in such environments are different according to the region of the human body. It makes the thermal comfort evaluation in an asymmetrical environment more complex than that in a uniform environment, because thermal sensation is highly dependent on local heat transfer characteristics. Hence, even though several limits have been adopted for asymmetrical environments in these standards, for instance, the vertical temperature difference between the foot and the head levels and the local draft that affected by local turbulence, the overall effects on thermal comfort combined with asymmetric radiation and local airflow cannot be properly evaluated. Meanwhile, environments are frequently transited too, for instance, the transitional space that defined as an independent dynamic space with different physical conditions. The Fanger model has been verified that it is not suitable to be used to predict thermal comfort in transitional space, because of its unstable and dynamic physical and metabolic rate value [9].

The main objective is to check whether the building's thermal behaviour is suitable according with European standards. This study has been developed through a deep research of the building characteristics and its environment. A building thermal simulation software as Designbuilder has been used to do that task.

2 Methodology

2.1 Building

The building analysed is nowadays the Museum of History of Valencia (MHV), but it was built as a water deposit in 1850, being a beautiful example of Valencian

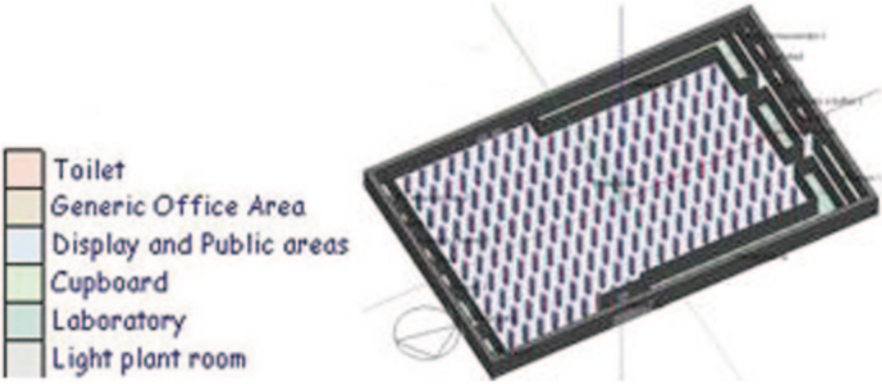
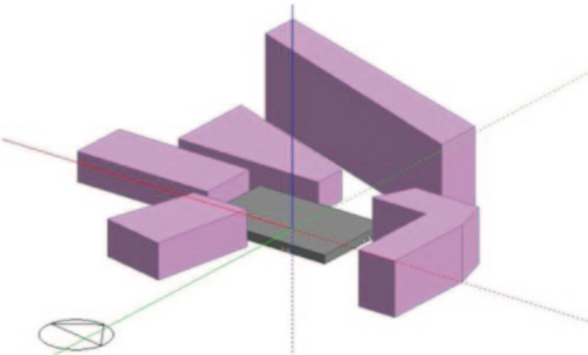


Fig. 1 Zoning museum

Fig. 2 Buildings in the Museum surroundings



industrial heritage, made of bricks and with large barrel vaults. It was refurbished in 2003 to host the Museum, and it has rectangular plant and one floor. The main access to the building is on the north facade (approximately 5° west from the North) and no separated spaces can be found in the interior (see Fig. 1).

Figure 2 shows a representation of the buildings, which are closer to the Museum, which have been considered for the calculations as shading elements.

The Museum of Valencia has 4 exterior walls and a large percentage of them are buried. But except for the north façade, they are all equal, have the same type of construction, materials and thicknesses. Therefore, there are 2 different types of enclosures to be discussed below:

Enclosures in contact with the outside air, oriented south, east and west (Fig. 3)

Main facade, oriented north (Fig. 4).

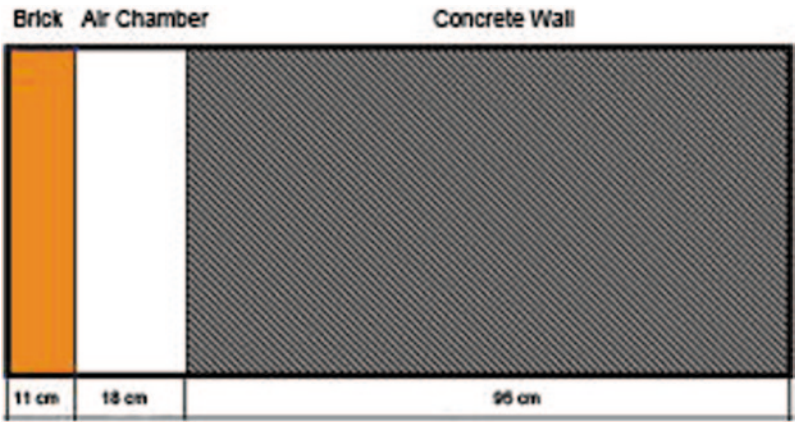


Fig. 3 Components of enclosures in contact with the outside air

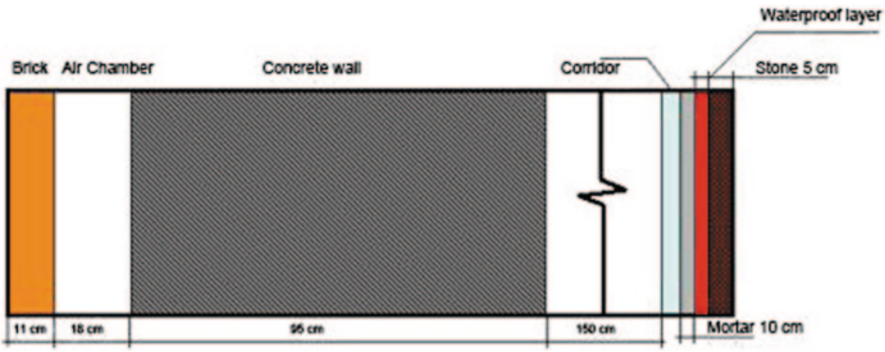


Fig. 4 Components of the north enclosure with

2.2 *Design Builder*

The software Designbuilder has different options of templates for the activity. The one chosen has been Libraries/Museums/Galleries which template has default values marked on the occupation, the use of Domestic Heat Water (DHW), air conditioning, ventilation, lighting, use of office equipment, etc. Therefore, those values have been modified to match with the parameters that actually the museum has. As the heating/cooling system use electricity as an energy source, there is no gas for the DHW, the lighting is faint to prevent the wear of historical documents and many other specific details for each area.

Table 1 Properties of the main front wall

Inner surface	
Convective heat transfer coefficient (W/m^2.K)	2.152
Radiative heat transfer coefficient (W/m^2.K)	5.540
Surface resistance (m^2.K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m^2.K)	19.870
Radiative heat transfer coefficient (W/m^2.K)	5.130
Surface resistance (m^2.K/W)	0.040
No bridging	
U-Value surface to surface (W/m^2.K)	0.511
R-Value (m^2.K/W)	2.128
U-Value (W/m^2.K)	*0.470*
With bridging (BS EN ISO 6946)	
Km—Internal heat capacity (KJ/m^2.K)	62.0000
Upper resistance limit (m^2.K/W)	2.128
Lower resistance limit (m^2.K/W)	2.128
U-Value surface to surface (W/m^2.K)	0.511
R-Value (m^2.K/W)	2.128
U-Value (W/m^2.K)	*0.470*

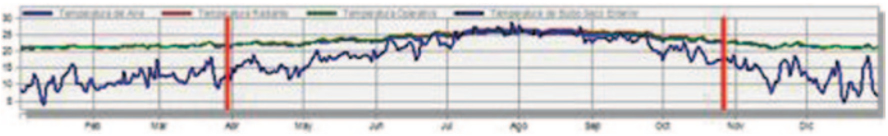


Fig. 5 Annual temperatures in the Museum

3 Results

Figure 5 shows the inside temperatures (light blue, red and green with overlapping lines) and outside temperatures (dark blue) of the museum during 2011. Red vertical lines separate winter and summer outside temperatures. For the following, any of the inside temperatures (air, radiant and operative temperatures) will be named as indoor temperature, because, as shown in the Fig. 5, values are the same for the three of them.

From January to April, the indoor temperature is around 21°, which can be considered a comfortable temperature for winter. From April to June, the indoor temperature is between 22 and 25°, and, still, these values are within the comfort conditions in summer. However, from July to September, indoor temperatures are higher than 25° which is, obviously, not within the range of comfort conditions. In October, the indoor temperatures are between 25 and 22°, and in November and December they are around 21° (within the comfortable range during this season).

The average temperature inside the museum is 23°, as shown in Fig. 6, and the relative humidity is 54 %. The total number of hours of discomfort is 886.19.

Fig. 6 Annual comfort data

The virtual fuel consumption of electricity of all audiovisual machines, lighting and air conditioning equipment of the museum throughout the year has been analyzed too. Lighting has high electricity consumption, since the light in the museum's opening hours is always on. Moreover, special light bulbs are used in order to avoid damages in the historical documents, and their consumption is higher than the one for normal bulbs. Following lighting, the miscellaneous system shows also a big consumption. This is because the museum has computers and machines (available during opening hours) that teach history virtually to visitors, and they have been taken into account for calculations. To finish, the museum climate control devices, in charge of cool temperatures and heating values, have a join consumption of 180 MWh, thus becoming the most consuming activity. The total electricity consumption of the museum in a year would be 481.35 MWh.

4 Conclusions

The thermal characteristics of the Museum of History of Valencia has been analysed for a full year. It is a historic building with very thick walls and a few holes that make it a good building from the point of view of thermal performance and energy efficiency.

The U-values of the walls have been calculated, being lower than the maximum U-values fixed by Spanish regulations (which don't apply to this building, due to its special historical characteristics).

On the other hand, after the analysis carried out over the monthly temperatures obtained inside the museum, we can see that the building works very well during wintertime and it slightly fails in summer, when temperatures exceed 25 °C. The main thermal advantage is its performance during cold months; it keeps the heat inside due to the wide walls and also because it is half buried. However, it does not happen the same during hot months. External conditions, as solar radiation, are influencing very much on it due to its unisolated and huge roof. These factors allow the increasement of inside temperatures.

The total consumption of the HVAC system, lighting and miscellaneous devices has also been shown, being the HVAC system the most consuming.

In addition, there are no big differences between simulation results and how the building works. Temperatures and energy consumption are very similar, therefore, the simulation can be valid.

Acknowledgements We would like to thank the collaboration of the *Museu d'Historia de València* and the *Ajuntament de València***.** The study shown couldn't have been developed without their support.

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Part IV
Heritage, Rehabilitation and Maintenance

Francisco Hidalgo-Delgado

Abstract The presentations cover various aspects related to the restoration of historic buildings or property. The life of their structures, the introduction of energy evaluation of restoration actions, the application and coexistence of new construction techniques with traditional, acoustic studies in adaptation to new uses, the study of rehearsal techniques employing as nondestructive ultrasonic testing and rational exploitation of tourism in these architectures, are topics of interest that are in the orbit of the actions of restoration and rehabilitation of our architecture. It is of great interest to know the experiences in all aspects referenced and certainly bring knowledge to specialists in this type of intervention.

The Time Variable in the Calculation of Building Structures. How to Extend the Working Life Until the 100 Years?

T. Cabrera, M. de las Heras, C. Cabrera and A. M. de las Heras

Abstract The idea that a building and consequently its structure is for a lifetime has stopped being a reference. CTE establishes that the life utility of a normal construction structure should be of 50 years.

If the time variable is introduced in the calculation of actions on structures, seems evident that different values can be used for a standard building, for a provisional structure with 10 years of life utility or for a monumental building with a life utility of 100 years.

The present presentation follows at all moment, the directives and formulations given in the different structural Eurocodes, till the moment not included in the CTE.

Finally the values of the actions that must be used to extend the life utility of a building until 100 years will be deduced, also it suitability and economic feasibility will be discuss.

Keywords Building structures • Actions structure • Time variable

1 Introduction

Since the publication of the Código Técnico de la Edificación (CTE) [1] in 2006, security in the evaluation of actions affecting the building structures must be done following the directives marked by the Eurocode [2].

In Europe the organization in charge of the standardization in the structure field is the European Committee for Standardization (CEN).

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Table 1 Indicative design working life (Eurocode EN-1990)

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures (1)
2	10 to 25	Replaceable structural parts, e.g. gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures
(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.		

CEN State members are: Austria, Belgium, Bulgaria, Croatia, Chipre, Cyprus, Czeecn Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Nederland, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey and United Kingdom.

CEN affiliate countries are:

Albania, Armenia, Azerbayán, Belarús, Bosnia y Herzegovina, Egypt, Georgia, Israel, Jordan, Lebanon, Libya, Jordan, Republic of Moldava, Montenegro, Morocco, Serbia, Tunisia, Ukraine.

The acceptance of an unify International regulation in the calculations of structures that reaches around five hundred million persons, got a huge importance both on a human scale and in terms of profession inside of what we designate as globalization.

The idea that a building and consequently its structure is for a lifetime, that is to say without temporal limit comparing it with the human lifespan, has stopped being a reference. CTE establishes that the life utility of a normal construction structure should be of 50 years.

In general the introduction of security in the actions of a building structure is achieved by multiplying its representative values with partial security coefficients named "γ" and combination coefficients named "Ψ".

The calculation situations covered by CTE and the Eurocodes, are three:

a. Persistent or transient.
b. Accidental.
c. Seismic.

If the time variable is introduced in the calculation of actions on structures, seems obvious that different values can be used for actions on standard structures or on temporary structure with a life utility of 10 years or for a monumental building with an agreed life utility of 100 years.

The present communication studies in depth the value of the actions that act on a structure according to the life utility it was initially designed for, specially when it is interesting that its life utility gets higher than the standard. The methodology used in this Communications follows at all moment, the directives and formulations given in the different structural Eurocodes, till the moment not included in the CTE. The quantitative importance of the persistent actions and the different variable climatic actions that act on a building structure, will be studied separately

2 The Actions on Structures and Their Combinations

The actions are defined as permanent (G), variables (Q) y prestress (P). For last limit stats (ELU) the following expression must be used:

$$\sum_{j\geq 1} \gamma_{G,j} * G_{k,j} + \gamma_P * P + \gamma_{Q,1} * Q_{K,1} + \sum_{i>1} \gamma_{Q,i} * \psi_{0,i} * Q_{k,i} \tag{1}$$

Where:

$\gamma_{G,j}$ is the security coefficient for permanent actions
γ_P is the security coefficient for prestress actions, if there is, $\gamma_{Q,1}$ is the security coefficient for the leading variable action and $\gamma_{Q,i}$ corresponding to the concomitant variable actions (accompanying the leading one)
G_k is the characteristic value of each permanent action
P is the characteristic value of the prestress action
Q_k is the characteristic value of each variable action and
$\psi_{0,i}$ the combination coefficient (simultaneity) for the concomitant variable actions (all of them well defined in the regulation)

When the life of a structure differs from the standard value, it is possible to act according to any of these options:

1. Define the different partial security coefficients γ according to the life utility.
2. Define the different combination coefficients $\psi_{0,i}$ according to the life utility.
3. Distinguish the different characteristic values of the actions according to the life utility.

The Eurocode is defined by the latter one and thus the guide of this study.

3 The Agreed Security in Structures (UNE-EN 1900)

In the calculation of structures and for its different last limit stats three levels referred to structural security are identified, these levels are:

- Level I: Semi probabilistic methods. Defined (in a structural code) by the characteristic value of the actions.

Table 2 Failure probability and life utility

Pf = Ø*(-β)	1,4 * 10 $^{-6}$	7,2 * 10 $^{-6}$	1,4 * 10 $^{-5}$	3,6 * 10 $^{-5}$	**7,2 * 10 $^{-5}$**	1,4 * 10 $^{-4}$
β	4,7	4,3	4,2	4,0	**3,8**	3,6
Years	1	5	10	25	**50**	100

Table 3 Design values for various distribution functions

Distribution	Design values
Normal	$\mu - \alpha\beta\sigma$
Lognormal	$\mu \exp(-\alpha\beta V)$ for $V = \sigma/\mu < 0{,}2$
Gumbel	$u - \frac{1}{a}\ln\{-\ln \Phi(-\alpha\beta)\}$ where $u = \mu - \frac{0{,}577}{a}$; $a = \frac{\pi}{\sigma\sqrt{6}}$

Probabilistic methods can be subdivided in two types:

- Level II: first order reliability methods called FORM. These methods make use of certain well defined approximations and lead to results which in most structural applications can be considered as precisely enough. This is the level at which our presentation will be developed.
- Level III. Fully probabilistic methods (exact probabilistic calculation). Methods at level III are barely used in the calibration of calculation codes due to the significant shortage of reliable statistical data.

4 The Probability of a Structural Failure and Rate of Reliability β

In proceedings of level II a measure of reliability is conventionally defined through the so called rate of reliability "*β*". Rate that EN 1990 relates with the failure probability "Pf" through the cumulative distribution function of the normal distribution function "Ø". Also incorporating, now, the structural life utility, to complete the information obtained from the values of Table 2.

5 Calibration of Characteristic Values of Calculation of the Actions

EN-1990 (Annex C.7) indicates the distribution functions recommended to modify the characteristic value of the defined action in a code, like CTE (Table 3).

6 Permanent Actions

We consider a permanent action for example an own weight G which follows a normal distribution. In this case we use de following formula:

$$G = \mu - (\alpha * \beta * \sigma) \tag{2}$$

When in the verification of the reliability of a structure an alternative period of time is used T_a in stead of the stipulated life utility T_d, then the value of calculation G must be determined through T_a instead of T_d. The characteristic value G_k of G is defined, for a permanent action, as its average value μ_G, that is to say:

$$G_K = \mu_G \tag{3}$$

The value of calculation G_d is given by the expression:

$$G_d = \mu_G - (\alpha_G * \beta * \sigma_G) = \mu_G - \left(-0.7\right) * \beta * \sigma_G = \mu_G * [1 + 0.7 * \beta * V_G] = G_k * [\gamma_G] \tag{4}$$

Where: μ_G is the average. σ_G is the standard deviation. V_G the variation coefficient (in statistics, the variation coefficient is defined as en $V = \sigma/|\mu|$).

$\alpha_G = -0.7$ is the sensitivity coefficient of G in the FORM method.

The partial security coefficient of G is defined by:

$$\gamma_G = G_d \; / \; G_k \tag{5}$$

After the expressions (ec.4) and (ec.5) we obtain:

$$\gamma_G = 1 + (0.7 * \beta * V_G) \tag{6}$$

With $\beta = 3.8$ and with a usual variation coefficient for permanent actions $V_G = 0.1$ then we have:

$$\gamma_G = 1 + (0.7 * 3.8 * 0.1) = 1.266 \tag{7}$$

EN-1990 increases security approximately a 5 % to consider the possible uncertainty of the model, then:

$$\gamma_G = 1.05 * 1.266 = 1.33 \approx 1.35 \tag{8}$$

That results to be the value recommended by en EN-1990 and CTE.

Now we will evaluate the security for a different period. In our case we will take the variable of time up to a century.

With $\beta = 3.6$ (100 years):

$$\gamma_G = 1.05 * (1 + 0.7 * 3.6 * 0.1) = 1.31 < 1.35 \tag{9}$$

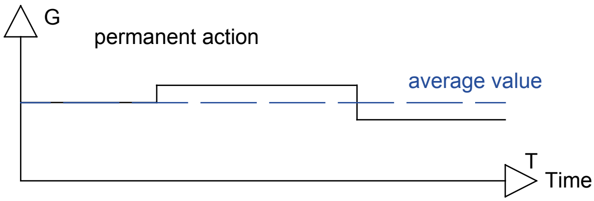

Fig. 1 Permanent action graphic

Table 4 Coefficients "X" of reduction for climatic actions $Q_{k, n}$ = X * $Q_{k,50}$"

Return period in years	Pn	Coefficient of reduction **X**			
		s_n	$v_{b,n}$	$T_{max,p}$	$T_{min,p}$
10 years	0.100	0.83	0.90	0.91	0.74
25 years	0.040	0.93	0.96	0.96	0.89
50 years	0.020	1	1	1	1
75 years	0.013	1.04	1.02	1.02	1.07
100 years	0.010	1.07	1.04	1.04	1.11

As it can be seen and contrary to expectations it results a smaller value than the previously calculated, with an approximated saving of a 3 %.

7 Variable Actions

In the variable actions with a return period different from the standard value of 50 years we will study the climatologically actions: snow, wind and temperature**.**

7.1 Snow Climatic Action

In accordance with EN 1991-1-3 snow loads, in Annex D, indicates that the characteristic value of the snow action $s_{k,n}$ for a return period f "n" years, is given by: $s_n = \boldsymbol{X} * s_k$,

Where:
$$X = \frac{1 - V\frac{\sqrt{6}}{\pi}\left[\ln(-\ln(1-p)) + 0.57722\right]}{1 + 2.5923V} \tag{10}$$

s_k, characteristic value of snow load for a return period of 50 years.

s_n, is the value of the snow load for a return period of "n" years.

p, is the probability of annual leave. For very small probabilities it is approximately equivalent to 1/n. Where "n" is the corresponding return period in years. (For example for $n = 50$ years, then $1/n = 0.02$ and consequently $p = 0.02$).

V, is the variation coefficient for the maximum annual snow loads. ($V = 0.2$ has been taken for the examples of comparison of the Table 4)

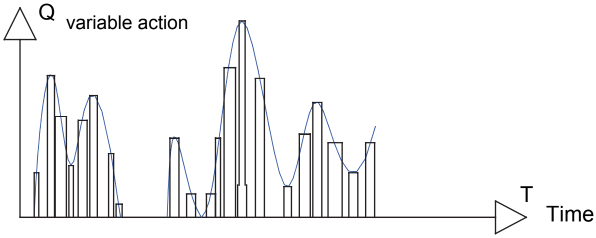

Fig. 2 Variable action graphic

7.2 Wind Climatic Action

EN 1991-1-4 Wind actions, indicates that the basic wind speed $v_{b,n}$ for a return period of "n" years *[not to be confused with the superscript n of the formula (11)]* can be determined by using the formula: $v_{b,n} = \boldsymbol{cprob} * v_{b,50}$,

$$\text{Where: } cprob = X = \left[\frac{1 - K\ln[-\ln(1-p)]}{1 - K\ln[-\ln(0.98)]}\right]^n \tag{11}$$

$v_{b,50}$ is the Basic wind speed for a return period of 50 years (average wind speed during 10 min. with an annual probability of being exceeded of 0.02, so to say $p = 0.02$).

$v_{b,n}$ for a return period of "n" years, p is the probability for $v_{b,n}$ to exceed the return period of "n" years.

According to EN-19991-1-4: The values of K can be provided by a national annex. (The recommended values by the standard are: K = 0.2 y $n = 0.5$).

For the examples of comparison (Table 4) it is consequently used: $K = 0.2$ (corresponding to the variation coefficient $V_v = 0.26$) and $n = 0.5$.

7.3 Temperature Climatic Action

According to EN 1991-1-5 Thermal actions in Annex A, indicates the maximum and minimum air temperature in the shade $T_{max}/T_{min,}$ for a return period of 50 years. For different return periods of "n" years:

$$T_{max,p} = X * T_{max,} \text{ for } X = \{k_1 - k_2 \ln[-\ln(1-p)]\} \tag{12}$$

$$T_{min,p} = X * T_{min,}, \text{ for } X = \{k_3 + k_4 \ln[-\ln(1-p)]\} \tag{13}$$

(Where: the equ. 13 can only be used if T_{min} is negative).

$T_{max,\,p}/T_{min,\,p}$ is the maximum/minimum of the air temperature in the shade for an annual probability of being exceeded "p" different from 0.02.

The recommended coefficients by EN-1991-1-5 are:

k_1=0.781, k_2=0.056, k_3=0.393
k_4=−0.156 (based on U.K. data)
p, is the annual probability of being exceeded for a return period of n years.

The summary of the reduction coefficients $\boldsymbol{X}$ for climatic actions (applied un such a way: $Q_{k,n}=\boldsymbol{X} * Q_{k,50}$ for the different return periods) Are summarizes in Table 4:

8 Conclusions

1ª The characteristic value of permanent actions can be reduced if the life utility of a building structure is estimated in 100 years. If the principle of prudence is applied this saving may not be considered.
2ª The characteristic value for climatic actions can be reduced when the life utility of a standard structural is shortened (life utility < 50 years).
3ª The characteristic value for climatic actions should be increase when trying to extend the structural life utility up to 100 years. In this regard, the increase of the standard values is very small: For the snow action the increase is a 7 %, while the increase for the wind action is a 4 %. The temperature effect in a building is unimportant, because structures are usually very protected.
4ª For the death loads the Eurocode has not established a formulation yet. Since we use agreed values, for example in a school 3 kN/m^2 in classrooms and 4 kN/m^2 in corridors and accesses, we should consider using them without changes.
5ª If we take the average value between the snow action and the wind action the resulting value is 5.5 %. If we evaluate that the joint action of both is less than the half of the sum of permanent actions plus the death loads, the economic overrun of taking the life utility of a structure up to 100 years should be less than 2 %.

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Assessment of an Energy Rehabilitation Cost on a Residential Block proposal. Analysis and Guidelines for Profitability Improvements

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Abstract Estimated cost of different building technology solutions to carry out a thermal rehabilitation in a residential block of flats is determined in this paper. In recent years the thermal rehabilitation improvements has been the result of the building repairs on facades and/or roofs due to pathologic process. Taking advantages of this maintenance works, the possibility of intervening on thermal materials and systems on the building envelope was presented. In this case the investment was the extra-costs that supposed the insulating materials only (differential cost). Nowadays the rehabilitation sector is growing up with the exclusive aimed to restore buildings considering energy savings. It is necessary to quantify the cost of this interventions motivated by the new regulation framework, to reduce CO_2 emissions and to certify existing buildings. The real cost of specific rehabilitation solutions and energy payback period is determined. The estimated annual savings of energy consumption is considered. The results may be useful for developing a framework that clarifies in which cases a rehabilitation of this type is worth.

Keywords Building rehabilitation • Energy rehabilitation • Cost • Profitability

1 Introduction

Until recently, the rehabilitation of existing buildings in Spain was defined based on the client requests, design and building structural aspects, that marked guidelines and execution budget of the construction. In these proceedings aspects of energy saving were contemplated occasionally, in which case they did not go much more than a carpentry change and a standard double glazing substitution.

The technical specialization produced from the building sector in last year, includes energy saving criteria, aspects unknown up to the moment and generate due to international agreements and European transpositions [1]. This specialization requires an assessment and a quantification of the different available solutions to rehabilitate the existing buildings.

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Buildings rehabilitation currently considers not only a replacement of damaged elements or equipment substitution, but a pathological defects treatment and the adoption of a solution that allows getting financial savings in the building lifetime, managing energy consumption and energy efficiency.

An energy-efficient rehabilitation will not that one that provides only the best thermal coefficients, or reductions in the energy demands. It will be the one that having the standards would be profitable for the owner and will be amortized over a reasonable time period.

Rehabilitation interventions don't finish just at the time of removing the scaffolding and concluding the construction completion certificate by the architect. They consider the all building period of live, like an energy consumption machine.

The origin of an energy building rehabilitation is based primarily on an energy demand reduction and secondly on an improvement performance of its equipment. All of this are due to the international worries of energy supplies, the interest of reducing CO_2 emissions from fuels fossil, the energy rising [2, 3] and the lower per capita incomes.

2 Objectives

This paper presents the proposals for an energy building rehabilitation based on energy aspects, acting on the building envelope with usually poor insulation material and important thermal bridges (Fig. 1). The energy savings are quantified under heating energy demand criteria acting in the passive building elements.

To quantify the effectiveness and profitability of the different solutions, the building technology characteristics of a residential building block are analyzed, defining a model with typical parameters of traditional construction built in Spain. The model was study with the LIDER tool, recognized document by CTE [4].

The building model data characteristics are: isolated block, ground floor +12 (two flats per floor), construction year: 1961–1980 and climatic zones: A3, A4, B4, C3, C4.

The building's energy demand for different initial constructive solutions is determined. The building technology systems are formed by:

- Exterior facade: cement mortar, ½ foot HD, muddy mortar, air chamber, HD partition wall, plaster.
- Facing brick facade: ½ foot facing brick, plaster, air chamber, HD partition wall, plaster.
- Non-ventilated roof: flooring, mortar, waterproof sheet, EPS 4 cm, lightweight concrete, wrought, cast.
- Ventilated roof: flooring, mortar, aerated concrete, brick board, air chamber partition walls, impermeable sheet, forged, cast.
- Carpenter: Aluminium TBB, PVC, glass—air chamber layer, low emissive

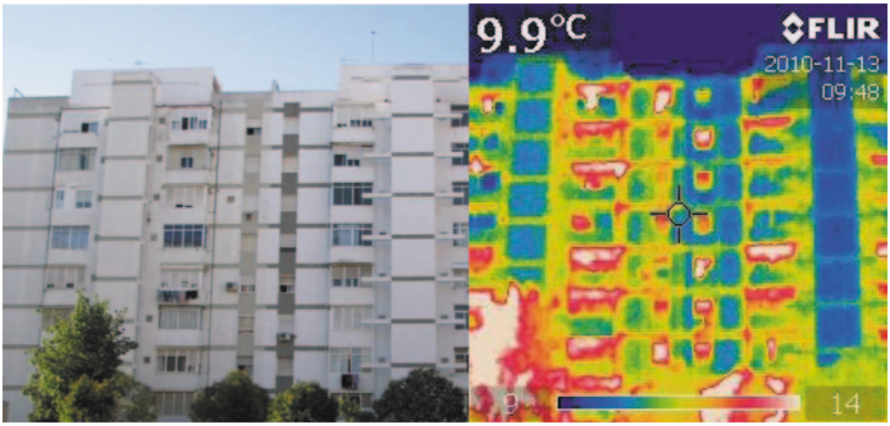

Fig. 1 Residential building of the analysis and thermography

Taking into account the different construction combinations and climatic zones tested, the results are two parameters that set the guidelines of the solutions profitability: the economic savings generated by each solutions and the rehabilitation total cost.

Proposals for energy building rehabilitation take into account facade, roof and carpentry interventions, on interior and external applications, considering different types of insulation material (polyurethane foam, EPS, poliyso foam, PIR, extruded polystyrene XPS, glass wool, MW; layers thermo-reflexive TER; polyurethane PUR; XPS + prefabricated concrete slabs, LP).

Also, a global intervention with an ETICS (external thermal insulation composite system) on facade with PIR, XPS on roof and PVC carpentry with low emissive glasses is consider (Table 1).

Considering all the rehabilitation proposals in the initial building model a total of 14 facade model types, 8 roof models and 4 carpentry ones are obtained. All of these for the five climatic zones defined. The combinations offer a total of 70 theoretical model in facades, 40 in roofs, and 20 in carpentry. The final results obtained produce results of heating and cooling demand.

3 Results

3.1 Assessment of Total Investment

The material execution cost has been determined based on different price lists of insulation and carpentry manufacturers [5–11], construction database prices [12–15] and materials offers by the year 2012. Due to the construction cost complexity and

Table 1 Rehabilitation proposals and results

		Intervention cost (€/m² of construction)	Economic save (€/year)	Amortization (years)	Differential amortization (years)
Cement mortar facade U-factor 1.27 (w/m² K)					
ETICS	EPS 5 cm	56.04	3,656.05	43.54	11.91
	PIR 5 cm	61.82	3,656.05	48.03	17.30
Internal surface	EPS 5 cm	30.19	2,910.32	29.46	10.39
	XPS 5 cm	32.10	2,932.11	31.10	14.00
	MW 5 cm	26.55	2,755.36	27.38	7.39
	TER 11 mm	31.03	3,728.69	23.64	9.90
	PUR 5 cm	26.04	2,905.47	25.46	6.36
Brick facade U-factor 1.31 (w/m² K)					
ETICS	EPS 5 cm	56.04	3,411.51	46.67	12.76
	PIR 5 cm	61.82	3,784.38	46.40	16.72
Internal surface	EPS 5 cm	30.19	3,053.17	28.08	9.90
	XPS 5 cm	32.10	3,077.38	29.63	13.34
	MW 5 cm	26.55	2,893.37	26.07	7.04
	TER 11 mm	31.03	3,888.49	22.67	9.49
	PUR 5 cm	26.04	3,050.75	24.25	6.06
Non ventilated roof U-factor 0.44 (w/m² K)					
External surface	XPS 7 cm	2.17	186.43	33.05	15.21
	LP (7+2) cm	3.34	116.22	81.73	24.39
Internal surface	EPS 7 cm	3.40	169.49	56.94	20.79
	MW 7 cm	3.07	164.64	53.05	16.84
Ventilated roof U-factor 1.22 (w/m² K)					
External surface	XPS 7cm	2.17	719.10	8.57	3.94
	LP (7+2) cm	3.34	588.36	16.14	4.82
Internal surface	EPS 7 cm	3.40	707.00	13.65	4.98
	MW 7 cm	3.07	690.05	12.66	4.02
Carpentry U-factor 5.70 (w/m² K)					
Aluminium + double glass		78.29	2,162.16	102.85	0.00
Aluminium + low-E double glass		80.50	3,389.72	67.46	1.85
PVC + double glass		64.83	2,370.38	77.69	0.00
PVC + low-E double glass		67.04	3,602.79	52.86	1.74
Combinated		125.25	8,353.24	42.59	8.67

variability is necessary to request budgets for each particular restoration case.To the rehabilitation cost will be necessary to add the extra maintenance works caused by the intervention, common in this type of installation. In the interventions on the building envelope the maintenance costs are lower.

There are economical support and incentives from the Government or energy entities that represent an investment reduction and they have to be considered in reducing the costs originally planned.

Having determined the energy cost of rehabilitation is necessary to determine the annual saving obtained with the energy improvement. These conclusions have been obtained as a result of the building parameterization with the LIDER tool, Ministerio de Industria [4]. The energy demands of heating and cooling in the rehabilitated buildings comparing the building model in values of percentages and kWh/m^2 are obtained.

From the data obtained, the annual bill considering an energy electricity consumption of 59.10 and a 40.90 % from other sources, using different conversion factors and energy price of kWh are obtained [16–19].

The amortization of the investment with these values are determined, also called period of return on investments.

3.2 Assessment of Differential Investment

Sometimes the rehabilitation works (the repair of building pathologies, structural reinforcement, damp, peeling walls, repainted…) are a good opportunity to provide the thermal envelope to the building and to substitute carpentry or some roof elements.

This is a great chance to reduce the cost of labor, auxiliary resources (scaffolding) and other derivatives costs (licenses, debris…). The disposal of insulation, which represents a minimal increase on the investment in this case, takes advantage.

To properly assess the return of an energy intervention in these cases, is necessary to consider the concept of "differential investment" as the difference of the cost of only the insulation solution from the initially global intervention planned.

The most common is that these interventions to improve the isolation resulting fromrepair of facades or roofs requested by the owners of the property, which is the time to raise the possibilities of placing insulation.

The "differential investment" will be the additional costs, both material, labor and accessories, exclusively associated with the insulation material. This differential shall be estimated to assess the profitability and amortization.

3.3 Assessment of Amortization

The most important concept to take into account is the amortization period in years, that relates the energy rehabilitation cost to the annual savings in heating and the cooling demands.

At this point we have valued the amortization of all the proposed solutions and the cost arising only the isolation material. This is defined as "differential amortization" with has got significantly lower values.

As an example, the Fig. 2 below gives the results of annual saving, cost and investment return in a C4 climate zone. This is the climate zone that offers the best investment ratios compared to other areas analyzed (A3, A4, B4, C3).

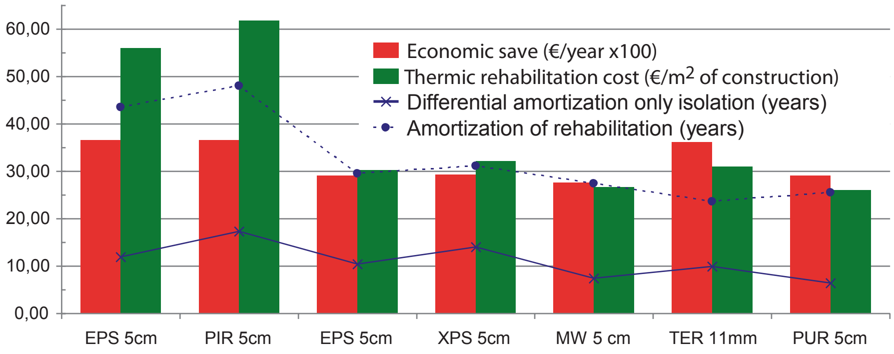

Fig. 2 Rehabilitation solutions mortar facades: economic saves and amortizations (C4 zone)

4 Conclusions

All the proposed solutions are an improvement of the building energy performance; some of them provide right amortizations, much lower than the building period of life.

Taking into account the repayment periods and the total investment it can be considered of interest the proposal of the internal reinforcement with prefabricated plasterboard on facades and the ventilated roofs improvement like the best options to adopt, initially with a very low insulation values.

The other studied interventions give results of high repayments periods, in which a specific study is necessary to carried out, assessing all the possible solutions.

On the other hand, considering only the value of "differential investment", all the interventions are amortized in an optimum period of time. The carpentry changes give an amortization period of 2 years that makes this option like one of the most profitable and currently driven by the local government aids. They are followed by the internal reinforcement of facades with an amortization period of 10 years and the ETICS one with around 12 years.

The global rehabilitation amortization is estimated about 11 years. In this case the cost is significantly higher, but the energy savings are too.

For a proper assessment of this amortization period is necessary to consider the savings generated in each year of repayment, which the best indicators are again the carpentry substitution, the facades reinforcement and ultimately, the roof interventions.

Anyway it is necessary to analyze each particular case in each climate zone, but it can be said that the optimum cost-efficiency criterion is to make use of other building works to introduce the insulation systems or carpentry substitution, and to reduce the costs through grants, local government aids, using "rehabilitation mortgages" and developing improving strategies to get better efficient buildings (Royal Decree in existing building energy certification) [1].

These passive rehabilitation strategies significantly reduce heating demands in existing buildings.

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Technological-Structural Analysis of the Preindustrial Buildings in Support of Their Recovery

Leonardo Giuseppe Felice Cannas

Abstract The *Recovery* of the pre-industrial construction is a process aimed at repristinating the functioning of buildings by adapting their performance to the more recent social needs, preserving, in the meanwhile, the cultural values that characterize them.

Historical buildings, especially "widespread construction", are in poor conditions because in the discipline of *Recovery* an effective and consolidated methodology has not been developed yet.

In the present paper the results of a research project undertaken in order to codifying of a more effective methodology of *Recovery* is presented: the *Technological Recovery* is illustrated, with technological features and structural functioning of the building as driving elements of the building intervention. Moreover the theoretical assumptions of the attempt to overcome the applicative limits through computer aided structural analyses and evaluation methods of the seismic safety of the historical construction is discussed.

Keywords Recovery • Technology • Structural • Seismic

1 Introduction

Among the hypothetical different of types of building works available on a historical building, ranging from *Restoration*, which aims at the maximum formal and material preservation, to *Replacement,* intended as demolition of the existing and construction of a new building, *Recovery* can be considered as intermediate between these two; it mainly operates to restore the functionality of the building according to the contemporary standards of quality and it retains all that is possible, from the technical and economic point of view, while it makes necessary changes, especially designed in order not to alter its historical—cultural identity [1].

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The process of *Recovery* is particularly suited to safeguard the "widespread construction" of city centres, that has undergone, and it is still experiencing, degradation more vigorously than the architecture of monuments. This decay is directly attributable to abandonment, improper alteration and lack of maintenance [2], and indirectly to a number of factors due to, in part, the inadequacy of the principles of the discipline of *Recovery.* At least in Italy, *Recovery* it is not able to widely spread in the cultural background of the technicians, it does not permeate the sensitivity of owners and managers, producing ineffective instruments for protection and promoting unsustainable or even harmful actions.

Therefore, the research aims at developing a fully satisfactory methodology for *Recovery* by revising and updating the state of the art, in particular taking up and developing the *Technological Recovery*, which is a particular methodology dating back to the 1980s of last century that was apparently shelved despite being particularly promising, with the help of today's computer aided structural analysis and recent theoretical innovations in the study of seismic behavior of historical masonry buildings.

2 The State of the Art of Recovery in Italy

Through an extensive bibliographic research, a synthetic picture of the state of the art of *Recovery* in Italy has been drawn. Four main schools of thought can be listed:

1.Town Planning—legislative current of thought It ranks buildings exclusively according to typological and formal features, often derived from weak historiographical assumptions [3]; for each building type more or less restrictive building works can be performed, appropriately coded a priori in a scale ranging from easy maintenance (minor repairs) to renovate (construction of a building partly or totally different from the previous one). This current, despite the appreciable effort to establish a control on the arbitrariness of recovery works, induces to give validity to a project uncritically just because it meets predetermined criteria that do not take into account the specific character of each historical pre-industrial artefact [4].

2.The Restoration current It provides that the historical widespread construction heritage is treated in the same way as for the restoration of monuments, formalizing the project on the basis of careful surveys and acting on a principle of strong conservative caution with respect to the materiality of the building [5]. This approach has the merit of placing the uniqueness and identity of the building at the heart of the project but it presents operating limits with respect to the quantitative dimension of the problem of recovering widespread construction [6].

3.The current of the Recovery Manuals It started in 1989 with the Manual of Recovery of the City of Rome. This methodology, just as in the *Restoration current*, places as the foundation of the project the in-depth knowledge of historical and traditional architecture, under the profile of settlement system, typology and distribution, but also and above all in terms of building materials and technological profile; at the same time it differs from *Restoration* because more pragmatically it accepts

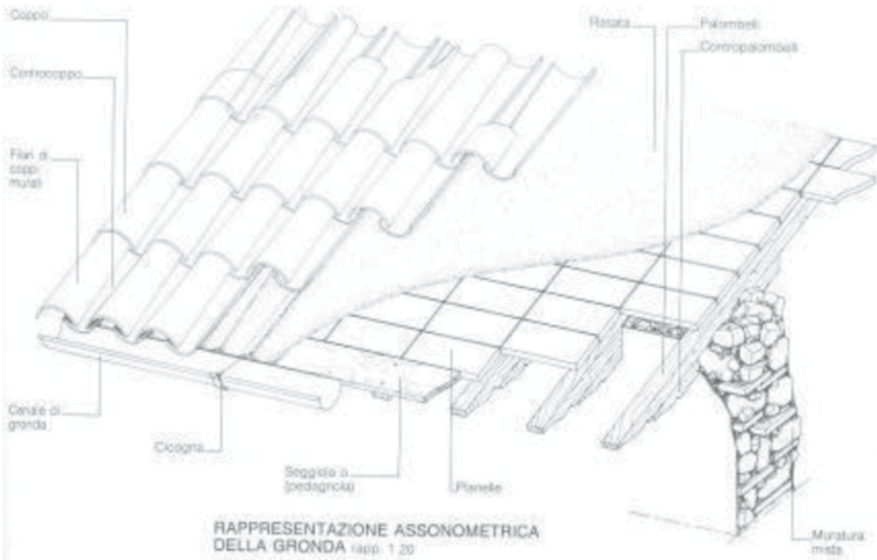

Fig. 1 Typical survey from a Manual of Recovery that are mainly focused on technological details of the building [8]

partial modifications and upgrades of the building, properly justified and implemented in close continuity and compatibility with the past manufacturing technology [7]. The Manuals can be regarded as a meeting point between the process of cultural rediscovery and of regulatory legislation, based not on rules but on suggestions, culturally and technically motivated, for the application of best practices, adapted to each specific context [7]. This method, while being more free from inhibitions than *R*estoration, keeps strong the instance of protection; is also particularly interesting the "teaching approach" of regulatory requirements, that appears on the latest versions about the regional context of Sardinia in which the reasons why the designers of *Recovery* should implement certain choices are discussed, involving them actively in the pursuing the goal of protection [7]. It is believed that Manuals have the defect to pay excessive attention to technical details (Fig. 1) while ignoring the most important aspects in order to pursuing the re-use, such as the understanding of global static functioning of the building, which is the primary function of each building according to the Vitruvian "firmitas".

Moreover, they seem to suggest implicitly, and anachronistically, the philological re-establishment of the building elements.

4.The current of Technological Recovery It is in many ways close to the *Current of Recovery Manuals* and is based on a principle of "reversing of the path design". In the *Technological Recovery* the characteristics of the building (typological—distributive, morphology and, especially, technological—structural) are the meter with which the designer chooses the uses adoptable through the recovery work. As a result these uses could be adoptable with minimal and compatible processing, contrary to what usually happens in the professional practice where the uses are aprioristically chosen, causing an heavy alteration on historical artifacts [9]. According to Prof. Galliani [9], the main theoretician of the *Technological Recovery*, the point that best defines the identity of a pre-industrial architectural artefact is the *structural design*, which consists of the logics by which the building fulfils the need to the requirement of "holding up": due to the configuration "in boxes" of historical buildings, where the vertical closures have the dual task of defining the spaces and support the loads, *structural design* combines in a unique concept all the conditions that create the culture of building of a certain place as the geomorphology of the site, the available building materials, the uses required by the civil society that are reflected in the spatial distribution [9]. A further fundamental concept is to taking note that historically the buildings have been changed, sometimes quite substantially (raisings, combinings, opening and closing compartments in walls), always using technologies consistent with the *structural design*, as if it were the equivalent of the genetic code for living organisms that grow and develop according to the instructions contained in their DNA [9].

The logical tool with which it is studied the *structural design* of the "organism building" is called *Structural Grid* (Fig. 2): this is a static working diagram, illustrated with an axonometric three-dimensional representation of the building, where only the components that perform load-bearing functions (whether they are primary, such as bearing walls, or complementary, such as bracing walls or ties) are indicated and depicted in a conventional manner as simplified geometric forms that conform to the prevailing dimensions (the walls and floors are planes, the beams are straight lines). This is a synthetic and analytical reading that produces a synthesis of the load-bearing framework of a building. The performer must, first of all, determine which elements actually play a leading role by synthesizing the information gained from a thorough survey [10]. These data be should refer not only to the geometric point of view but, above all, to the technological features that determine the static, such as, in general, the features of technological details (the thickness and assembly of the walls, the presence of chains and tie rods, the presence of discharging arches, the characteristics of the floors as the direction that the beams) and any signs of deterioration and static instability [10].

In summary, the *Technological Recovery* is a method whereby you can take action having as "limit" for changes to do not alter the *structural design*. Thus it is a versatile approach to improve the quality of living but, in the same time, it does not cause irreversible damages to the stability and identity of the building, embracing all instances of conservation of other currents of action but without being tied to cumbersome philological "iperconservative" settings.

3 The Technological Recovery: Merits and Limitations

The *Technological Recovery* was considered the most promising method to address the topic of our research, so it was decided to act operatively in order to obtain practical evidence about the alleged merits and possible limitations: the case studies

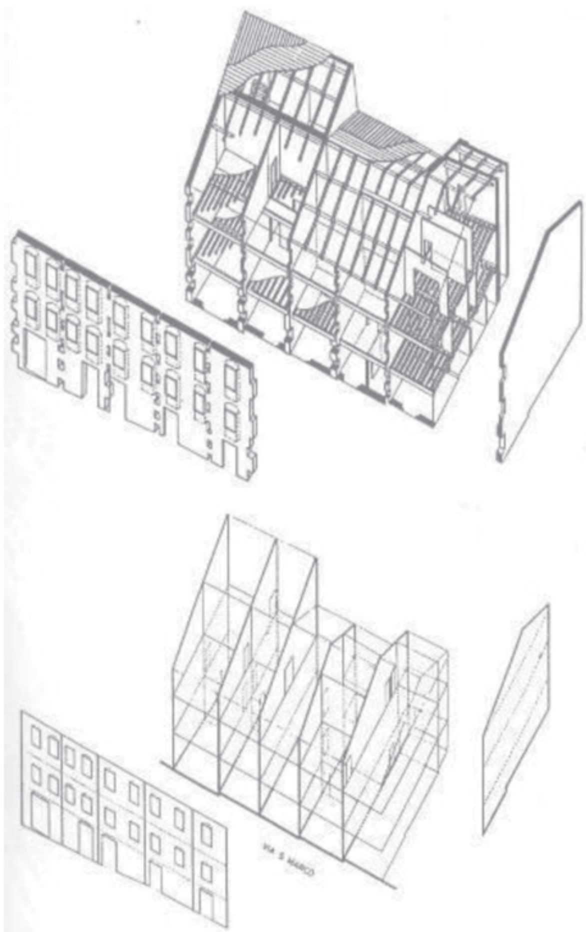

Fig. 2 Typical example of a *Structural Grid* that describe the structural functioning of some row houses in Siena (Italy) [10]

were identified in two historical districts in the city of Cagliari called Villanova (Fig. 3) and Stampace (Fig. 4), of medieval origin, consisting mainly of row houses, which present all typical signs of the decay of European historical centres.

As regards the positive aspects, the following step by step the drafting of the *Structural Grid* has a valuable educational value: it is a maieutic process by which the “precautionary” component of the project is enhanced, given that the technician retraces and embraces the process of construction and structural functioning, so he can take an informed decision on which actions are appropriate and do not cause further damage because they are framed within the *structural design.* Furthermore the three-dimensional reconstruction of the building, easily performed with modern modelling software, overcomes the limitations inherent in the two-dimensional representations and allows to immediately grasp the interactions between the structural components and the neighbouring buildings (such as the mutual contribution to the stability that it is established between the row

Fig. 3 The district of Villanova in Cagliari (Sardinia, Italy) [12]

Fig. 4 The district of Stampace in Cagliari (Sardinia, Italy) [12]

houses). A further positive point is the thinking in terms of compatibility with the *structural design* that actually legitimize actions in favour of habitability, such as for example the reconstruction of building elements with the latest technology (ventilated roofs), the exploitation of high volumes for inserting new structures and new equipments (mezzanines, false ceilings, floating floors), the designing of small openings to improve ventilation and lighting of rooms (skyligths, openings in secondary facades) [11].

The limits of the process refers to the arbitrary, qualitative and synthetic character of the *Structural Grid*, created with the intent to provide a connection between the pre-industrial building features and the modern professional culture of planners (derived from the logics of industrial production). It has the fault of leading to overly simplified and arbitrary readings of the technological-structural prerogatives of the historical buildings, closer to the working diagram of modern structural mechanics, characterized by a limited practical interest in *Recovery* because they intentionally do not take into account essential features of the building. The "modelling" of the static behaviour of a historical building is a very complex task, because it does not have a static pattern clearly subdivided into load and not-load bearing elements, and also because it underwent so many alterations in consequence of which new unexpected tensional stresses in its elements have arisen. Therefore, to avoid the risk that the *Structural Grid* is reduced to a mere abstractive and self-finalized exercise, this should not be considered as the final pre-planning process but rather as a component of an iterative process which is assisted and progressively refined by the computer aided analysis of the deformative and tensional status of the structure, such as the finite element method [13].

Taking into account that the structural calculation software are essentially based on models, which reveal severe limitations in estimating the actual behaviour of a historical building because they can not take into account all the infinite variables peculiar to pre-industrial buildings (one only needs to think of the difficulties in the attribution of a single modulus of elasticity to heterogeneous materials such as masonry), you can hypothesize it is possible to overcome this obstacle by considering appropriate parameters that take into account the uncertainty of calculations. The proposal is to borrow the approach of the *Confidence Factor* (CF), already implemented by the Italian and European regulations for the evaluation of seismic safety of existing masonry buildings, that is to decrease the potential capacity for resistance inferred from the calculation by the assignment of safety coefficients related to the *Knowledge Level* (KL) of the historical building obtained due to surveys [14]. The *Confidence Factor* can be a powerful logical tool for understanding the functioning and conservative status of the historic building because it systematizes in a tabular method all aspects of the building technology that define its carrying capacity, therefore it draws the attention of the designer on their identification and causes him to pass judgment on their quality.

4 Conclusions

The *Technological Recovery*, updated with the positive contamination resulting from computer aided structural analysis and the concept of the *Confidence Factor*, can be conveniently used as the basis for the preparation of handbooks to support the definition of recovery work on historical building, located in a uniform areal from the point of view of traditional building technologies: the *Confidence Factor* must in fact be shaped by a thorough study of the local building culture, so as to provide essential background information with which to make assessments, by analogy, of the role actually played in the hierarchical structure by the different building elements.

This need derives from the awareness that many aspects of the construction will not anyway be included in the calculation models, the results of which will necessarily be correct in a qualitative manner by the designer; furthermore, in the daily professional practice [15], for reasons related to the timing and economy, a reference text, didactic and easy to read, will be very useful to fully explain the behaviour of buildings belonging to the local building culture of the context in which one intervenes, for both the overall and individual construction details, in order to facilitate a sort of structural "anamnesis" of the particular case dealt with in turn.

The present research will continue in the future with a deeper study of the technological features of the districts of Stampace and Villanova, in order to better calibrate the parameters and the numerical factors of the corresponding *Confidence Factor* through a case study series as large as possible.

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Consolidation of Historical Masonry: Past Experiences and Future Forecast

S. Mora Alonso-Muñoyerro, A. Rueda Marquez de la Plata and P. Cruz Franco

Abstract In this summary of work are reviewed some construction procedures have been used "modern" techniques for plant consolidations traditional/historical, they could no longer continue to fulfill the function for which they were built.

After reviewing some background very representative application of those techniques, will travel significant historical examples and some own professional experiences. Ending with some intervention experiences outside the masonry, almost like a bright orthopedics, that maintain it just after knowing it but without interfering in their central core, with some experiences of Paolo Rocchi, Lorenzo Jurina.

The lack of knowledge, understanding and curiosity about traditional construction systems/history, its evolution and justification based on experience (trial and error), it is sometimes justified by criteria of building systems such as reinforced concrete and steel.

Keywords Consolidation • Historical masonry • Compatibility • Injections

1 The Problem: Pre-industrial Construction Versus Technologic Construction

Number of years have passed and many pages have been accumulated since it was believed that to preserve the monuments, you could "embalm" it with invisible injections.

Building operations highly mechanized, industrialized, that once be started, they could be repeated easily, in a period of time when labor reaches a large value.

The theory of architectural criticism directed towards the image, did accept without discussion technologies that were used indiscriminately new building systems and materials in the interior of old architectural members, while they were not warned and preserved epidermal appearance. Sometimes the original building

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would be reduced to mere scenery, while the experiences of traditional and "pre-modern" based on the maintenance, remain almost forgotten.

The fact that in recent times have been discussed frequently in the past the building systems (traditional/historical) with the logic of modern building systems of the twentieth century has led to problematic situations.

The recovery of material culture reassess traces that society has made its elements "manufactured" has renewed interest in the need to preserve the values visible and the hidden of old factories.

Some authors, as recognized as Paolo Marconi, Cesare Feiffer, etc., Have been contrary to those interventions that "introduce" a new structure in the "existing" not respecting the mechanical and constructive essence of the building, causing cracks, not only physical, between them.

With this writing and with the experience of some of my restoration works, we want to begin to give importance to the consolidation of historical fabrics in a similar way as they were built.

2 The Past

Modesto López Otero, in his speech entitled "Modern Technique in Conservation of Monuments") in connection with membership in the Academy of History in 1932, claimed that the history of conservancies is the history of construction resources.

For centuries the construction techniques and materials were not major changes, but in the nineteenth century, new techniques and industrialization, and its application to historic buildings, will pose different problems.

When the physical transformation of the original material made her unfit to fulfill the function for which it was intended in the building, the usual procedure was to replace it, or reinforme its surface globally or punctually.

The technique of concrete represent a contribution of capital importance, allowing even the conservation of the deformations and the "old" appearance of the elements (in support of boitiano speech), but with the contradiction of a possible replacement of the "structure" saving the "look".[1]

At this time starts blind faith in technology… and also in seeking solutions durability.

Since the consolidation surface treatments usually have used resins, products of petroleum distillation, etc., Other… For efficiency, the product should be applied after cleaning surface to reach the maximum depth and ensuring a great thickness of consolidated material.

This is in contradiction with the concept of patina, since the effectiveness of cleaning is the only guarantee efficient work.

This concept of consolidation, superficial, deep, structural… calls into question the issue of **reversibility** (one of the leading concepts of the Charter of the

[1] Brandi, Cesare. Teoria del Restauro. Edit Einaudi, Torino 1.977.

Restoration of 1972) since it is obvious that one of the highest aspirations of the products used, is its long life.

And its when the figure of the architect, must reach such an importance to be more than the technician or researcher who makes a perfect cleaning or applying coatings perfect.

It must be an informed professional, with overview, to see if there were the degraded material traces of old restorations, to put in front certainty about the original appearance of the item.

The architect must ensure the end result of a series of strategic decisions in relation to stratification, favor the original state or take a few mutations that deserve to be primed.

It would also question the problem of **durability** of both the products and the compounds formed by the material treated. In general, we have extrapolated the results of artificial aging cycles, in laboratories, but questionably extrapolated to natural aging, the monument in its environment, rather than depending on climate and.

We will not mention the problem of **compatibility**.

The architect may be the professional who works joining theoretical concepts and good practice.

3 Structural Consolidation

Spain has been a pioneer in the art of consolidation by injection, applied and/ or studied in the restoration of the Basilica of San Vicente de Avila (1889), Santa Maria de Castro Urdiales (1889) and the Cathedral of Seville (1890).[2]

In Italy, the interventions of consolidation through the technique called "cementazione" focus primarily on supporting structures in poor condition, but with important coatings can not be touched, like San Marco in Venice (from 1895).

Giuseppe Cygni, Sisto Mastrodicasa, Giorgio Torraca, Alfredo Corsanego, Cesare Feiffer, Paolo Marconi… address the issue of consolidating mixtures injections by gravity. In general, seeks to remake the internal continuity of the material and decohesiond figured. This aims to mixtures with elastic modulus similar to the factory to restore retraction solving the problem of uncontrolled compatibility…, which are the problems of low porosity and poor slurry permeability to water vapor, among others.

Ferdinando Lizzi, defends the shots under pressure, and mixtures (grouting) and internal pre-cleaning with water injection. And armed injections came….[3]

The "explosion" of the conglomerate under the pressure of rust, after being used in restorations, such as Balanos on the Parthenon, has highlighted the need for replacement.

We knew that nothing was safe and durable, which was searhed as those techniques of reinforced concrete.

[2] Fernandez, J. Proyecto de restauración de la catedral de Sevilla. 1.890 Archivo General de la Administracion. Alcalá de Henares.

[3] Lizzi, Ferdinando. "Static Restoration of Monuments" Sagep, Génova 1.983.

Some very representative historical examples of the use of armed injections we have on the Acropolis of Athens, the Aqueduct of Segovia, the Temple of Ceres at Paestum, and, in Spain, the church Alcocer.

Now, Korres and Tulipa do believe in the goodness of natural materials and traditional techniques.The most important thing is to find a compound with structural behavior "better" than the initial structure, due to the adherence of the injected malts, and fill the gaps and eliminate any discontinuity.

Will be necessary to study wall structures, although are difficult but not impossible to interpret. Teachers as Antonino Giuffre have begun to study the mechanical behavior of traditional/historical structures.

The culture of the overuse of technology (such as overuse of injections armed with steel mills to strengthen), has led to an impoverishment of the study and knowledge of the mansonry, "masonry culture", which has not been put into consideration, assuming it obsolete.

Injections are the result of a technocratic perspective which fetishizes technology, and excludes manual interventions, more craft, for economic reasons. The technique of injections armed, easily spread because it is considered very effective and relatively inexpensive for the results.

A major problem is the cementing material, either a resin or a cement mixture. Resins, which have had an elite market and are the result of the use of oil, are subject to doubts about the durability and irreversibility, being, as cementitious mixtures, virtually impossible to follow in his peregrinations through the masonry walls. Tomographic control is expensive and difficult, as well as indicating the discontinuity of the impregnation.

It could work well with hydraulic fluid injections mesh, if they cared the question of compatibility of the injected material with the mesh that this is going to saturate, the more the better affinity with existing compounds. Researchers such as Giorgio Torraca are studying the issue of mixtures based on natural hydraulic lime and inert timely characterized at low resistance, but able to mix the masonry.

There will always be doubts about the effectiveness static, of possible inclusions of rigid cementitious mass into different composition wall mass and stiffness. First of all: that the rigidity obtained leads to situations of fragility rather than ductility by altering physiological processes of formation of natural joints between mass and mass, and leading to further create joints and fractures in other hard to predict.

4 Conclusions

In my professional life I have chosen three churches to study, with different types of masonry and three tipes of intervention: cementitious injection under pressure, armed injection, and injections by gravity.[4]

[4] The monuments chosen were Santa Maria de Grujalba (Burgos), Nuestra Señora de la Asunción, en Villalba del Rey (Cuenca) y San Pedro de Arlanza en Hortigüela (Burgos).

My experience is that the more favorable response is obtained with injections under pressure. The masonry construction system based on two sheets with a central core, which mortar were dispersed, improved substantially, brought back to cohesion.

Other interventions such as the consolidation of the church of Collemaggio in LÁquila (Italy) after the last earthquake, tried to find "ortopedic" solutions, external to the historic construction. This masonry remains without changing its composition, which has a important documental value, supported by new elements.

Tourism and Architecture. Jørn Utzon in Majorca: Can Lis

C. Aguiló Ribas, M. J. Mulet Gutiérrez and M. Sebastián Sebastián

Abstract The architect Jørn Utzon arrived in Majorca in the 1950s, and some years later built himself the house known as Can Lis. It has recently undergone a careful restoration process (2012), which involved some of those who helped build his second Majorcan home, Can Feliz, in the 1990s. The Island Council is currently appraising Can Lis as a possible listed building, and the present article draws attention to its special value as well as the restoration itself. The Danish architect is shown as the exponent of a different kind of tourism to the usual package variety associated with the island.

Keywords Majorcan tourism • Utzon • House • Sandstone • Restoration

1 Jørn Utzon, A Tourist in Majorca [1]

Jørn Utzon (Copenhagen, 1918–2008) first visited Majorca prior to 1957, the year he bought a plot of land near Santanyí [2]. Many decades later this was where he constructed his second Majorcan home, Can Feliz (1994), while its 1971 predecessor, Can Lis, was built on the coastal cliffs of the same municipality.

At first Utzon was just another postwar tourist from northern Europe visiting one of the burgeoning Majorcan resorts—one more statistic in the phenomenon of mass tourism. In the end, however, his story turned out rather differently. He chose the island not only for relaxation but also as a place in which to live, remaining with his family over several extended periods. He came in the postwar years following a period of Majorcan autonomy, the high noon of Franco's dictatorship. As his daughter Lis has observed, the architect was already interested in the Mediterranean, but his arrival owed much to chance, possibly prompted by conversations with friends. He was one of many intellectuals and artists (Raoul Hausmann, Florence Henri, etc.) who, from the 1930s chose the archipelago as an ideal place for settling down to their creative lives and routines.

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2 Jørn Utzon, Architect

> The absolute essence of architecture can be compared to a seed, while one of its fundamental precepts must have something of the inevitability contained in the principle of natural growth. [3]

Architecture and nature are intimately linked to the person and career of this Danish-born architect, Majorcan by adoption and known above all for his Sydney masterpiece.

His work evolved out of a trend which developed originally in the Scandinavian countries, from Finland to Denmark: the New Empiricism, which involved a profound grasp of space, time and function in architecture. Drawing on surrounding natural elements as well as the specific requirements of the client, this "rational" architecture is designed both by man and for man.

The concept arose largely from the *Bygmesterskolen* ('Building Schools') established in 1911 by P.V. Jensen-Klint. These stood at the centre of a movement whose core principles were an awareness of materials, craftsmanship, and social responsibility. Its roots lay in vernacular architecture, while the movement's aim was to create a new type of architecture that revived the natural underpinning of traditional crafts, thereby "returning architecture to the people" [4]. Among the school's typical features one should draw attention to its interest in sculptural form, balanced textures, traditional materials, and the honest expression of all of these in consummate craftsmanship. Its goal, in short, was to reconcile tradition with modernity.

This is the professional background of Jørn Utzon, son of a naval engineer who at the age of 19 began to study architecture at Elsinore in Denmark. His teachers, as he himself pointed out, were Erik Gunnar Asplund (1885–1940), whom he considered "the father of modern Scandinavian architecture" [5], and Finland's Alvar Aalto (1898–1976), of whom Utzon remarked that "on seeing his works for the first time, I understood that architecture could be something marvellous" [6].

For Utzon an architect should feel completely at home with the materials themselves: "If we understand the nature of a material, its potential can be utilized far more effectively than if we simply rely on mathematical formulae and artistic forms" [7]. Materials, their colours and textures, the environment, and architecture's human dimension are the key elements out of which Utzon established order and harmony in his buildings.

From this theory, he elaborated two basic concepts: the platform and what he termed "additive architecture".

His interest in the platform derived from trips to Mexico during which he visited the pyramids at Uxmal and Chichen Itza in Yucatan and Monte Albán in Oaxaca. These Mayan structures became, in the architect's own words, "one of the most important architectural experiences of my life" [8]. The Mayas arranged and fashioned these platforms with great sensitivity to their natural surroundings, and based them on a fundamental principle: "A massive force radiates outwards from them" [9]. This idea of the platform is fundamental to an understanding of Utzon's stellar project, the Sydney Opera House, with its huge platform that rises out of the Australian city's bay, its roofs like gigantic shells with their curving spherical forms. The source of these roofs lies just as far from his native Denmark, and was clearly influenced by the overhanging roofs of the Far East. At Can Lis, Utzon's house on Majorca, we also encounter use of a platform, as it is also built on a podium.

The second concept that distinguishes his work is additive architecture. For Utzon, this kind of architecture is possible only by combining considerable knowledge of industrial materials with traditional materials and techniques. The concept was created during the process of reflection that followed his departure from Sydney. Disagreements during the third and final phase of the opera house's construction forced him to abandon this brilliant project, inaugurating a new period in which he immersed himself in a synthesis of geometry, modular architecture and standardized production.

The principle of addition is based around adding on different parts of the project in a unitary manner, while simultaneously allowing spaces to retain a certain individuality. In this way the architect is "able to respect and reconcile, without too much difficulty, all the demands of design and layout, as well as all the requirements for addition and change, since architecture, or rather building in its essence, is the result of the sum total of elements rather than a mere composition or something dictated by a façade" [10]. To carry out this theoretical concept, Utzon advocated systematic use of industrially produced building elements, as these "can be incorporated into buildings without having to cut or adapt them in any other way" [11]. Can Lis is again one of the best examples of this kind of architecture.

Utzon called himself a "builder", so his work is based on two core beliefs: construction and the landscape. In short, his architecture is one which combines the wisdom of the vernacular with the architecture of antiquity [12].

3 Can Lis

Between1971 and 1973 Jørn Utzon built his own residence on Majorca, Can Lis, combining two lots he had acquired some years earlier. The house is located in Porto Petro, in the municipality of Santanyí. This south-east part Majorca is known as the Colonia del Silencio.

Utzon here encountered the first of the elements typical of his architecture, thanks to one of the area's natural features: this was the platform formed by a cliff more than 20 m high, providing a privileged view over the Mediterranean [13]. The sea itself is the main protagonist, as the entire house looks out on it. This is achieved by following the principle of additive architecture, with the house created by connecting up five units strung out in an uneven line (Fig. 1).

Access is from the unit dedicated to the kitchen and dining room. Its U-shaped plan creates a large courtyard surrounded by a porch. To the west lies the simplest of the units, a small enclosed courtyard which contains a work table. Further east, the

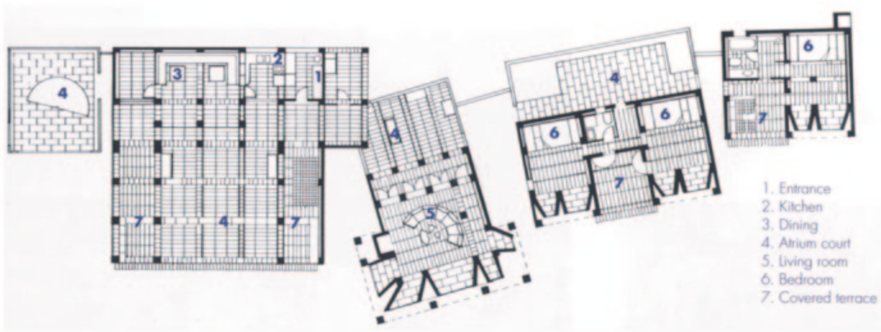

Fig. 1 Plan of Can Lis. STEN MøLLER, H.; UDSEN, V. *Jørn Utzon—Houses*. Living Architecture Publishing. Denmark. p. 140

house develops according to degrees of privacy: the next unit in sequence is devoted to the living room, and the two that follow are dedicated to bedrooms.

The building observes a regular constant of Utzon's work—adaptation to the site: this is seen not only in its organic and environmentally friendly outline, which reaches double height only in the living room, but above all in the use of local sandstone (*marés*) as building material. This abundant local limestone was commonly used for building on Majorca and Minorca, and is composed of fossilized sands which vary in grain, cohesiveness, and colour, albeit within a range of ochres. The stone is highly porous and only slightly compacted, factors which make it easy to work but also permeable and not very resistant to weathering [14].

In Can Lis, the *marés* was used both for the vertical structure of the load-bearing wall and also for inbuilt fixtures, surfaced with glazed ceramics. Pre-stressed concrete beams and ceramic ceiling tiles were meanwhile chosen for the horizontal structure. These elements remain wholly visible, as if the house was actually part of the cliff on which it stands, had always been there.

During the years Utzon lived in the house it underwent certain modifications. First of all, certain joists began to display excessive sagging, so pillars and beams in the living room's side units were doubled; joists on the side facing the sea were also replaced for similar reasons. The reinforced concrete in the single-bedroom unit had structural problems, so a new reinforcing pillar was erected in the centre of the room. The upper part of the walls, in addition, had problems with damp because sandstone is excessively porous and vulnerable to precipitation, as already mentioned. So traditional construction materials were again employed, in the form of a row of Moorish tiles placed along the walls' upper surfaces, without changing the flat roofs of the various modules. It was a natural response, spurning the slightest artifice, just like the house itself (Fig. 2).

The house survived in this way until the first decade of the 21st century. When Utzon died in 2008, Can Lis passed to his son Kim, who entrusted its refurbishment to the Majorcan architect Francisco Cifuentes. In 2011, although no restoration had yet been carried out, the house was acquired by the Jørn Utzon Foundation in

Fig. 2 Exterior and interior of Can Lis. Condition in June 2006

Denmark, which began a full rehabilitation project under the direction of the Danish architect Lise Juel (principal architect) and Francisco Cifuentes (associate architect).

This rehabilitation was completed in April 2012. It aimed to return the building to its original condition while also providing housing for young researchers and artists who had been awarded grants by the Foundation. The underlying premise of the project was total respect for the house and its craftsmanship, continuing the natural development it had witnessed up until then. To carry this out they contracted the team of Pep Monserrat, a local builder who had worked with Utzon on his second home, Can Feliz, in 1994. The work of the restoring architects' was based first on analysing the building first-hand and secondly on the experience accumulated by the team of builders. Their rehabilitation focused on eight particular areas:

- Structure. Deterioration was caused mainly by weathering due to the building's proximity to the sea. It was worse on the exterior and in the living room unit, which stands slightly in front of the others, and is thus less protected. Joists had been adversely affected by moisture, while the steel rebars had been corroded, resulting in breakage and loss of concrete. The least affected parts are sound, and after passiving the steel rebars with anti-corrosion materials, all areas where concrete had come off were replaced. In more serious cases joists were reinforced on their underside with stainless steel plates measuring 60 × 6 mm. secured with screws also of stainless steel. Finally, the joists whose rebars were completely severed were replaced by identical ones. This also applied to joists that had been folded back by Utzon in order to create a single beam.

  The sandstone (*marés*) had also been eroded by sea breezes, especially with the exterior pillars. Replacing fragments was only possible in the supports of the joists, and mortar filling was applied elsewhere. This was done manually, avoiding any kind of uniform finish in order to continue with the natural, almost spontaneous spirit that pervaded the original project. Various tests were conducted on site to make sure that the mortar's colour was similar to the sandstone in question, while the builders were supervised in order to guarantee, paradoxically, that the final look should be as imperfect as possible.
- Roof. There were only a few isolated problems due to broken waterspouts, which were all replaced.

- Carpentry. The doors feature traditional Majorcan shutters while the large windows have fixed outer frames and glass. Untreated pinewood was used for both, which has stood the test of time extremely well, and in only a few cases had doorframes in contact with the ground been attacked by moisture and fungi. It was thus decided to replace only the affected section, choosing a timber that was similar, even in its veins.
- Electrical installations. Due to the house's configuration electrical installations had previously been visible. The problem here was failure to meet current legislation regarding the size of cables and lack of grounding. In addition, plugs and sockets had become obsolete. It was decided to completely replace the system, maintaining at the same time the original concept. As Utzon originally opted for the simplest white plug, its current equivalent, also white, was selected.
- Bathrooms. The two bathrooms, one for each bedroom unit, were originally made of stone, just like the rest of the house. They were later fitted with ordinary white tiles. This covering has been removed in the latest refurbishment. Fittings, basins and toilets have been renovated to match contemporary requirements of comfort, while keeping the austere minimal spirit. To take an example, the showers have been refitted so that the floor itself serves as the shower plate. The project first of all envisaged adding a new bathroom to the dining room and kitchen unit, using the small room adjoining the dining room. This was the most significant change *vis-à-vis* Utzon's original scheme, but in the end it wasn't made, as there was no real need for it.
- Kitchen. Originally, the kitchen was separated from the dining room by a partition that served both as a shelf to store pots and pans, and when closed as a door. Both functions have been removed, as this situation was unacceptable by current performance standards. A compromise solution was chosen instead. The partition wall was rebuilt, but not up to the ceiling, and the door was repositioned. The location of the kitchen sink was retained, but it was replaced, as was the oven as well.
- Fixed furnishings. Not only outdoor benches and tables but also the living room sofa and table were made of sandstone with glazed ceramic surfaces and corners. Wear and tear had resulted in pieces becoming broken, and these have been replaced with the help of ceramicists such as Toni Cumella, who has a workshop in Barcelona. He provided items of ultramarine blue, no longer produced on the Island.
- Moveable furniture. The most significant change was the replacement of the four benches and two dining tables and chairs with a conventional table. The original furniture was made entirely of wood, except for metallic legs. Just one bench, which had been moved outside, had been preserved. The refurbishment saw missing furniture items remade and restored to their places alongside the surviving bench, so that the contrasting tones of both woods was clearly evident. In this way the dining room has become a visual representation of the tranquil coexistence of old and new, the basic premise of the recent rehabilitation project.

In this way Can Lis has regained its original appearance while being given a completely new lease of life. It is currently being examined with a view to being listed as a key part of the island's cultural heritage, a fine example of how contemporary architecture can be produced on Majorca which is in harmony with the island's traditions.

4 Concluding Remarks

Can Lis marked the return to traditional building in sandstone, which was abandoned during the 1960s with the adoption of rapid construction methods and the influx of foreign builders unfamiliar with local traditions [15]. The Danish architect's connection to the island has led to an initiative for recovering these traditions.

After Can Lis, Utzon built Can Feliz, his second home on Majorca, between 1992 and 1994. It features the same construction system based on sandstone load-bearing walls, although the house here consists of far more compact volumes.

The imprint of Utzon, above all his respect for sandstone, is undoubtedly present in current Majorcan architecture, both with regard to new buildings as well as renovations. Key examples include the flour mill at the Windmills Museum (Museo de los Molinos) in Jonquet (Palma 2002), carried out by Eva Prats and Ricardo Flores, and the new house Ca'n Bielet (Felanitx, 2008), designed by Carles Oliver, in which sandstone blocks were reused to build separate units serving as a garage and a workshop, adapted in this manner to Majorca's rural landscape.

Both of these embrace Utzon's notion of accepting the external factors of architecture which, in the case of Can Lis, were also responsible for most of its pathologies. Thus, apart from the miscalculations responsible for the excessive sagging in the gaps of the façade and a defective beam in the bedroom caused by a manufacturing error, the other pathologies were caused by its own environment. In the first place, the natural environment, with the humidity which corroded the joist rebars and encouraged the growth of mould in sandstone and wood, as well as sea breezes which eroded the stone. Secondly, the human environment which, with the passing of time and daily use made it necessary to renew the bathroom and kitchen and replace the ceramic pieces. These actions have been carried out with the same respect for building materials and the same traditional know-how that have allowed the house to survive as a living entity.

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Assayta District Hospital. Ethiopia. Maintenance, Rehabilitation and Building in Extreme Conditions

E. Castaño and A. Galindo

Abstract The Assayta health center, Ethiopia, has to be expanded and transformed to become the District Hospital. In this process, local authorities and a Spanish NGO are working together with the collaboration of some University researchers. The transformation process is happening at different stages: the first scope are the maintenance of existing buildings which show some damage, second, the rehabilitation of old abandoned barracks that will assume in the future new roles as medical visits, and finally the construction of surgery and motherhood buildings. All this intervention is being carried out by local staff with low qualifications, suffering high weather temperatures around 50 °C and located in an isolated region 10 h drive from the Capital City where the supplies are available. This paper explains how the experience was developed from the University researchers view, the conclusions reached and their possible transfer to the building scientific society.

Keywords Building in the desert • Maintenance in difficult access • Limited building • Low quality material • NGO promotions

1 Introduction

This communication shows the experience we gained with the building works in a desert area such as the Afar Region in Ethiopia (Fig. 1).

After the extensive work of the Amigos de Silva NGO in primary care in Assayta capital, one of the most barren regions of the planet, it was raised the need to rehabilitate the precarious health center buildings of the town. The purpose was to plan new buildings to transform the health center into a District Hospital building hosting 42 beds and another building with two theatre rooms for surgery purposes.

The interventions in its first phase performed the rehabilitation of the different premises already consolidated and tackle the construction of the first hospitalization building. Current situation is pending on obtaining further funding to continue

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Fig. 1 Assayta aerial view, in Assayta. (Ethiopia)

with two future specialist buildings, one for surgery and if possible other one for motherhood. The building working experience in this region has many differences with what we are used to in Europe, due to the limited circumstances of the place and conditions.

2 Construction in Extreme Conditions

2.1 Location

Assayta is a town located at the northeastern Ethiopia near Djibouti, in a quiet desert outside armed conflicts [1]. The population of about 25,000 inhabitants is composed of nomads who move around the desert area looking for water wells for their camels. There are few villages where commercial services, education and health care are concentrated, meaning the reference points in their annual exodus. The capital of the Afar region is Semera, an artificially and bureaucratic center located in the desert which plays the role of neutral administrative center between different nuclei dominated by different tribes/ethnic groups. Transport communications within the region are performed by road, the main one is the axis between Djibouti and Addis Ababa. Ethiopia does not have access to the sea so Djibouti natural port is making most of the goods that supply the capital city. The distance from Addis Abeba to Assayta is about 650 km but ten hours are needed to get there by car and 15 h by lorry due to the road conditions. This implies that it takes one day for each delivery to reach the place, since all specific provisions need to come from the capital city.

2.2 Environment Conditions

The temperature average during the day in Assayta is 50 °C and during the night that high temperature does not soften reaching even 40 °C [2].

Autumn is the storm season leaving sporadic rains that help watering the fields. During the summer, sandstorms affect the construction processes forcing to protect the buildings and decks from sand and preventing the blowing of roof pieces.

Near the city a river runs keeping its channel throughout the year but it does not flood enough the nearby meadows due to the hard ground so, in the area there is no productive agriculture. Economy and society is supported by camels and goat ranches [3].

The power supply of the city is obtained by means of large diesel generators, reason why the supply is very irregular depending on the stocked oil. In a regular basis there is electricity only 8–12 h a day, both during day or night. Only the bank, the hospital and some administration buildings have electricity supply guaranteed. In contrast, telephone line and Internet work normally thanks to the satellite systems.

The water supply is also unstable due to the dependence of the pumps that boost water into town. Therefore everywhere, mainly in the building work, the water is stored in tanks when the supply is available.

Given the high temperatures the thermal feeling is so suffocating, that it makes difficult to have a productive and continued work rate, only local workers are able to manage in that conditions. Thence schedules are settled depending on the weather, the journey begins around 6–7 am, breaking from 12 to 5 and finishing around 18–19 pm [4].

2.3 Building Materials

The structure is done using concrete made in place. Concrete and iron are brought from the Capital City, which means an important extra budget due to the transport and monitored storage costs that should be included.

For other materials needed on the concrete manufacturing, they are provided by the near environment as the sand coming from closed deposits and water obtained from the local rivers.

This makes difficult the concrete to be homogeneous as many different sources are used for the water and sand and depending on temperature and humidity environmental conditions

On the top of this no analysis is made on the sand quality or water [5–7], nor any breakage trials are tested on concrete samples

Fig. 2 Detail of concrete construction. (Photo by author)

Fig. 3 Detail of concrete construction. (Photo by author)

The foundation is done by means of footings made of big stones collected from the surroundings and compacted with concrete, where the starter bars are embedded. The rest of the structure is built with pillars and beams made of reinforces done in place and filled with concrete (Figs. 2 and 3).

Mounting the reinforced structure as well as mixing the concrete is all performed manually by low skilled workforce, thus the dosages and encounters are not well working, which requires quite often to redo the unions for best results.

The partition walls, both internal and external are done with concrete blocks done in a mold in the work, therefore the performance and quality are quite uneven (Figs. 4 and 5).

The electrical mechanisms and plumbing supplies normally come from Chinese manufacturers that provide very competitive pricings but poor quality. Mechanisms are usually spoil soon as they are made mostly of plastic.

When budget is available, it is well worthy to use European or American supplies; they are more expensive but more sustainable, especially considering the high temperatures and difficult maintenance of the equipment in such a difficult access region (Fig. 6).

Fig. 4 Block construction, detail. (Photo by author)

Fig. 5 Block construction, detail. (Photo by author)

2.4 Equipment and Machinery

Equipment and construction machines are rather limited and uneven. A shovel or a bulldozer could be rented for one or two days at very high prices to clear the ground and digging the foundation, although it will be required manual work and many workers to finish the cleaning of the land. The most sophisticated machinery we found is a cement mixer and a mold for the concrete blocks.

2.5 Health and Safety at Work

Working conditions are very rudimentary and no specific concern is done to protect the worker safety. As the number of workers is high, every day they are selected in

Fig. 6. Detail of water distribution pipeline. Photo by author

Fig. 7 Construction aids, ladders and scaffolding, in Assayta. Ethiopia. (Photo by author)

the marketplace to work on that day. Hopefully some of them will continue the next day, but they cannot afford to be injured. They work without helmets, they don't use gloves and often they are barefoot (Fig. 7)…

There isn't any metal scaffolding available and to reach the top of the buildings they use ladders made of logs tied with ropes (Fig. 8).

Material transport is performed manually without the aid of auxiliary means, except for small trucks made by hand as the image (Fig. 9).

2.6 *Project, Contracts, Deadlines*

The building rehabilitation does not require a specific project or technical professionals, though a short agreement is signed off with the contractor to establish the minimum terms & conditions.

Fig. 8 Construction aids, scaffolding, in Assayta. Ethiopia. (Photo by author)

Fig. 9 Construction aids, in Assayta. Ethiopia. (Photo by author)

To construct a new building as a hospital, it is required to open a public competition and select one of the three proposed offers as the most appropriated.

The selected contractors were sited in Mekele and Addis Ababa, both of them over 600 Km away from the site.

The three party relations between the Ministry of Health (building owner), Amigos de Silva NGO (promoter and budget execution owner) and the contractor are not easy due to the lack of understanding. Though the speaking language is English, the communication is not always smooth. Too many cultural differences make the process to be quite complex.

Here it should be noted that the Ethiopian health ministry orders the new building to the NGO that manages the whole project.

The designs are given always referring to a fixed model applied in other district hospitals in which the plan drawings are quite enough well detailed.

The technical work has to focus on revising the draft, redefining the project execution, performing construction details, and most over in the implementation monitoring, the technical and administrative issues and expenses control [8].

3 Discussion and Conclusions

Facing for the first time a building project in an underdeveloped country, the first intention is to transfer the knowledge acquired in your own country about construction and efficiency into the new intervention, but then you realize that this attitude is wrong because the circumstances are so different that it's better to assume that another way of building is possible and what it might be needed is to improve the systems used locally.

Building in Ethiopia needs to recover the old building manuals we used to have 40 years ago to optimize the most traditional means of construction.

The concrete blocks and the material loading are enough for the building and society needs in an area such as Afar.

Our mission then will be to optimize the implementation process and to improve the available resources taking into account the limited conditions.

Our work will focus on the study the details, redesigning the knots, analyzing the encounters, providing good solutions and easing the selection of working materials.

At this stage we are developing new building systems taking advantage of local sand and water, modifying the designs as long as possible to get cross ventilation, lifting the covers to leave the air run through it, but preventing from the storms.

In short, special attention should be given in placing properly not only the electronic mechanisms but also the water channels to be better protected from bad weather and to allow access in case of blockage or material breakage.

Finally the aim is to achieve the third building regarding efficient and sustainable criteria and improving the building infrastructure of the hospital complex. Due to the limited conditions of such an isolated area away from good suppliers, managing so rough materials and fighting against so extreme weather temperatures, the key is to obtain an architectural design that balances low quality of local material and manpower with sustainability and easy implementation building.

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Evolution of the Derelict Buildings from the 60's–90's with Change of Use: The National Dance Center in Paris

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Abstract The study of the causes which led to the abandonment of buildings built during the last generation, in the 1960's–1990's, show the different irregularities in this architecture. Based on these irregularities one establishes different ways to help and organize the decision making process for the possible renovation and reuse of these buildings. The National Dance Center in Paris serves as an example in this restructuring process. One studies the reasons for this derelict from the original building in 1997, which was built in 1972, under The Brutalist Architectural Movement and the restoration process to convert it into the National Dance Center. From this standpoint and the use of other examples, we will analyze the need and the restoration process that certain buildings undergo in order to be used for a different purpose. This process is efficient, profitable and conserves the unique features of the original building.

Keywords 1960 Architecture • Restoration • Upgrade • Change of use

1 Introduction

When one sees the demolition of a building in an abandoned state, which has been recently built one wonders why the building is in such a ruined state. Buildings are built to withstand more than one generation, with some exceptions, which can be grouped under ephemeral Architecture. A demolition is in one form or another something that is in very poor state or inadequately built. A building is not knocked down upon one´s whim, it is viewed as a punishment for something that is poorly executed, it is an eyesore, and it could also be a result of a disproportion.

Nowadays, we are dealing with low budgets and frugality. The present tendency of reducing costs and the decline of grand architecture is an advantage for public or private construction. Now is the time to value restoration and utilize what has already been built.

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Our self-generating culture tries to restore the works of modern architecture. It is clear that restoration and refurbishing is needed in ecological bounty; demolition is not a choice, buildings must be renewed.

2 Methodology

This case examines three different aspects: The first is the reason why the building is abandoned and its irregularities. The second is the analysis of the success or failure in restoration based on different buildings but mainly on The National Dance Centre, main objective of research of this thesis. Finally, one draws conclusions offering different approaches which, at the same time, are possibilities of action that can be really useful in the restoration of already existing buildings regarding the last generation´s Architectural Heritage and to achieve the renewal of the most important buildings.

3 A Reference Point, the Pantin Administration Restoration for the National Dance Center

The National Dance Center, which is considered to be part of the Brutalist Architectural Movement, is a perfect example of the precision in how restoration on buildings between the 1960's−1990's has been carried out. The building was abandoned at the time and it was built in 1972 as an Administrative Building for The Town Council in Pantin. It had remained unused since 1990 until it was converted into The National Dance Center. Taking this into consideration, we seek to find the real argument reformation or building renewal gives and thus, support our hypothesis in this thesis. A positive outlook is needed in the renewal process.

3.1 The Original State, Administrative Center in Pantin

The project to renew the building was originally brought forward in 1964 by the architect Jacques Kalisz [1]. He worked on AUA (Atélier d´Architecture et Urbanisme) [2]. This architectural study has great influence in France, it brought numerous collaborators together who were involved in the massive construction and examination of problems in urban development. Their projects were closely related to the urban development during this period in France. It was characterized by the "villes nouvelles" construction; they concentrated on the public and social facilities of the left-wing population on the outskirts of Paris. In 1960, Jean Olive, Pantin's Communist Mayor appointed Jaques Kalisz and Jean Perrotet to carry out the construction on The Administrative Center in Pantin, the most important public work in the municipality.

It is likely that a set political and ideological situation gives way to this type of construction. The political and ideological decline in the coming decades ruins the validity of the building.

The architecture is compromising and looks to answer the user's needs by applying an understandable, subtle, simple, but uneven approach. Brutalism is used and it is based on reinforced concrete and for its great use in volume and geometrical grids.

Pantin's Administrative Center responded to an extensive program that consists of approximately 20,000 m^2. Different public services are grouped together: the police station, the treasury department, social security office, employees' restaurant, parking and diverse administrative services. These public services are divided into four floors with parking in the basement.

The building is completely made out of reinforced concrete, on site and prefabricated; it is recognized by its geometric façade and the huge central atrium with interior staircases and ramps. It is also distinguished by its amplitude, the intensity of its light, which is continually changing.

The building recalls The Proletarian Utopia in France, Kalisz planned to make a working class palace which served the people. The staircase and the entrance ramp ascend through the entire building, giving different views of its grand interior. The height of the rooms is a rarity in architecture and the interior is finished with concrete adornment.

When the Proletarian Utopia declined and Pantin's inhabitants stopped viewing the building as a public administrative monument and began to view it as just another administrative building, the decline began.

The building was under development without focusing much on its technical aspect; it was converted into an architectural work of art. However, it was impractical as an office building and besides, it was difficult to maintain. Although it was valued for its ingenuity and ambition, it was neglected in its time and remained in an abandoned, disastrous state. It had many functional problems, which made the original purpose of the building useless.

3.2 The Key Points of Success- National Dance Center Conversion

In 1998, the Pantin municipality sells the building to The Ministry of Culture for the symbolic price of one franc. The Ministry of Culture attempts to convert it into the national Dance Center. A strict contest was organized in 1999 and Robain and Guiesse architects [3] won. The contest was organized so that the changes which were to be made to the building were not dramatic, so that it be adapted later to possible future changes. It is a three- part plan due to financial reasons and to make certain that the new use of the building is adequate.

A symbolic building neglected for years, proves that the conversion is a perfect strategy for the conservation of Architectural Heritage.

Its conversion responds favorably to the possible causes of its previous instability:

Management and Ownership The change in management and ownership of a building is significant. At the same time Pantin starts being part of Paris, the ownership passes to The Culture Ministry. This change allows the building to acquire a new perspective that is more realistic than the last. As the Central Administrative Building has no use, a new Parisian period starts. The management is prudent and reformation is planned backwards in case things do not work out as planned. The fact that the building process has completed the three steps shows that it was successful.

Change In usage, renewal process The conversion of this building, originally an administrative building and afterwards a dance center, did not need to undergo many transformations because the original building adapted ideally to the new plan. The change in usage brought the building back to life. Today, The CND is a considerable achievement for Pantin, when a few years ago it had been considered a curse. The CND is an institution which is dedicated to the choreographic development and dance. The new modification of the building is naturally suitable for its new function. It seems as if the atrium in the entrance with its staircases and ramps had been previously pondered upon to represent a piece of choreography as you enter the dance hall.

As a result of this reformation, new pride is renewed after all the neglectful years.

Image and Architecture The architect's merit in converting the building emphasizes the exterior and spatial beauty of the original building and also integrates the use of new technology without any difficulty.

Each generation changes; though the original building was mainly executed by Jaques Kalisz and Perrotet, except for the structure which was designed by an engineer, the reformation was achieved by numerous experts of complementary disciplines: lighting, acoustics, graphic design, furniture …

A constant factor that is maintained while restoring the original building is the architect´s dedication and care. Although the resources change in the second intervention, hard work and determination remains the same. It may be one of the major concepts to successfully finish the task.

Robain and Guiesse architects define the ideas of their intervention in their report, they were willing to keep the building in its original state even though the building's new use would change drastically.

Originally the building just overlooked the street but now, thanks to a transversal axis, it also looks out on the canal. This intervention provides the central space with a new light and a new dimension. A new internal façade ranging the height of the building has been designed. It is a wall made of red stucco which can be considered the symbol of the dance institution. This wall hides the entrance to the dancing halls but it also holds the installations and the pipes. The old cells, built around the yard, have been turned into changing rooms for the dancers. The yard, which used to be uncovered, has been roofed creating thus a private atrium for the use of the dancers, the staff and the visiting dance companies.

Both the old concrete partitions and the new installations are kept uncovered. Most of the walls remain untouched with just some minimum interventions as, for example, the ones made in the offices where the concrete walls are partially covered with plasterboard, which allows us to see what the spaces were originally like.

The classrooms or dancing halls, eleven in all, fit in the existing volumes respecting the original concrete walls without almost any change except for the requirements of the acoustics which demand concrete inserts in some of the walls in order to preserve a perfect sound.

Techniques The structure and concrete façades pose a great threat to deterioration. Concrete restoration was the prelude to other types of interventions in the building.

The concrete panels have been meticulously and precisely restored in the facades. These panels, just 8 cm thick, suffered from different pathologies. The remaining parts were cured and the missing parts rebuilt keeping the same color and aspect. After removing the defective and damaged parts, the concrete was treated with a superficial technique “gommage” which revealed the areas which had air bags. An antioxidant product was used to treat the pathology in the long term all over the building. They tried to reproduce the original material which varied from smooth to grainy depending on the different parts of the building. After several trials they decided to use three different types of mortar. This phase, in which concrete was treated, lasted for twelve months and restored the visual appearance of the building in the city.

The second phase consisted of adapting the facades to the new use and of protecting the edges of the concrete panels by means of small settings. An exogenous material, anodized aluminum, was used. Some of the openings are covered with opaque panels. Mobile vertical blinds are installed in the dance halls which overlook the canal. However, opaque fixed panels are installed in the side that looks out on the street as well as in the coffered ceiling and in the concrete panels. The glass walls are changed by extremely thin facades and by standard aluminum frames.

The new intervention, for example, is so discreet. There are few changes in the physical aspect of the building. Some doors, shutters, and small features have been added. These features do not represent a style themselves; they are only tiny details that were added. These elements are made with aluminum in its natural state and fits perfectly with the concrete and at the same time contrasts with its massiveness [4].

The most difficult task was the installations, which in this case was even more difficult due to the type of change in usage. For example, the dance halls needed acoustic isolation, which was not planned in the original building. Working with the acoustics on bare concrete, is not easy. If dance and music are added to the process the problem becomes even more complicated. The building has been executed using really thick walls and concrete frameworks which are interconnected, and are the cause of serious problems to the acoustics, especially in the adjoining dance halls. The solution was to install floating floors and rearrange the classrooms according to the degree of isolation needed, but trying to keep the maximum amount of concrete on the walls and ceilings.

The concrete volume made up of beams, framework and walls besides the required installations: isolation, acoustics, electricity, illumination, etc., is systematically uncovered. The walls remain practically untouched apart from the isolation coating which, on the other hand, always reveals the concrete volume and its sculpted geometric designs. The coffered ceiling is covered by fiber cement and wood panels. The glass facades and the mirrors are hidden behind light color curtains which contribute to preserve the acoustics. The original double floor, which provides a space of 50 cm. between the two floors, permitted to install floating acoustic floors on top of springs, solving thus the problem of sound transmission produced by the dancers' jumps, as well as keeping the same height for both the corridors and the dance halls.

Illumination deals with shading and light concepts. Emphasizing the concrete is not the main goal of the restoration so the architect tries to illuminate the contents of the rooms rather than the rooms themselves.

Changes in location In The CND case, location has been an important factor. In only one generation, it came from being a suburb to being the city center. Pantin's municipality evolves parallel to Mitterand's great works in Paris. Mainly the La Villette development [5], a neighborhood next to Pantin, which came from being a degraded area filled with abandoned warehouses to being a tourist attraction. The reformation of its warehouses, creation of a park, the construction of a science and industrial museum and also the upgrade of the L'Ourq Channel is the reason for its success. This reform around the borders of the channel spreads throughout the belt of the city and reaches Pantin. What had been for years a common and nearby suburb to Paris in the 1970's, radically changed with La Villete's development. It is now part of Paris; its development is clear and swift. What was the last stop on the underground is now a close destination in the middle of a normal route.

The National Dance Center has become a landmark and contributes to the cultural renewal of this old suburb.

4 Conclusions

a. The change in use as an adaptation to new times

It is doubtful that a building is only apt for what is first intended for. The building survives the use it was made for and is in some form a living thing, therefore, its ability to adapt is one of its main characteristics. Society evolves and adaptation becomes a way of life. If you do not deny this ability to adapt, evolution will occur.

The change in the purpose of the building implies adaptation to the new norms, which produces a complete change in the building.

b. The architectural focus

Architecture differs from other fine arts; the only surviving architectural works of arts are the ones that are used. An unused building need to be used so that it suit's the architectural design of the building. Building renewal means offering the users of the building the best part of it. Any new generation using a building would enrich its original purpose.

Any reformation of building made today, needs to be clearly communicated to be understood and approved. Specialist can help in this field again.

c. The Urban Focus: Place

To a citizen, architecture and the city is part of the landscape although, it is not often considered. When his surroundings change, he becomes unaware of what he sees and this can be bothersome. Modern architecture in previous generations made a violent change in urban landscape, today; however, it is a natural aspect of the city and forms part of the citizen's memory. Architecture will always be tied to its location.

The conditions of a place can change from one generation to the next. There is the possibility that the degradation of an area drags down its buildings with it. Nevertheless, it is more frequent when the area is undervalued or revalued, as the surrounding areas of a city in the 1960's play a crucial role in the city center in the 1990's. This change helps give new life to a building situated there, if it is able to respond to its new outcome, perhaps a change in the its use or expansion which allow new perspectives. However, a building can be condemned because at the time it had no future plans for changes in its use and a reformation would be unprofitable.

One should also consider the possibility that conversion or restoration of a building during the 1960's–1990's could serve as an example to build up the area.

d. The Economic Standpoint: Economic Means-Property and Ownership

The owner of the land is also responsible for the reason why buildings are abandoned due to frequent speculation, lack of upkeep, change of direction on his properties. The landlord is the owner of the destiny of his building.

The economic standpoint becomes more and more important in times of economic drawbacks, major interventions lesson, and big projects also. One has to take advantage of what already exists. A building offered by the past generation, by rule of thumb, needs less intervention than a demolition or rebuilding.

e. The Technical Standpoint

We stand before a generation that has directly inherited the constructive principals of the Modern Movement. What was said to be a novelty in the past has now been perfected. Construction techniques ensure a solid and lasting execution. This mastery means in many cases the creative usage of materials and building.

Yet, in the cases in which intervention has been drastic, removing almost ever trace of original construction, the structure remains. Once again, the dominate technique stands out. We are very far from the costly restorations in concrete and steel since the beginning of the twentieth century. We stand before structures and norms closely related to the ones today.

Perhaps, the most important challenges in the reformation of a building from the 1970's are the installations. Its evolution and demand factor changes a lot from one generation to the next. Its importance is great and its adaptation or new purpose is absolutely necessary. The pipe, s place and machinery storage will play a decisive role when planning the project. Lighting, heating and automated technology have made a great leap in one generation to the next. Today, the possibilities and the requirements are greater. Lighting can also be an effective tool to give a building a new image. The architect's actual work with a qualified and specialized team enables the work and solutions to be more profound.

The National Dance center in Paris serves as a model to systematize similar future transformations.

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Modern Architecture and Its Construction Techniques in Sardinia, Italy. The case of the Arborea's Church (OR)

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Abstract Founded in 1928 as Villaggio Mussolini, thanks to a substantial work of reclamation, Arborea (OR) is a key asset for the knowledge of construction techniques of the Modern period: built in a few years, it's a snapshot of technological progress in Sardinia during the 1920s and 1930s. Here we can find different architectural languages and construction techniques, ranging from masonry construction system to reinforced concrete frame.

The paper's focused on buildings constructed until 1932; among them, we can identify two categories: buildings related to the production activities of the farm settled in the reclaimed territory, and the civil ones. For the first, according to requirements, it was preferred a reinforced-concrete construction system; instead, contemporary civil buildings (Eng. Avanzini) united by an eclectic language, were generally characterized by masonry, but we can also find floors made up of reinforced concrete and hollow blocks. An exception to this rule can be found in the church (Arch. Bianchi): here, unexpectedly, it's used a particular reinforced-concrete frame.

Keywords Arborea • Modernism • Construction • Techniques • Foundation

1 Introduction

This work is about the study of the construction techniques related to the little city of Arborea (OR), founded in 1928 under the name of "Villaggio Mussolini";in 1931 it became municipality with the name Mussolinia, and then it changed its name into Arborea, in 1944.

The examination of the construction techniques by which the city was built, gives a contribution for the knowledge of the technological progress in Italy and Sardinia in the first decades of the 20th century. The particular situation of Villaggio Mussolini, built in a few years in a territory which had just been reclaimed by a great activity of drainage and land reclamation carried out by Società Bonifiche

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Sarde (Society of sardinian reclamation- SBS), represents a snapshot of progress, knowledge and construction practises related to the period of the foundation. Informations like these are very important in case of recovering, restoration and valorization of modern buildings, in order to define their value, their novelty, therefore the suitable kind of interventions and modifications [1]. Until now studies like this have focused on some isolated cases such as the one on the GIL building by G.B. Ceas, built in 1933–1934 [2], but there is still much to learn about the building of the first urban core, to be more precise, buildings constructed until 1932–1933.

Among them we can find two categories: buildings for civil activities, such as schools, the Town Hall, the hotel, the shop-building, the houses for employees, the hospital, the Church and so on; and buildings that are mostly related to the production activities of the farm headed by Società Bonifiche Sarde.

The buildings of the first category have common stylistic features, characterized by a bold eclecticism influenced by new-Romanesque and new-Mannerism inspirations [3], probably due to being designed by the same designer, the engineer Carlo Avanzini, director of Società Sarda Costruzioni (Sardinian Society of Construction—SSC), that was subsidiary of SBS [4]. Through archival research and the examination of the available documents, in particular the specifications, it has been possible to notice that the common stylistic features of the first category of buildings are largely reflected on their construction techniques: the most used one is characterized by masonry that, as in the case of the Town Hall which was designed by SSC, is associated to floors made up of reinforced concrete and hollow blocks, linked to the masonry by riddles.

As far as the buildings related to the production activities, we can notice a preference for the reinforced-concrete frame often shown externally, even if there are contaminations and exceptions; below, it will be described the Market Hall, also designed by SSC.

The Church, instead, built in 1926, represents an exception, and probably not by chance it's the only one edifice built during that period that has been designed by another designer, the architect G.G.E. Bianchi. Here it's used a structure made of reinforced-concrete portals, even if it's not possible to see it from the outside because it's covered by a heavy masonry, that characterizes the aspect of the building.

2 Construction Techniques

2.1 The Town Hall

The construction of the Arborea Town Hall started after that Villaggio Mussolini had become a municipality with the name Mussolinia, in 1931.

The building covers a 600 square meters-sized surface; consists of a main building with two floors, and two buildings of three storeys, 15 m high to the eaves. In

Fig. 1 The town hall under construction. Private archive

addition to the offices of the municipality, there are other offices including the one of Post and Telegraphs, and three apartments for some employees.

As we can read on the specifications, the building is described as a "house made of masonry"; the structure of the building is, made of masonry of raw trachytic stones and hydraulic lime mortar, and bigger and harder stones in the corners, in the junctions of the walls and in doors and windows lintels, according to the good workmanlike. The floors are made up of reinforced concrete and triangular hollow blocks type Berra, calculated for an overload of 350 kg/sm; their solidarity with the walls is guaranteed by reinforced-concrete riddles as high as the floor, for the part fitted in the masonry. Also the main staircase, the beams of the stairwell of the first floor and the beams of the corridor are built in reinforced concrete. The roofs are either pitched or flat; the terraces are made either of reinforced concrete and hollow blocks type Berra or, in some specific cases indicated on the specifications, of slabs 10 cm thick. Furthermore, the specifications recommend using Portland cement and following, for works in concrete or reinforced concrete, the Royal Decree 18th of July 1930 n°1133 and the prescriptions indicated in the Presidential Decree of the 15th of July 1925 related to iron materials. Pitched roofs are made of a traditional wood structure made up of a first row of fir-wood beams or trusses, a second row of beams (13×16 cm) placed at 1 m centres, another row of little beams (8×4 cm) placed at 0.5 m centres, a row of splits (2×2.5 cm) and a Marseilles tile covering.

With the exception of the top floor of the lateral bodies, finished with plaster in hydraulic lime mortar, the rest of the surfaces are coated with ashlars variously carved: from the documents we can read that there are 316.36 sq. m of trachytic slabs refined by *mezzana* tip and jointed with cement mortar, 58.60 sq. m of artificial trachityc slabs, rusticated and jointed with cement mortar, and 48.30 sq. m of slabs of natural trachyte rusticated in the exposed parts and squared in correspondence of the support plans, jointed with cement mortar. Internal and external frames are made of fir or Swedish pine wood; sills and doorsteps are made of Carrara white marble. Elements such as ledges, balaustrades, are made of concrete [5] (Figs. 1 and 2).

Fig. 2 The market hall interior. Private archive

2.2 The Market Hall

Providing the city with a Market Hall becomes necessary because of the increase of population, in order to complete the municipality's equipment of public facilities and, in particular, to make safer the victualling and selling of supplies. The construction of the building starts after the stipulation of the contract between the Mussolinia municipality and SBS, that occurred on the 28th of December 1931 (on that date they proceeded also to sign the contracts for the construction of the police station and of the slaughterhouse). Also the Market Hall has been designed by SSC.

The building consists of a 18 × 13 m-sized main body which includes eight dealers, four shops, an office and a storehouse. In the northern and in the southern side, it has two entrance bodies that have the specific function to protect the inside against mosquitoes.In the report attached to the project, also this building is defined as "house made of masonry"; otherwise, its structure is a bit more articulated. It's made of masonry 25 cm thick, made up of concrete hollow blocks, built upon a foundation masonry made up with raw trachytic stones; there is also a crawl space filled with raw trachytic stones. Upon the crawl space there is a concrete floor; the roofs are pitched and their structure is made up with of a first row of fir-wood beams or trusses, a second row of beams (13 × 16 cm) placed at 1 m centres, another row of little beams (8 × 4 cm) placed at 0.5 m centres, a row of splits (2 × 2.5 cm) placed at 0.3 m centres, and a Marseilles tile covering. In the central hall, we find a reinforced-concrete frame structure, which holds the exposed reinforced-concrete trusses of the roof. Also in these specifications it's recommended to follow the Royal Decree 18th of July 1930 n°1133 and the prescriptions indicated in the Presidential Decree of the15th of July 1925. The walls are finished in hydraulic-mortar plaster, and provided with large hopper windows [6].

2.3 The Church

SBS commissioned the project for the Arborea's church to G.G.E. Bianchi, an architect from Milan. The construction began in 1926, at the same time of the construction of the school and the hospital. The edifice is different from the others of those years, by being one of the few not designed by Avanzini. However, from a stylistic point of view, we can notice, overall, a harmony of language; also the Church, in fact, is characterized by the same neomedieval style, which unites the most of the edifices of the first period, and refers to some stylistic elements of the last Romanic period. The building, as originally designed, is formed by a large single nave 22 × 10.40 m sized, and 12.50 m high at the base of the roof; an apse 7.70 × 5.50 m sized and 11.30 m high, behind which there is a sacristy made of three rooms, two of whom are 1.95 × 1.95 m and the other one is 7.70 m × 3.20 sized. On the western side there is small office; above the main entrance there is a loggia for the chorus. The belltower is 31.90 m high; it's provided with a clock and three bells, and hides the first tank for drinking water of the area.During the following years two little side chapels have been added, near the apse.

By reading the report attached to the project, we know that the structure of the building is made up of "reinforced concrete and trachytic stone masonry and cement-mortar". Particularly, the nave's structure is constituted by reinforced concrete portals of 10 m span, and 10.50 m high at base of the lintel, that is shaped as a tympanum: it has a cusp 4 m high and two arms of 6.50 m in length.

The piers have a symmetric "double T (cross) section", the section of the lintel is shaped as a double T too, but variable. There are five portals, 4.50 m centres; the lower surface of the lintel is shaped as a pointed arch, with the exception of the portal that leads to the apse that is lower than the others and its lintel is shaped as a round arch. Moreover, here there are two paired pillars. We can find a similar variation also in the forepart; also here we can find portals, but they substitute the double-T section with a rectangular one, and the lintels are not arch-shaped anymore. Higher than the ones of the nave, these portals follow the particular scheme of the façade: the lintel, in fact, it's not based strictly on two piers, but one of them is replaced with one of the pillars that hold the belltower, in the northern corner of the forepart. In order to avoid tipping over, the portals are connected with a long beam, shaped according to a broken line to connect the different heights of the ridges.

The elevated structures rest on concrete foundations.

The roof of the nave is made up of a frame of wood (pitch pine) beams, upon whom there is a row slabs of firm-wood 2.5 cm thick linked to the beams; upon the slabs there is a row of eternit- tiles, linked to the lower structure by iron screws and washer. The roof of the apse, that is the only part of the building together with the lateral chapels which has only a masonry bearing structure, is made up of a very particular wood truss.

The walls are characterized by the presence of windows variously shaped: they could be rectangular, shaped as a pointed arch, circular, and closed by immobile or moving shutter; the masonry is almost always not finished; in the forepart, in correspondence with the rose window we can find a part that is finished with deco-

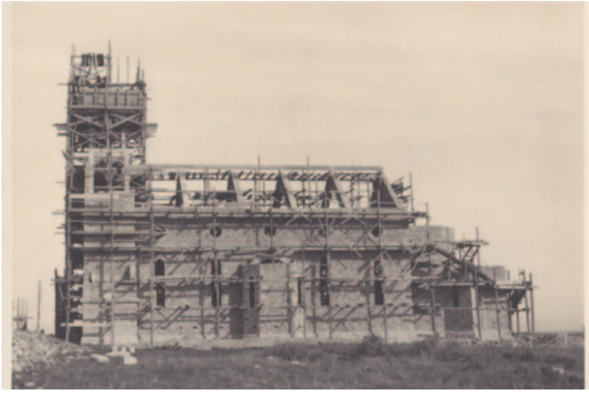

Fig. 3 The church under construction. Private archive

rated plaster, and also in the higher part of the lateral walls and of the apse there is a surface of a waterproofing plaster made up of hydraulic mortar. There are a lot of elements made up of artificial stones, such as ledges, mouldings, cornices, tympanums above windows and above the main door, consoles, windowsills and ornamental slabs. The internal walls are finished with plaster made up of hydraulic mortar, and then painted and decorated; also the portals are decorated [7] as in the Nordic style (Fig. 3).

3 Conclusions

This survey, still ongoing, wants to give a contribute in defining the construction techniques used in Sardinia during the 20s and 30s of the XXth century, but it's not yet exhaustive: there are still many buildings in course of study, in order to delineate the technological picture, as comprehensive as possible. What we have been able to infer, so far, seems to confirm the theory that in Italy the modernization of techniques has gradually occurred, entering a context that was very tied to the masonry [8]; it's demonstrated by the frequent use of the bearing masonry associated with floors made up of reinforced concrete and hollow blocks This ongoing research, by studying documents related to the project and to the construction, will allow, among other things, to verify if this particular floor had been used in the buildings prior to 1931; so far, the buildings considered date back to that year. About other buildings such as schools or the hospital, contemporary to the Church, currently we have some historical photos from which it's clear that the bearing structure is the masonry, but we cannot state, with certainty, the kind of floors; even if it seems to be plausible that they could be the same used in 1931–1932. It seems that a wider use of the concrete is preferred in case of specific requirements [9], as in the case of industrial buildings that require large spans and fire resistance. In the buildings of the first period, then, concrete technology is used in a strictly functional way, in order to solve problems and meet specific needs, without particular consequences from the formal point of view [10]. The language generally remains mostly linked to the tradition although, in the case of some industrial buildings evidently free from representative functions, such as the granary silo, the frame is shown externally without any attempt to hide it.

On the base of these premises the reinforced-concrete portals of the Church suggest another interpretation of the link to the masonry tradition: here, in fact, comes up again, the diaphragm-arch, typical of religious architecture, even if they are made up of concrete. These structures are embedded in the masonry and completely hidden, externally; so the representative function is still given to the masonry. Internally, they are finished with plaster and then decorated in a traditional way, covering the new material.

Thanks to previous researches, we know that, in the following years, in particular in 1933–1935, took place an evolution of the interpretation of the potentiality, even formal, of concrete, and this gave life to interesting buildings, characterized by more modernist features. This is the case of the draining pump designed by F. Scano, and of the buildings designed by G.B. Ceas, that is House of the Fascist Party and the GIL building; the structure of the gym of the GIL is made up of reinforced-concrete portals, and the swimming pool is demarcated by two big portals that have a span of more than 20 m, where we can find some interesting structural solutions which are, currently, in course of study.

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Information System for Architectural Accessibility (ISAA)

A. García-Quismondo and Andrés Montoyo Guijarro

Abstract The present paper is in line with the scope of research in the application of new information technologies to architectural design. Specifically, those applied to stating the accessibility conditions of existing buildings and premises for disabled persons.

Spanish law 26/2011, of compulsory enforcement in the whole country by 2015, foresees the obligation to adapt all goods and services available for public use which may be subject to reasonable adjustments.

This is the reason why it is necessary to provide technical staff with the right tools to help developing his work in the research and diagnostics of accessibility problems in the building environment.

This paper involves the presentation of a developed software system which allows defining all the necessary requirements in a building in a structured manner. Considered as a whole, these requirements will help defining both the accessibility level and the deficiencies of a building and, at the same time, proposing improvement solutions.

Keywords Accessibility • Universal design • Databases

1 Introduction

The present paper is in line with the scope of research in the application of new information technologies to architectural design. Specifically, those applied to stating the accessibility conditions of existing buildings and premises for disabled persons.

The aim of this paper is to present a new computer tool to support accessible design: "Information System for Architectural Accessibility" (ISAA).

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2 The Need of This Research

Accessibility for persons with some kind of disability is a crucial element that needs to be taken into account in the design of buildings and premises, both new and going through restoration works.

Since the Declaration on the Rights of Disabled Persons [1] of 1975 up to nowadays, international laws have tried to achieve the removal of architectonic barriers to provide the same rights to all citizens regardless their individual capacities. After the Convention on the Rights of Persons with Disabilities [2] of 2006, many countries initiated actions that will define the evolution guidelines of the accessible design in the next decades. As an example, ADA Standards for Accessible Design [3] was published in 2010 in the United States of America. In Europe, the passing of a European accessibility law is foreseen by the end of 2012 [4]. The DB-SUA, a regulation on accessibility [5], of compulsory enforcement in the whole country and which foresees the obligation to adapt all the existing buildings by 2019, was passed in Spain in 2010. However, Spanish law 26/2011 (August 1st), ruling regulatory adaptation to International Convention on the Rights of Persons with Disabilities [6], has modified the year 2019 scenery, as it foresees the obligation to adapt all goods and services available for public use which may be subject to reasonable adjustments by 2015.

Despite the legal (and moral) obligation to adapt properties of public use so they can be used by anyone, both designers and technical staff endure many difficulties when adapting existing buildings. According to a survey completed by the ACCEPLAN on architects [7], more than 44 % of them consider that there are problems in the implementation of regulations when completing renovation and restoration works.

Those are the reasons why it is necessary to provide technical staff with the right tools to help developing his work in the research and diagnostics of accessibility problems in the building environment.

3 Objective of Isaa Tool and Contextualization

In order to be able to adapt existing buildings to accessibility conditions, a diagnosis stage on the initial conditions of each property is essential. To reach this goal, it is necessary to implement a proper methodology during data collection and organization phase, as this will allow us to make decisions in the proposal of intervention stage.

Computer tool ISAA is intended to make data collection, and its subsequent organization, as comprehensive and structured as possible. It will also provide with a database of the property under consideration for future action.

The development of this tool is integrated into a research paper[1] of greater length including the tasks of identifying needs, developing the methodology of building

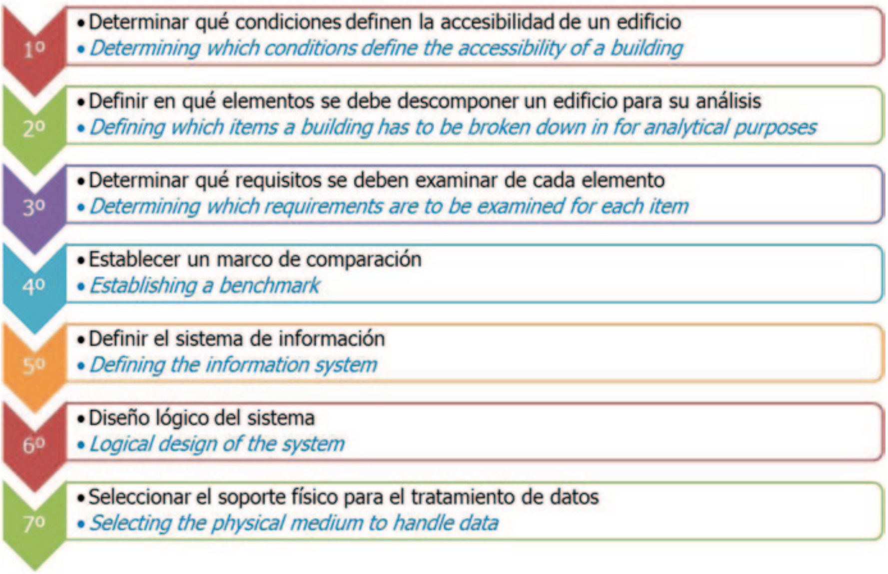
[1] The conceptual formulation and methodology of the whole project was presented in the 7 VCT—7th Virtual City and Territory Congress, held in Lisbon on October 11–13th, 2011. (http://www.7vct.dec.uc.pt) [9].

assessment, and preparation of a *Help manual on accessible design and implementation* [8], in html format, for network use.

4 Methodology

The purpose of the tool is to store data describing the physical conditions of a building. These data will be used to assess the accessibility conditions of the premises, so they will need to be stored with a specific organization that allows cross references with standard parameters for evaluation. The tool also provides certain parameters of reference, though users can customize them.

Stages followed during creation of ISAA tool are listed below:



The physical medium chosen to handle information is a Database Management System, specifically Microsoft Access 2010, as it is the most widely used and it includes new functionalities for networking.

5 Description

A brief description of the main features of ISAA tool is included below.

5.1 Start Panel

Initial navigation panel allows the following possibilities:

- Defining a new building
- Modifying or adding new data for existing buildings
- Displaying factory default parameters of reference
- Customizing and storing parameters of reference
- Printing reports on the status of data collection of buildings which are already in the system
- Requesting help on tool functionalities
- Connecting with the online Help manual on accessible design and implementation Manual

5.2 General Data and Data Entry Stages

When initially entering data for a new building, the general data screen must be fulfilled. This screen also acts as a navigation panel to advance in the data collection in a structured way. Data entry of the whole building must be completed in three consecutive stages. These stages will allow describing all of the building elements (either itinerary of room elements), and cross-referencing them, and also describing other essential elements for accessibility, such as *signalling*, *communication* and *security* requirements (Fig. 1).

5.3 Example of Data Collection Panel

Below an example of data collection panel is shown, specifically the one related to *Itinerary* elements, which is made up of several navigation tabs based on different types of elements; a general listing, in the header, of the elements introduced as building components; and a central screen of data collection. All screens follow the same setup, and in some cases additional buttons will appear to open secondary data screens for items such as handrails, bathroom fittings, furniture, etc (Fig. 2).

6 Utilities

- This computer application provides functionalities to store in a structured way all the necessary data to assess the accessibility of a building, whether geometric, spatial or related to material features.
- An unlimited number of buildings can be stored and data can be modified and updated whenever needed.

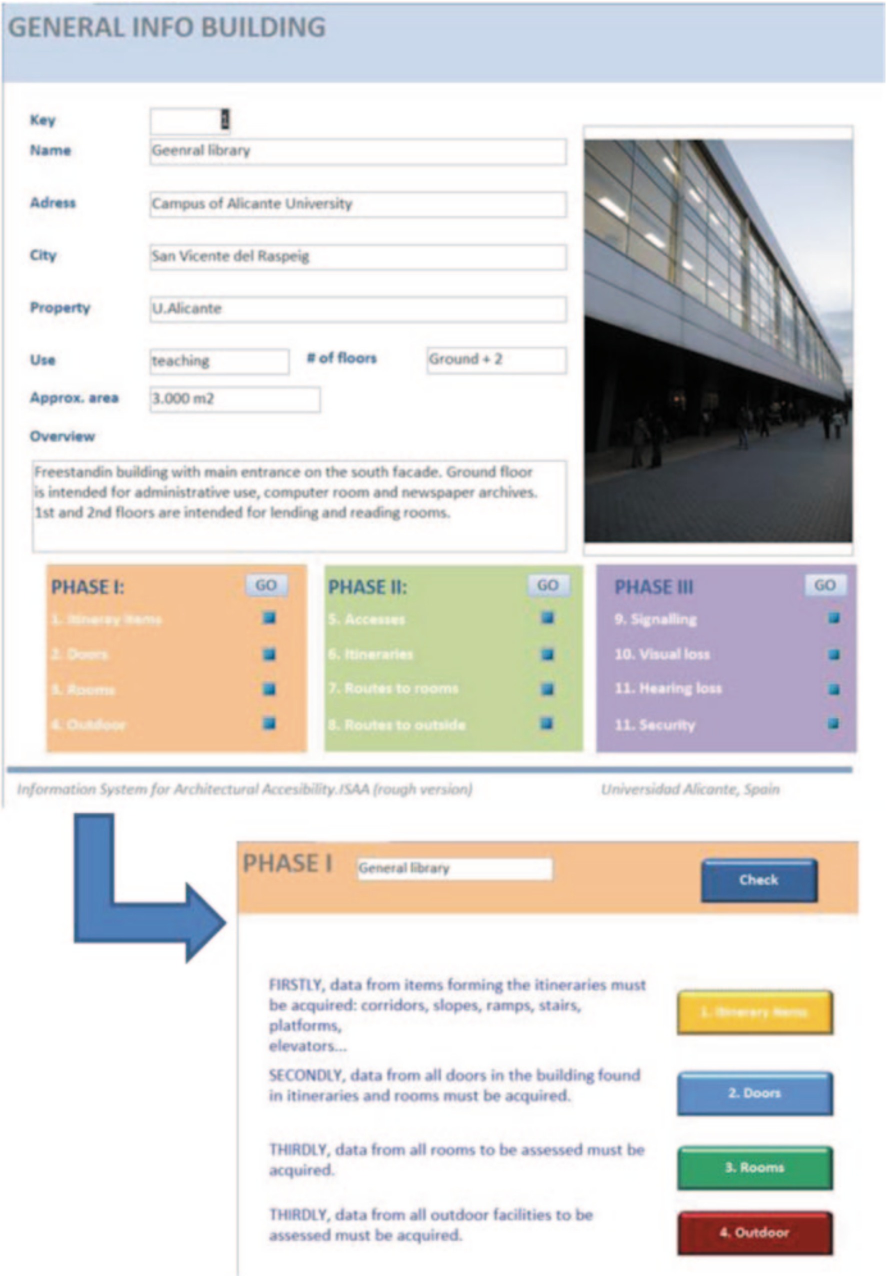


Fig. 1 General info of building

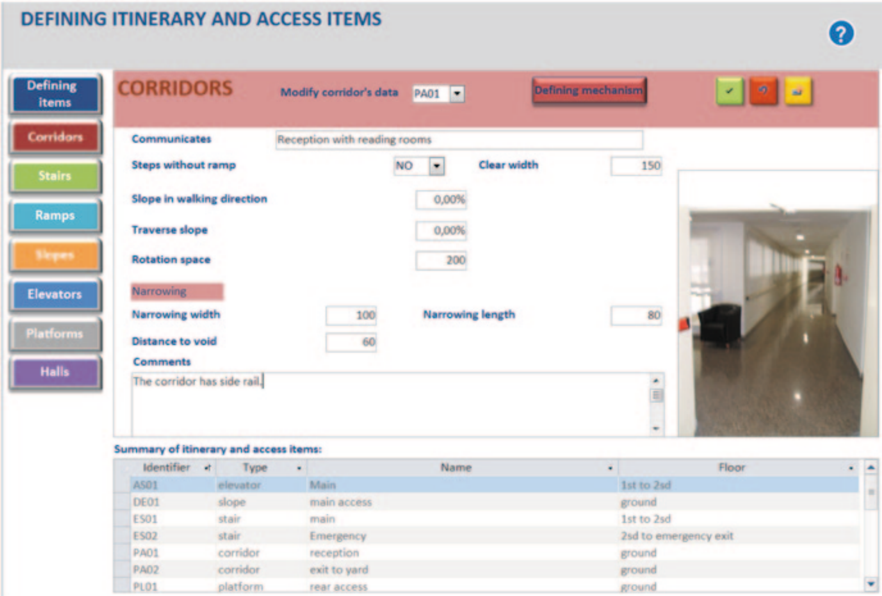


Fig. 2 Panel to define itinerary and access items

- It is possible to define both existing buildings and others in development stages.
- It is possible to define whole buildings or just specific premises or areas.
- All the necessary data can be introduced, regardless of its type, whether room or itinerary data (stairs, ramps, elevators, etc.) and also more specific elements such as bathroom fittings, mechanisms, furniture, lighting, etc.
- Data are not duplicated as each element type is defined once, and then it is linked to all the areas where identical feature elements can be found.
- Photographs and plans can be included to improve information completeness.
- Forms aimed to in situ data collection and result reports can be printed.
- It is also possible to compare collected data with parameters of reference to determine which elements should be corrected.

7 Trial Stage

ISAA tool is currently going through an experimental phase. In order to assess its usefulness, deficiencies, and to implement the necessary updates, it will be subject to a trial stage.

As its main function is to serve as a data warehouse to assess the accessibility of the built heritage, trial stage will be completed in association with a public organism with technical staff experienced in the architectural accessibility area and in the process of developing some kind of Accessibility Plan related to the built heritage.

After data on selected buildings have been introduced, a report with details on issues detected and improvement suggestions will be generated. This report will be used to improve the application and build the final version for its release.

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Study and Characterization of Stone Mortars Used as a Volumetric Reconstruction Material in Conservation-Restoration of Monumental Heritage

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Abstract This paper is focused on the evaluation of different repair mortars used for volumetric reconstruction in Monumental Heritage. The research purpose is to analyze and understand degradation processes, to study the compatibility with the original litotype and to make predictions about the durability of the material and in order to evaluate their suitability. Here, a series of specimens with different mortars and binders have been prepared: a mortar of lime in paste (*Unicmall,* and sand), a mortar of powder lime (*Cumen*) and two mortars with hydraulic binders (*Parrot* and *Petratex*). In the same way, a series of normalized physical (mechanical)-chemical tests have been performed. For the characterization of materials has been used SEM/EDX and electromechanical twin-screw machine. The results of the tests have been compared with a calcarenitic bioclast stone from the quarry of Hellín (Albacete) and the intrinsic properties of these materials and their behavior in environmental conditions have been determined. All tested mortars offered satisfactory results for restoration purposes and can be used as a material of structural and ornamental reconstruction, proved by the good compatibility with the natural stone and the durability test results. The best results with regard to the natural stone have been obtained with the hydraulic binder *Petratex*.

Keywords Mortars • Volumetric reconstruction • Compatibility • Binder

1 Introduction

Mortars are homogeneous mixtures of one or more binders, aggregates and a solvent, which may contain organic and/or inorganic additives to improve their rheological properties [1]. The importance of the mortar in the rehabilitation of buildings and

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Table 1 Studied commercial products

Name	Composition	Solvent	Additives	Manufacturer
Petratex	Hydraulic lime mortar particle size 0–2 mm	15 % distilled water	–	Parex group
Parrot's mix nº 4	Hydraulic binder and especial agglomerates (not determined)	49 % distilled water	16 % Parrogum Adit 6	Pinturas parrot
Unicmall	Non-hydraulic lime paste (80 microns) 62 % humidity and silica sand (particle size 0–2 mm)	nothing or little	–	Unicmall
Cumen	Non-hydraulic lime powder with limestone sand and inorganic pigments (highly chemical stable)	17,5 % distilled water	–	Cumen, SL
Bateig Azarache	Natural stone: bioclastic calcarenite	–	–	Piedras Fósil Hellín, SL

monuments has been essential for its aesthetic, historical, physical, chemical and mechanical nature. Hence, it must meet functional requirements to ensure stability and compatibility with the element restored [2–4]. In this sense, it is fundamental to study and create restoration mortars that offer physical-chemical affinity with ancient materials [5]. Currently on the market there is a wide range of materials for its use in the reconstruction of missing parts of artworks made up of stone materials. These are products made from traditional lime binders (high purity calcium lime), hydraulic lime, gypsum and cement, or synthetic mortars, all easy to handle and recently, widely used in works [6–7].

This paper highlights the main results after characterizing and evaluating the degree of deterioration of commonly used commercial materials through accelerated ageing tests and determining of their effectiveness and suitability in relation to natural stone material [8].

2 Experimental

2.1 Materials (Table 1)

2.2 Methods

27 samples were prepared for each mortar, three for each of the performed tests, giving a total of 108 samples. The following acronyms have been used to identify the mortar samples: *Petratex* (Px), *Parrot* (Pr), *Cumen* (Cu), *lime-Unicmall* (and sand, Ca)

and *natural stone* (Pn). The dimensions of the samples were made from molds with regular geometric forms (cubic 5 × 5 × 5 cm and parallelepipeds 4 × 4 × 16 cm) following the 25-PEM RILEM 1980 Standard (open porosity, freezing-thawing and salt crystallization cycles), the NORMAL 7/81 standard for water absorption-desorption curves and UNE-EN196-1 for flexural and compression tests. Sample specimens have been obtained through a direct moulding process. The different mortar mixtures have been kneaded homogeneously according to the technical specifications and then poured into a mould. For the specific case of the non-hydraulic air lime mortar paste a silica aggregate in proportion lime: sand (1:2.5) was used.

All specimens were subjected a minimum period of nine months testing. After demoulding, the surface of the specimens was treated with corundum abrasive paper 04-PVI 200.

2.3 Instrumentation

Instrumentation used for the characterization of mortars (before and after artificial accelerated ageing):

- Scanning Electron Microscope (SEM/EDX) Morphological examination of the sample were obtained by using a Jeol JSM 6300 scanning Electron Microscope, operating with a Link–Oxford– Isis microanalysis system. The analytical conditions were: 20 kV accelerating voltage, 2 × 10–9A beam current and 15 mm working distance. The polished samples were carbon-coated to eliminate charging effects**.**
- Electromechanical twin-screw machine IBERTEST ELIB-200E/W, for compression and flexural tests with maximum load of 10 kN (two screws) or with frame (from 20 kN), twin screw and 2 or 4 guiding columns. Results of mortar specimens subjected to different loads have been compared with natural stone.
- Electronic precision balance ST-1200, load 0,5–1200 g, precision 0,1 g. Dry, water saturated and hydrostatic weighing.

3 Results and Discussion

3.1 Morphological Study

Morphological analysis by Scanning Electron Microscopy (SEM) highlights the different textural characteristics of mortars and natural stone. In cross sections images by the SEM of the of these materials the presence of microspheres as aggregate in the mortar *Parrot*, and e.g. the similar texture of the mortar *Petratex* with respect to the natural stone can be observed. The presence of numerous pores and voids in the *Cumen* mortar can be seen which, together with mortar of lime and sand, is apparently showing aggregates of larger size (Fig. 1).

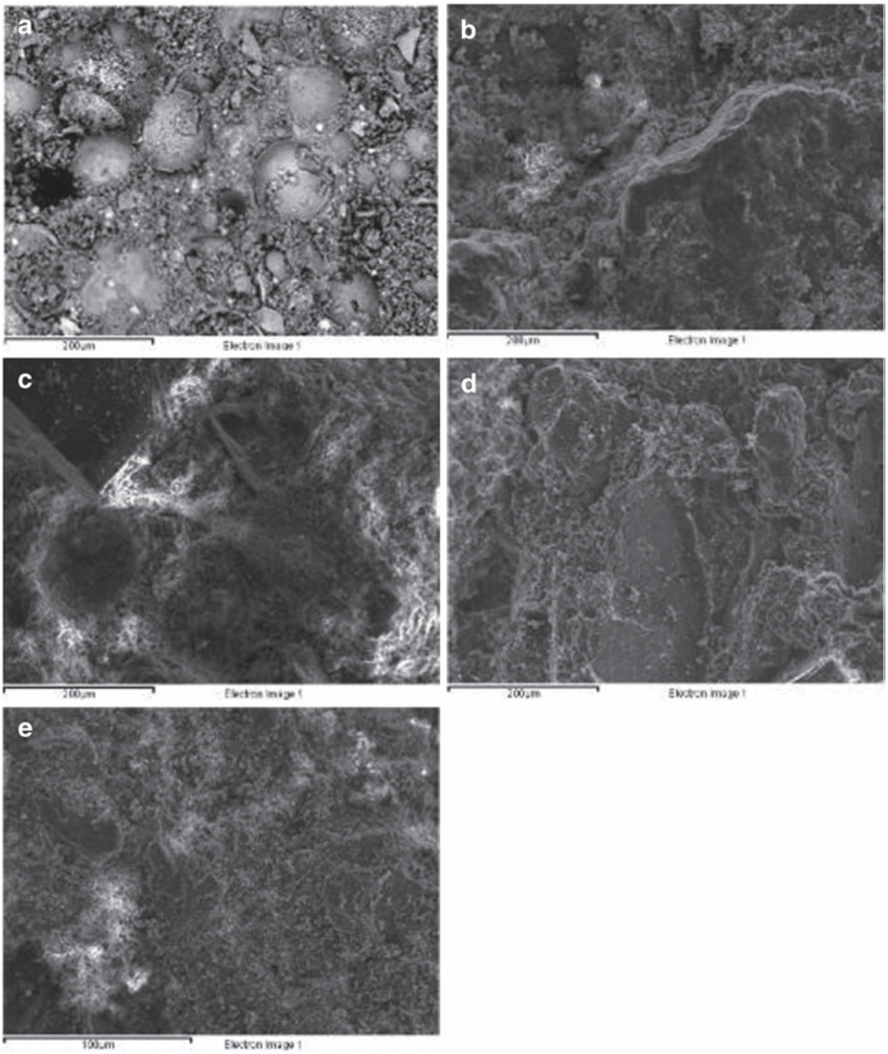

Fig. 1 **a**–**e** SEM images of the mortar surfaces and natural stone. **a** *Parrot*, **b** *Petratex*, **c** *Cumen,* **d** *Lime-Unicmall* (and sand), **e** *natural stone*

3.2 Absorption and Desorption

The test is performed base on the NORMAL 7/81: "Assorbimento d'acqua per immersione totale: Capacità de imbibizione totale" recommendation. The purpose of this test is to determine the natural capacity to absorb water. The results obtained in tests of absorption and desorption are summarized in Fig. 2a, b.

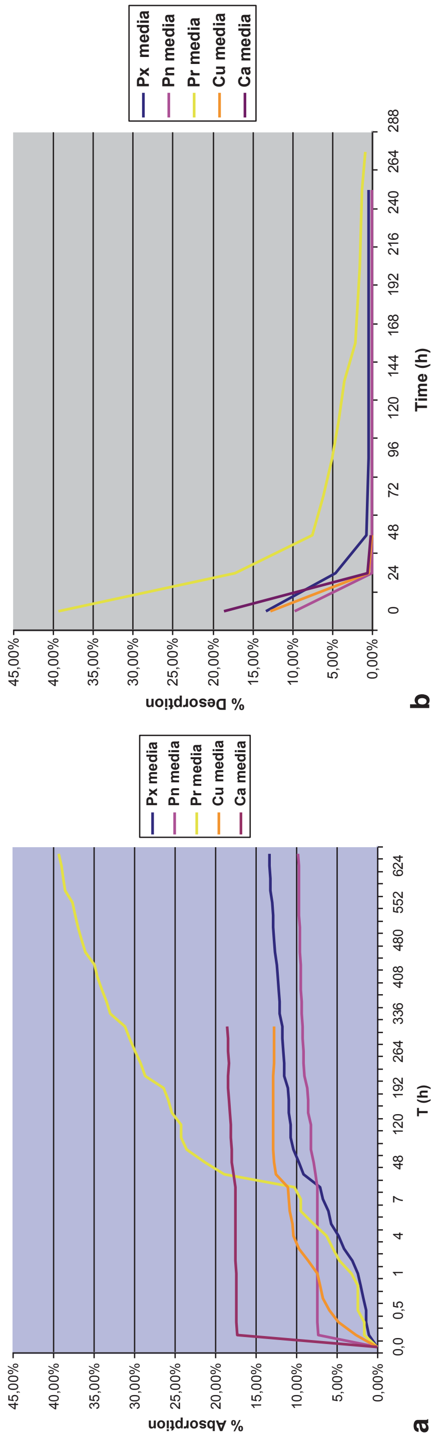

Fig. 2 **a** Absorption and **b** desorption diagrams. Mean values of three specimens for each material

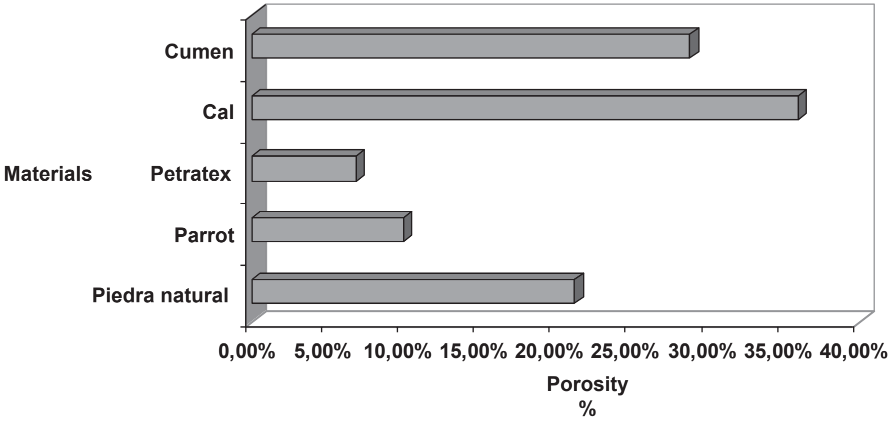

Fig. 3 Open porosity of the analyzed materials

The graph shows a rapid uptake in the specimens prepared with aerial *lime mortar* (Ca) and stone (Pn). In the first case, the absorption mainly occurs in the first 10 min of immersion, reaching values of absorption of 17.27 % (weight%), whereas in the samples of natural stone, is only 7.25 %. The other mortars show a more gradual absorption and *Cumen* mortar absorption reaches values of 2.67 % in the first 10 min. The mortar *Petratex* and Parrot show an absorption of less than 2 %, and, in the case of *Petratex* 13.31 weight % was achieved at 648 hours (saturation level). However Parrot shows a gradual increase in absorption over the entire cycle.

The study of the desorption curves obtained show the rapid loss of water from the mortar specimens lime-sand and *Cumen*, followed by natural stone. All of them achieved a percentage of 0 % at 24 h. Same as the rapid absorption, this behavior is explained in the Lime and *Cumen* mortars by the larger pores and a high interconnection. Drying kinetics is slower and progressive in *Petratex* and *Parrot* due its lower porosity and interconnection.

3.3 Open Porosity

The test is based on the R.I.L.E.M.-I.1. (1980, Porosity accessible to water) recommendation, which defines the porosity accessible to water as the ratio, expressed as percentage of the volume of the pores accessible to water and the apparent volume of the specimen. Higher values correspond to the lime mortar (Ca), followed by *Cumen* and natural stone. This result corresponds to the first two materials with respect to their behaviour in the absorption and desorption tests, confirming significant levels of porosity. The natural stone presents a high porosity value, but with a low absorption uptake values, which might indicate a low interconnection pore system and poor capillary forces. The lowest porosity average value corresponds to the *Petratex* mortar with a 6.88 %, evidencing a little porous material, as shown in Fig. 3.

Table 2 Mechanical resistance (flexural and compression) with corresponding standard deviation (S). Three specimens tested for each material. Note the differences of resistance in the different materials tested

Sample	Flexural resistance (Mpa)	Standard deviation (S)	Compression resistance (Mpa)	Standard deviation (S)
Natural stone (Pn)	5.107	0.431	33.634	0.086
Parrot (Pr)	3.651	0.517	8.163	0.031
Petratex (PX)	4.501	0.331	11.550	0.366
Lime-*Unicmall* (and sand, Ca)	1.274	0.157	4.961	0.035
Cumen (Cu)	1.455	0.173	3.433	0.017

3.4 Mechanical Resistance: Flexural and Compression Test

The procedure was carried out following the Norma UNE-EN-196-1 standard for the determination of mechanical strength of cement and the results of flexural resistance are shown in Table 2. By comparison, the best result was obtained by natural stone (Pn) with a flexural strength of 5.1 MPa, followed by the *Parrot* and *Petratex* mortars with quite satisfactory values of ~70 (~90 % respectively) compared to natural stone. The lowest values yielded the *Cumen* and *lime-Unicmall* (and sand) mortars. These results indicate the suitability of the mortar *Petratex* for interventions where there is a certain mechanical resistance necessity, as its flexural strength value is very close to those of natural stone (~90 %). The differences of the physical resistance for the compression tests of natural stone to the mortars are more significant. While compression tests of Pn return a value of about 33,6 Mpa, *Parrot* and *Petratex* (again highest values) yielded to values of 24 and 33 % of the natural stone. Very low compressive strengths values have been obtained for the *Cumen* and *lime-Unicmall* (and sand) mortars (3.4 and 4.9 MPa), which is only a 10 and 15 % respectively of the compressive strength of natural stone. The rupture of the natural stone, *Parrot* and *Petratex* occurs in planes parallel to the application of force, indicating a more cohesive material and a better crystalline structure.

3.5 Freezing Resistance

The results show a significant loss in the lime-sand and *Cumen* mortars, which after completion of the third cycle have shown significant losses as sugaring, spalling and rounding of edges, reaching a loss of more than 50 % of its volume after finishing cycle 21. In contrast, natural stone and the *Petratex* mortar exhibit a good resistance without significant weight changes. Visually, the Parrot mortar deterioration is of low intensity, given the cohesion gained by the synthetic additive to the hydraulic binder and the low porosity value is responsible for the almost imperceptible weight loss in the mortar *Petratex* (Table 3).

Table 3 Weight variation in [g] after completion of the freezing-thawing cycles with corresponding standard variation (S)

Sample	Cycles (nº)	Weight variation (g)	Weight variation (%)	Standard deviation (S)
Natural stone (Pn)	48	5.587	2.122	4.483
Parrot (Pr)	48	14.210	15.789	0.251
Petratex (PX)	48	7.690	3.757	4.559
Lime-*Unicmall* (and sand, Ca)	5	−12.057	−6.894	13.081
Cumen (Cu)	37	−49.270	−22.714	3.391

3.6 Salt Crystallization Resistance by Total Immersion

The procedure was carried out following the recommendations of the 25 PEM RILEM 1980 Commission (Essay V.1 b). All samples tested increased slightly in weight after the salt crystallization test, which is explained by partially crystallization of the sodium sulfate solution in the pores and fissures. The specimens of lime-sand and *Cumen* begin to lose gradually weight from the 4th cycle, without passing any of these ten cycles, a fact that is manifested macroscopically as sugaring, spalling and fracture of parts, and consequently material loss. Similar the natural stone (Pn) begins to lose weight in the 4th cycle but, although seriously deteriorated, passes 15 cycles of the test. In contrast, in the set of *Parrot* and *Petratex* specimens an increase of 2.69 and 5.85 % respectively after 15 can be observed, indicating salt crystallization in pores (progressively increasing with cycle numbers). As seen in Fig. 4 they are stable to wear and tear with a deterioration of low intensity.

4 Conclusions

The absorption (desorption) values exhibited by the air lime-*Unicmall* (and sand) mortars are superior to natural stone, while the hydraulic mortars offer very different behaviours. Whereas the *Parrot* mortar yielded undesirable results, the *Petratex* exhibits progressive and gradual absorption-desorption curves and therefore the material will be less likely to change. Porosity values of the lime-*Unicmall* (and sand) and *Cumen* are increased and higher than the natural stone, while porosity is low in the *Petratex* and *Parrot* mortar. Mechanical test results indicate the suitability of the *Petratex* mortar for interventions when physical resistance is required, as their flexural strength values are very close to those of natural stone. The *Parrot* mortar, although less resistant, offers quite acceptable parameters. However the *lime-Unicmall* (and sand) and *Cumen* mortars are not suitable for restoration works requiring high mechanical strength. Additionally these two mortars show severe degradation with loss of mass in the test of resistance to freeze-thaw cycles. On the other hand, *Parrot* and *Petratex* mortars, as well as natural stone have remained virtually unchanged with low-intensity damage.

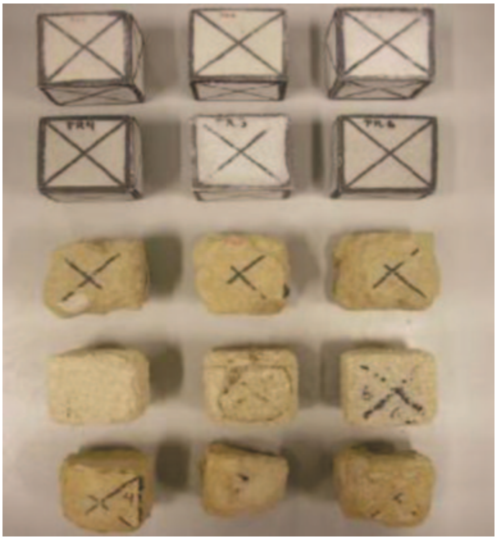

Fig. 4 Final result after salt crystallisation test. The Px an Pr (*row 1* and *2*) have hardly ostensible alterations. Pn, Cu y Ca (*row 3*, *4* and *5*) show macroscopic degradation with weight loss

Finally, *lime-Unicmall* (and sand) mortars, *Cumen* and natural stone show significant degradation and weight loss after salt crystallization test. In contrast, the *Petratex* and *Parrot* mortar do not exhibit weight loss nor significant changes during the test salt crystallization test.

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Situations That Modify the Good Behavior of Wood by Altering Its Moisture

R. Cebrián

Abstract Wood is an ever-present material in the history of architecture and has always been valued by its unique features. To get to know this material and make a proper use of it, we have to pay attention to humidity. This degrading factor is especially aggressive, particularly in a marine environment.

Therefore, keeping wood in good condition has traditionally been a problem for coastal settlements and it is there where the study of the results gathered becomes of special interest.

This piece of work entails a comparison among three cities selected by their specific qualities Las Palmas de Gran Canaria, Venice and Dakhla) and sets out the similarities and differences among the various degrees of damage on their external woodwork.

The relation among the results will allow us to isolate the determining factors to keep the material in good condition, considering that some of them are circumstantial.

Keywords Wood • Timber • Moisture • Maintenance • Conservation

1 Introduction

For its historic use, wood is a very important element which must be taken into account in the conservation, restoration or renovation projects of historical constructions. For the restorer's work it is vital to understand thoroughly its features and its traditional and present use.

The reconversion of historic centres, the rehabilitation of obsolete areas and a good conservation of the heritage are key for a good management of tourist resources, having a great application in environments such as the Canaries or Venice. Moreover, it is known that wood maintenance is a more delicate problem for cities near the sea, given the high content of mineral-laden moisture present in the environment.

This research starts with the main aim of getting to know the behaviour of the external woodwork of historic centres in several coastal cities, in order to obtain a comparison among them and reach conclusions about the ideal conditions of use and maintenance.

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The places under study have been chosen to be subsequently compared according to the above-mentioned factors, and also because of the chances that their joint study may offer. Three cities were decided to be taken as the base of this study, each of them with different conditioning factors but also with some features that make them representative as models of analysis.

The first one is Las Palmas de Gran Canaria, which has more than five centuries of history.

It is the first place where the Spanish construction model was exported to, adapting it to local materials, and it is pioneer in exporting it not only to America in the 16th century, but also to the Spanish Sahara in the 19th century. Furthermore, it has a number of typical construction elements made out of specific wood (such as the *Tea*-pine wood typical from the Canary Islands).

On the other hand, for its traditional culture of restoration, its historical use of traditional materials such as wood and its climatic conditions, which make it unique due to the relative humidity and marine environment, Venice is the perfect scene for the study of the effect of those factors on the said material.

Moreover, as the Canary Islands are a tri-continental platform, it was found very interesting to compare the construction and use of this material of those two marine climates with that of the north-western coast of Africa, specifically the city of Dakhla, for its cultural proximity. The Canaries, as a link between Africa and Europe, is the ideal place to consider the influence among them and the enrichment of the islands' plural culture.

Thus the objectives of this comparative study can be summed up as:

- Determine the effectiveness of maintenance techniques from different cultures.
- Identify characteristic physical and chemical patterns of behavior of the material in situations affected by similar marine moisture.
- Classification of situations that lead to a final misbehavior material, in order to prevent them before they occur.

In order to know and be able to reach the best conditions for use and maintenance of exterior wood elements in coastal cities, which have the difficulty of having a constant presence of marine moisture.

2 Methodology

Although this piece of work consists of two stages, this study focuses on the second part. In spite of that and as base of that second stage, it is necessary to set forth some background about the methodology used, so as to reach logical conclusions.

The starting point of the first stage is a comprehensive study of each city with the aim of determining the state of each particular element in relation to the data and, then, making a comparative study of the sampling.

After analysing the existing bibliography and carrying out an inspection of the areas, the values were measured. A Hanna thermo-hygro sensor model HI 91610 was used to determine the environmental conditions, whereas the relative humidity of wood was measured by a Protimeter Mini handheld moisture meter.

As regards the design of independent variables, the samples were chosen seeking a pattern as common as possible. Therefore, it was decided that they had to match a series of requirements when including them in the selection. Two types of parameters were set: those to homogenize the samples and others to determine enough heterogeneity to make the results be assumed as representative.

Homogenizing: Age (>50 years), state (wood affected), height (<30 m over sea level), temperature (20 °C< and <30 °C), time (indirect-radiation daylight). Each city has the enough stable aspects to condition the sampling in the other ones.

Heterogenizing: location, high-water area, type of wood, air humidity, orientation (sun radiation), type of protecting treatment, distance to the ground. These factors give enough variety in the situation of the element so as to diversify the samples.

Once the measurements were made in different spots, the most representative values were chosen and then detailed in matrix tables. In most cases, the values have been taken from lower areas or nearest to the support, for instance, frames and rims of doors and windows and heads of beams. In those points, the capillary action of water transmission is more pronounced and this is reflected not only in its state but also in the values. Moreover, an average value of the rest of the element is provided in order to establish a reference of the state of the whole set.

A zone-defining diagram was drawn up so as to be able to locate each result within the construction element sample. Thus, the results of each sample point are defined in the matrix with a number between 6 and 60 and a letter from A to T.

A graphic map on the moisture of a particular element and the saturation distribution in the internal beams of the ground floor of a Venetian palace are added hereto as support of this study.

Due to the great variety and combination of the factors observed and the results dispersion in contrast to the observation and inspection and other factors that will be commented along this exposition, this researcher believed that a deepening into quantification and qualification of the results would be of great interest, matching one of the initial aims.

Therefore, in this second stage, the research covers the particular circumstances that lead to a bad behaviour of the material. These precise cases serve as helpful examples to follow a proper maintenance, as they represent situations to avoid when using wood as external element of buildings.

3 Particular Circumstances Observed

Thus, herein are listed some of the particular situations involved in the way that humidity (marine in this case) affects wood. They will also be categorized according to the type of moisture effect (through infiltration, condensation, capillary action or accidentally).

Fig. 1 Entrances from the canals, Venice

3.1 Cases Related to Capillary Humidity and Low Areas in General

3.1.1 Acqua Alta

The effect of constant rising damp is devastating for wood and in the case of Venice is much more pronounced due to the humidity of substrata and the presence of *Acqua Alta*, which boosts the effect and can be also categorized as accidental moisture. The most marked case regarding construction elements is shown as an example of it: the entrance from the canals into the palaces (Fig. 1).

3.1.2 Flooding by Rainwater (Intermittent Inundation)

Not only is the "Acqua Alta" phenomenon responsible for intermittent floods, which end up bringing about the putrefaction of wood in its lower parts. One example of this is the door of my own house. The continuous paving works in a street of the old quarter have caused the sidewalk curbs to lose height.

If this circumstance is added to being located in the lower part of a hillside and, therefore, on a sloping street, it is very easy for the run-off level to flood the house entrance during rainy seasons (Fig. 2).

Fig. 2 Door on a sloping street, Gran Canaria

Fig. 3 Degradation in *lower* parts, Gran Canaria

3.1.3 Façade Setback and Its Effect on Lower Parts

Moreover, due to the projections of cornices and lintels and the backward position of woodwork in relation to the façade line, this lower part is also the most attacked by the sun radiation and environmental damp or rain. This continuous exposure to the daytime evaporation and absorption of rising damp accelerates the degradation of this sensitive part of the elements (Fig. 3).

Fig. 4 Obstruction of *lower* part, Dakhla

3.1.4 Obstructions Preventing Evaporation

The obstruction of the lower part of elements due to abandon or lack of maintenance worsens the state of these parts, as it prevents the evaporation of the damp retained by the accumulation itself and because of lack of sun radiation. The measurement carried out in the door of this picture taken in Dakhla showed that it was one of the most affected by humidity due to this precise situation (Fig. 4).

3.1.5 Increased Damages

The combination of humidity and presence of xylophaga and fungi multiplies the chances of damage in the lower parts of wooden external elements. Humidity favors the appearance of these biotic agents. Insects need a minimum of 8–12 % to carry out their vital functions, whereas fungi need 20 % (Fig. 5).

On the other hand, their presence generates a series of cavities and holes in the element. Such cavities modify the coefficient of wood porosity and, consequently, its reaction to the water capillary action. Therefore, a symbiosis relation is established between humidity and xylophaga, which deeply affects the construction element and exponentially worsens their attack when it is jointly.

For this study, doors in Las Palmas and Venice have been chosen as examples of these situations, which can be found very often.

3.2 Cases Related to Accidental Moisture and Infiltration (or Rainfall)

3.2.1 Faulty Installations

Accidental moisture cases are as varied as their possible causes. *Acqua Alta* and rainfall flooding have been already mentioned as accidental phenomena because

Fig. 5 Increased damages (xylophage), Venice

Fig. 6 Degradation by faulty plumbing in *sottoportego*, Venice

they are considered casual, unexpected and also unwanted. But there are many examples of this kind of moisture.

The picture shows classic damage by accidental moisture, which is caused by a faulty installation. It is a Venetian *sottoportego*, on which a floor trap presumably had been leaking for a long period in view of the damage caused (Fig. 6).

3.2.2 Combination of Infiltration Damp and Evaporation

The environmental or rainfall humidity, usually in combination with other factors, may be aggressive too, for example, combined with sun radiation, which degenerates

Fig. 7 Abandoned cloister without woodwork, Venice

the finish in presence of rainwater. As an example, an abandoned cloister in Venice, where the lack of protection due to absence of woodwork has favored the constant attack of these two combined elements. The area of action can easily be noticed, like in the above-mentioned case of lower parts unprotected by lintels and cornices (Fig. 7).

3.3 Cases Related to the Use Given to the Construction Element (and Condensation Damp)

3.3.1 Overlaps

The first example given are woods serving practically as a boarding up element, which totally remain overlapped to other elements (Fig. 8).

Also for this reason, the lack of evaporation is fatal for wood because its moisture content always remains over the admissible values in the part in contact with the other substrate.

3.3.2 Inadequate Thrust and Hitting

Constant improper hitting or thrust may cause deterioration of the finish and the material itself, leaving the way in open to moisture and other degrading agents.

In this case, the door leaf that is meant to open has been slammed, especially hit on its lower part, where the sealer has been displaced and fractured. This area is attacked in a much more visible way by humidity than the rest of the door, and particularly more than the left leaf (Fig. 9).

3.3.3 Absence of Hinge Maintenance

Linked to the previous case and the surface capillarity, we can find some others with a peculiarity. The lack of regular maintenance in one of the gate leaves (or both)

Fig. 8 Overlapped wood elements, Venice

Fig. 9 Degradation by hitting, Venice

Fig. 10 Degradation by absence of hinge maintenance, Venice

specifically makes it descend by its central part, thus remaining at the mercy of two kinds of attacks: the hitting and dragging and the capillary action, which produce a first deterioration followed by the above-said attacks (Fig. 10).

3.3.4 Condensation by Glass

There is a case that deserves a special mention for its singularity. Two doors of identical manufacture: the left one or door 1 (left) is in a state of important lack of maintenance, whereas the right one or door 2 (right) is in good condition to the naked eye.

After analyzing the moisture content, it is confirmed that, as expected, the moisture content in the lower part is much more adequate in door 2, which is more distant from the pavement (Fig. 11).

However, glass has been fitted over the higher part of door 2 causing the moisture contents to increase sharply in this part due to the condensation created by the glass and its dripping on the door.

Thus, we can assume that a door kept properly ventilated – for example by leaving it open—can show more adequate moisture contents than the same door if it is closed in a non-ventilated environment.

Fig. 11 Condensation by glass in *right* door, Venice

3.3.5 Inadequate Use of Material

There are cases in which the use assigned to the wood is inappropriate. For instance, this happens with the Venetian *palline*, which, although they are traditional and essential for docking, clash with the saline environment and the change of tide height. It is so much so that changing them twice a year is a very usual proceeding.

Another clear example of that was found in Dakhla, where a thin chipboard sheet served as cover of a humble family's dwelling, which was ruined by the rare rainfalls (Fig. 12).

3.4 Cases Related to the Structure or State of the Element Itself

3.4.1 Disparity of Thickness

Going back to the effect of water absorption and evaporation on wood, one of the factors that have an influence on the transition from one to the other is the thickness of the element. Several cases have been found confirming that a wood veneer less than one centimeter thick will suffer damage faster than structural elements or solid woodwork. This effect occurs without distinction in the different types of humidity and, moreover, not only the lower parts affected by capillary action but also the middle parts affected by environmental humidity are damaged in the same way (Fig. 13).

3.4.2 Putrefaction of Ferrous Elements

The inlay of ferrous elements in the wood may develop in damages caused by the rusting of ironworks which are transmitted to the wood.

Fig. 12 Inadequate use of material, Dakhla (*left*) and Venice (*right*)

Fig. 13 Degradation by the thickness of the elements, Venice

Fig. 14 Degradation by ferrous elements, Venice

At first, the iron increased its volume, growing inside the wooden element. Later, its surface layers come off leaving cavities in the wood previously compressed, letting water seep in. Moreover, the flakes formed in the surface attract water physically as well as chemically. From the physical point of view, as surface tension of water is created between the gaps of such flakes, it remains restrained by the attraction of its own molecules. Regarding the chemical part, the ferric ions generated from the iron-humidity union of wood deteriorate the cellular wall. This union acts as an electrolytic cell, where one serves as anode and the other as cathode.

This combination of factors produces localized damages visible on the surface adjacent to these elements lacking in maintenance.

In the picture we can see different kinds of elements that have favored this type of damage. Railings that become adjacent to the wooden element due to its increase of volume as well as nails, rivets and reinforcements fitted in the element (Fig. 14).

3.4.3 Incisions and Cavities

Also the incisions made by elements that have disappeared create a way in for moisture, like in all the above-said cases in which surface porosity varies. We can see in the picture how the attack of humidity is greater in the areas where there are orifices (Fig. 15).

Fig. 15 Degradation by incisions, Venice

Fig. 16 Degradation by craking, Venice

3.5 Cases Related to the Structure or State of Adjoining Elements

3.5.1 Cracking by Flection

The present picture shows how a crack in a beam/lintel produced by action of the upper wall has favored the easy penetration of humidity in its fibers and, in turn, moisture has brought about the appearance of wood-decay fungi (Fig. 16).

Fig. 17 Degradation by differential thrust, Venice

3.5.2 Thrust

In this case, however, the differential settling of the staircase with access to the doorway creates differential thrust in both leaves of the gate. These gaps between the leaves will generate the said damages for bad use or faulty maintenance of hinges and its subsequent deterioration by damp in the lower parts.

3.5.3 Loss of Material by Compression Action

Here we can see how the beams have suffered loss of material due to a prismatic rupture of its fibers caused by compression stress for overloading. The beam, probably because it is in bad condition, has not borne the load exerted by the upper wall and forging and, in turn, the fracture and loss of material creates a free way in for humidity, with the subsequent attack of fungi and a bigger loss of resistance. This is a clear case of particular circumstances linked, which cause bigger damages (Figs. 17 and 18).

3.5.4 Surface Tension by Sinking

In this picture, we can see how the rendering of a façade repeated for years and even centuries and, consequently, the increase of thickness may be a particularly harmful

Fig. 18 Degradation by lost of material, Venice

situation for a wooden beam. It is now embedded in the wall so that the façade line remains overlapped to it. This creates a water surface tension, similar to that of many sills with absence of run-off for rain, which ends up accumulating water in the beam. The fibrous and cracked state of it, probably due to the joint attack of fungi and sun radiation, worsens the result (Fig. 19).

4 Conclusions

4.1 First Stage Result Analysis

Below, the results and discussion of them will be presented based on the data obtained during the sampling of elements in the three cities.

During the analysis of results, there is a distinction on the moisture limit value for the woodwork (18 %) and structural elements (22 %).

In Venice, 46.94 % of the cases are above permissible moisture levels provided by the moisture meter manufacturer. For the city of Dakhla elements that exceed these levels are the 42.10 % of the sample. However, for the city of Las Palmas de Gran Canaria, there has been only a single item that exceeds the limit values. A preference in the use of varnish over paint has only been observed in Las Palmas de Gran Canaria, corresponding to 60 % of the cases, while in Dakhla is present in 26.32 % of the analyzed elements and in Venice in 24.49 %. This was already observed in a preliminary examination, furthermore, part of the woodwork varnished analyzed in Dakhla is of Spanish construction, and therefore under Spanish construction criteria. The rest are mostly treated with other paints.

In general, the construction elements analyzed in a survey of the city of Las Palmas de Gran Canaria are better preserved state than the others. Ignoring at first possible weather influences and other conditions taken into account when homogenizing the samples, there is another possibility to explain this fact. It may be a

Fig. 19 Degradation by surface tension, Venice

simple question of maintenance of the woodwork and structures. In Las Palmas, the external timber over 50 years that are still in use are usually on listed buildings, in high income areas, cared by their owners or administration.

Although in Venice the owners have higher income, many of these buildings are vacant and neglected, being this, one of the most known problems.

There are two reasons for the damaged state of Dakhla buildings. It could be summed up into the advanced age of the quality spanish constructions and the lack of quality of the recents ones. However, considering that the weather is much more severe in the last two cities, this is a reason enough to find their timber worse.

The timber with moisture content of 40 % or higher, suffered some damage that transformed its fibers, making them a more porous material. Sometimes, unprotected parts of the elements results in a drier state. In this cases, the pores of the material are exposed to direct absorption and evaporation. Due to this, wetting and drying process are faster in this cases. These frequent process can easily deteriorate the uncovered parts, hence the common practice to protect the material by applying products that prevent the pores to be exposed to the weather. Therefore, it can be deduced that dry wood is not necessarily healthy.

In relation to weather action, is important to know that measured values are highly influenced by the capillary action, whereas with a good protection, environmental conditions are less relevant.

4.2 Assessment Achievement of Aims and Objectives

Regarding the initial aims, patterns of characteristic physical and chemical behavior of the material are closely related to the particular circumstances exposed on this work, so the statistical study can only point to patterns generated by climatic or general maintenance peculiarities for each city.

By virtue of the comparative study the effectiveness of maintenance techniques in adaptation to the environment have been noticed higher in Las Palmas de Gran Canaria.

Anyhow, particular circumstances are frequently present in the city of Venice, where good ventilation, especially at the bases of the elements is especially critical to balance the moisture.

The climatology of Dakhla (salt laden winds and sudden changes in daily weather conditions), and Venice (with harsh seasonal changes) are of very negative influence on the effectiveness of maintenance techniques.

Once discovered the wide variety of circumstances affecting the expected state of the material and regardless of location, it is clear that this precious material requires proper conditions of balanced moisture and periodic maintenance.

After this study, we can state that the degrees of absorption and evaporation are essential for the state of the element. Any circumstance which may alter the behavior of wood in presence of them will have an influence when it comes to assess the final state.

The main ones depend on: capillary humidity and the condition of lower areas, accidental moisture and infiltration, the use given to the construction element, element configuration and state of adjoining elements. We can reach the third of the initial objectives once these circumstances classified.

Consolidation Degree Estimation by Means Ultrasonic Analysis in Simulated Constructive Historical Elements

M. A. López, J. Gosálbez, J. R. Albiol, A. Salazar and J. Moragues

Abstract Much of heritage buildings are made of stone, mortar or brick, and degradation processes are inevitable. Due to historical and cultural value, non-destructive evaluation techniques (NDE) are essential for the assessment and restoration tasks.

In this work, we study the capability of ultrasonic to detect fissures and to determine the degree of consolidation in high resistance mortar, similar to historical stone materials. To join this aim, artificial and controlled cracks/fissures have been generated and have been consolidated simulating different types of failures, filling or no adherence. The probes have been analysed by means flexion and compression strength testing, destructive testing. During the process, the probes have been measured by ultrasounds and the results have been correlated with destructive testing results. Their sensibilities have been analysed and justified. It is concluded that certain ultrasonic parameters offers a viable alternative to ED to detect cracks and to evaluate the degree of consolidation.

Keywords Ultrasound • Heritage • Detection • Consolidation • Signal processing

1 Introduction

Much of heritage buildings of our cities are made of stone, mortar and brick as constituent materials. Although they resist along the time, degradation processes are unavoidable and affect both structural and aesthetic properties [1, 2]. Knowing the reality of the historic buildings and their degradation will be of great relevance for the assessment of their conditions of stability and for planning a possible restoration.

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Due to historic and cultural value, it is necessary to preserve the integrity of these elements [3]. Therefore, the detection of its status must be as least invasive as possible and Non Destructive Testing (NDT) [4] should be employed as far as possible: ultrasound, X-Ray, ground penetration radar… These kinds of testing do not alter the analyzed element, it is possible to analyze the whole historical element and it can help to select the intervention techniques. Additionally, they can provide information after restoration techniques to asses if reparation tasks have reached their objective.

Nowadays, this evaluation is usually carried out by means destructive testing which is applied over removed material: resistance, absorption, porosity crystallization of salts, dimensional variations [5] … In this way, an extra degradation and alteration are forced and it is not viable to apply to the whole element.

In this work, we study the capability of ultrasonic [6, 7] to detect fissures and to determine the degree of consolidation in high resistance mortar, similar to historical stone materials. To join this aim, artificial and controlled cracks/fissures have been generated and have been consolidated simulating different types of failures, incomplete filling, poor adherence and no consolidation. The consolidation process has been carried out with epoxy resin [8] and the probes have been analyzed by means flexural and compressive strength testing (Destructive Testing DT). During all the process, the probes have been measured by ultrasounds and the results have been correlated with DT results [9, 10]. The results have been analyzed and justified and it is concluded that certain ultrasonic parameters offers a viable alternative to DT to detect cracks and to evaluate the degree of consolidation.

This work is divided in 4 main sections. The first one corresponds to this "Introduction". The second one corresponds to the testing campaign and describes: mortar specimen preparation, dimension, defects, pathologies, consolidation process, destructive testing, non-destructive testing, ultrasonic equipment, signal processing related to ultrasonic signals… In Sect. 3, the results are analyzed and justified and finally, section 4 describes the main conclusions. The authors would like to remark that this work was carried out at Architectural Constructions facilities in collaboration with iTEAM and that presented photographs and graphics are original of this work.

2 Testing Campaign

2.1 Mortar Specimen Preparation

For this testing campaign, we have used mortar as basic material. The dosage was selected to obtain high resistance mortars, similar to the heritage stone materials (compressive strength over 100 MPa). Table 1 shows the percentages of the used materials. The mixing process is done in 5 L mechanical mixer with two speeds according to specifications (UNE-80102 'Determination of setting time and volume stability'). The kneading process is carried out in order, respecting and repeating

Table 1 Percentage of dosage

Material	Batches (%)			
	1	2	3	4
Silica fume	7.81	7.83	7.84	7.84
Cement	38.98	39.20	39.18	39.18
Arid 0/2	26.43	26.05	26.06	26.05
Water	9.70	9.79	9.80	9.80
Aditive	2.31	2.36	2.35	2.36
Alumina silicate	14.77	14.77	14.77	14.77

Fig. 1 Cutting process

kneading times for each of the elements, the total time per each batch was about 13 min and 30 s. Once the kneaded is done, we proceed to fill prismatic mold of 40 × 40 × 160 mm, providing three samples per batch and compacting with 25 strokes with standard UNE-80102 compactor. Therefore, a total of four batches were done with the same dosages, representing a total of 12 samples (Figs. 1 and 2a).

Sound state or Stage 1 The curing process was performed in a moist chamber for 24 h. After this period, the specimens were demolded and immersed in water at 60 °C for 72 h. Throughout the experimental program, the specimens were kept in a moist chamber to preserve and maintain the state of saturation. All the probes are still in perfect state, therefore this stage was called "Sound state" or "Stage 1".

Unsound state or Stage 2 The cracks or defects were modeled as a cut that is made with a circular cutting disk in one of its sides with a thickness of 0.5 cm and a depth of 2 cm (Fig. 2f). We call this state as "Stage 2" or "Unsound state" because the probes present pathology (crack). One of the probes was left as pattern specimen (Probe 4.1).

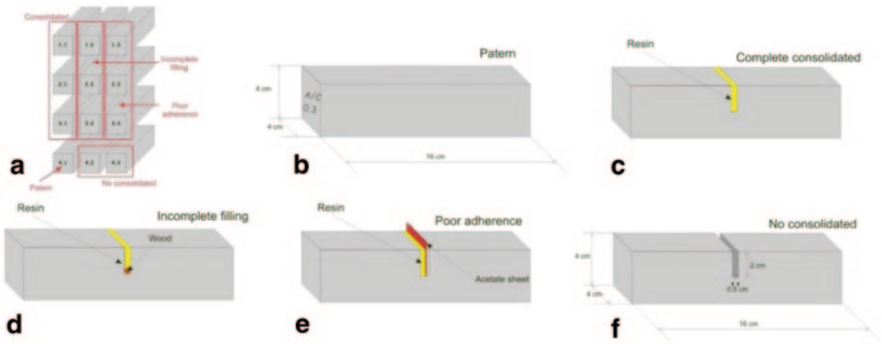


Fig. 2 Batches probes and kinds of implemented consolidation

Consolidated state or Stage 3 Once the specimens were artificial and controlled damaged, we proceeded to repair the crack by means an epoxy resin, in this case Sikadur ®-32N model (SIKA), which has a very good adhesion on fresh concrete or mortar with rapid hardening and high strength. We call this state as “Consolidated state” or “Stage 3”. For this purpose, the following types of consolidation were carried out: probe “Pattern” (Fig. 2b), which remained intact. Second, “Incomplete filling” (Fig. 2d), a piece of wood was put at the bottom of the probe to avoid that resin fill completely the defect. Thirdly, “Poor adherence” (Fig. 2e). An acetate sheet impregnated with oil was put in one side of the crack. This fact provokes that the resin did not stick on one side. Finally a unconsolidated probe (Fig. 3f).

2.2 *Ultrasonic Equipment and Measurements*

The performed ultrasonic analysis was through/transmission technique. This technique is based on injecting an ultrasonic pulse from transmission transducer. This pulse propagates through the material and is received and recorded by the receptor transducer. The acquired pulse is analyzed to determine its changes respect to the transmission one and correlate this change with physical properties of the material.

In this application, all specimens were measured during the whole process: sound state, unsound state and consolidated state. Two different measurements were taken for each specimen and for each state: direct measure along its longitudinal axis (Fig. 3) and indirect measure along its vertical axis (Fig. 4). Different ultrasound frequencies were tested: 500 kHz, 800 kHz, 1 MHz, 2.25 MHz and 5 MHz. Although high power ultrasonic equipment was used, finally 1 MHz (K1SC General Electric) frequency was selected because it was the higher frequency that was able to pass through the longitudinal axis and be detected. The ultrasonic equipment was MATEC PR5000, that it is high power equipment. The acquisition equipment was a digital oscilloscope, TDS3012, and the sample frequency was setup at 100 Mhz with a total scanned time of 100us.

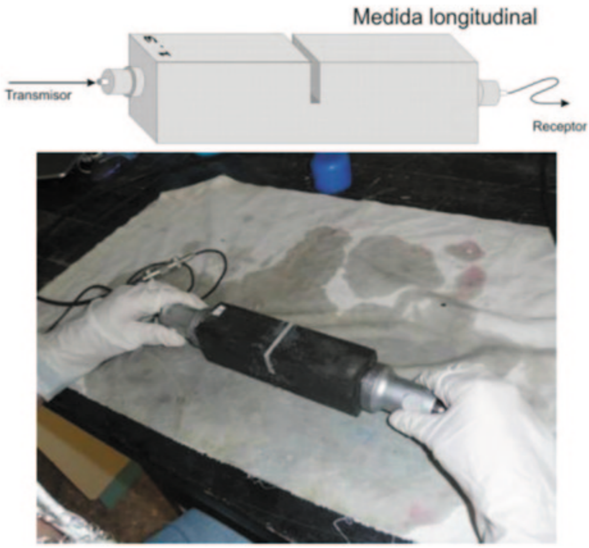


Fig. 3 Longitudinal measurement (direct)

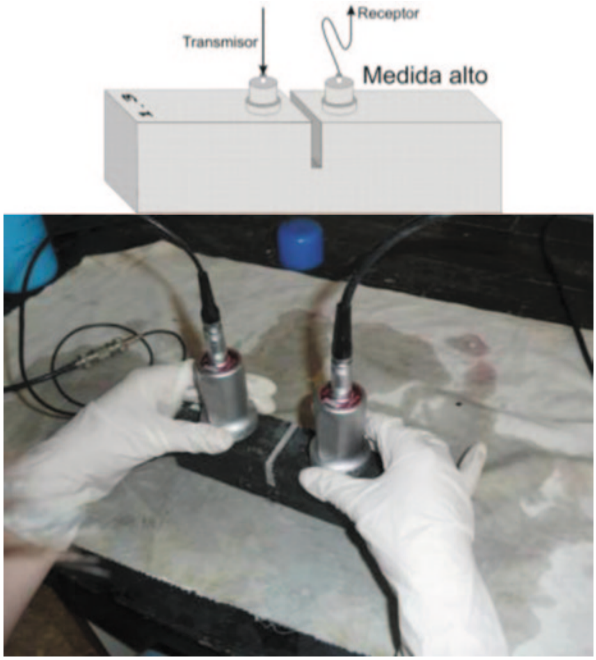


Fig. 4 Height measurement (indirect)

Different parameters can be extracted from ultrasonic signals [11] to be correlated with destructive testings/consolidation state. But in this work, we have used two habitual parameters, velocity and signal received power. The propagation velocity is estimated beginning from time of flight. This time flight is obtained when the signals is over the 30 % of the maximum of the enveloping signal.

For the received signal power, we used equation (1) that is estimation of signal power for the discrete signals. For this case, the power has been estimated between samples 3150 and 5500 for the longitudinal measurements that correspond to 31.5 μs and 55 μs respectively.

$$P = \underbrace{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} |x(t)|^2\, dt}_{\text{Continous signal}} = \underbrace{\frac{1}{N_2 - N_1 + 1}\sum_{N_1}^{N_2} |x(n)|^2}_{\text{Discrete signal}}$$

2.3 Destructive Testing

Once all ultrasonic measurements were taken and the consolidation process was done, destructive testing was performed to validate the capability of ultrasound to estimate the degree of consolidation. The destructive testing were flexural strength (R_F) and compressive strength (R_C). The method for R_F (N/mm^2) was the concentrated load taking strain measurement using a strain gauge "Ibertest". The load was applied vertically at the center of the prism with a uniform increase at a rate of 10*N/seg* until failure. One half of each sample was collected for R_c (N/mm^2). All data were recorded using a computer equipped with a control program.

Taking into account these, we can assume that R_C is associated to intrinsic properties of the material and R_f is associated to the kind of pathology and its consolidation.

3 Analysis and Justification of Results

Finally, the useful measurements were the longitudinal ones. Indirect measures produced a no-clear arrival signal and significant deviations were introduced in velocity parameter. By the other hand, power and frequency parameters did not show a great sensibility because the consolidated zone was not irradiated properly.

The first analysis that was performed was comparison between NDT parameters of Sound state against R_C. It is important to remark that R_c is not conditioned by the defect, so we are verifying the capability of ultrasound to detect the intrinsic properties of material. This analysis shows good correlation index for linear tendency (Fig. 5) for all measurements and parameters.

By other hand, if NDT parameters of sound (Stage 1) are compared with NDT parameters of Unsound state (Stage 2), we can appreciate a decrease of velocity and power. The decrease of mean velocity is around 0.71 % that suggests that this parameter is not useful for defect detection. By other hand, the decrease of power is around 5dB (implies a 50 % of power in W) that is enough significant for defect detection. The velocity is not able to detect this kind of defects because the defect is not large enough to suppose a significant velocity reduction, while it is for power reduction. This fact has been verified by means simulations (Table 2).

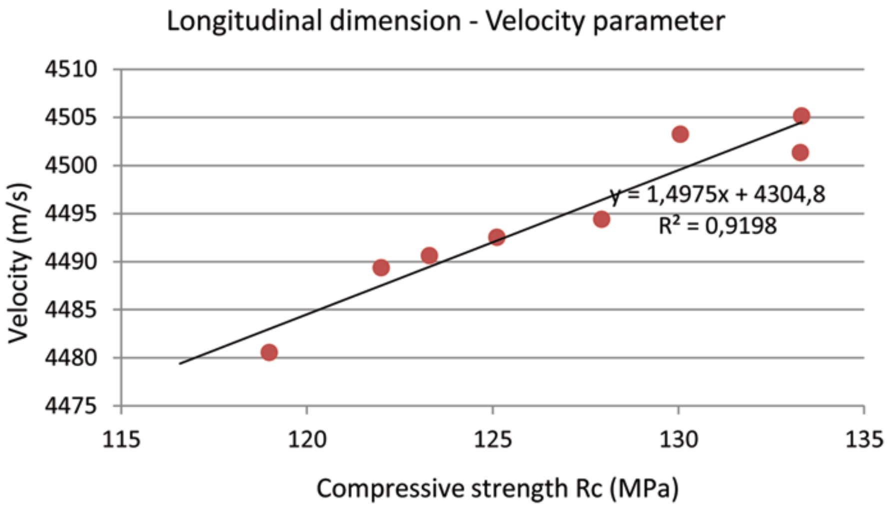


Fig. 5 R_C vs velocity in sound state

Table 2 Correlation index for ultrasonic parameters

	Velocity	Power
Longitudinal dimension (direct)	0.91	0.78
Height/width dimension (indirect)	0.74	0.75

Finally, we analyze the capability of ultrasound to determine the consolidation degree. To reach this objective, firstly we demonstrate that R_f is conditioned by the kind of consolidation as it is showed at Fig. 6. It is important to notice that "Non consolidate" probe and "Poor adherence" probes have the same low R_F because the gripping surface is null for both cases. Therefore, if NDT parameters of the Consolidated state (Stage 3) are correlated with R_F, we can conclude that this is a viable technique to estimate the consolidation degree. In Fig. 7, we can see a correlation index over 0.8 between ultrasonic power and R_F. Therefore, we can assume that ultrasonic power parameter is able to detect the defects and to estimate the degree of consolidation. Again, the velocity parameter did not offer good results (correlation index below 0.2) because the defect is not large enough to do a significant reduction of velocity.

4 Conclusions

In this work, we have tried to demonstrate that ultrasonic NDT is able to detect the presence of cracks and its capability to estimate the degree of the consolidation after repairing tasks in heritage stone materials. To join this aim, firstly high resistance mortar probes similar to heritage stone materials were made. Secondly, an artificial

Fig. 6 Relation between kind of consolidation and R_F

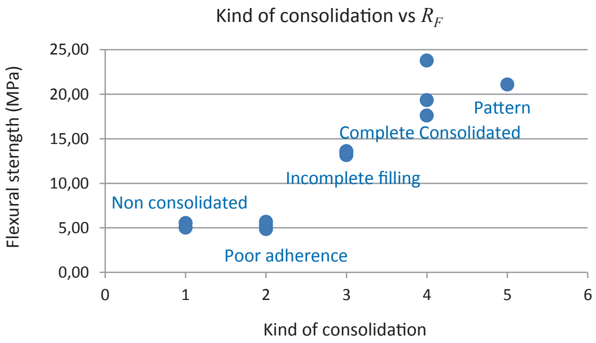
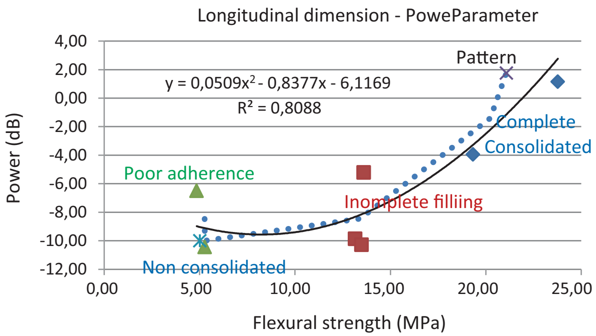


Fig. 7 R_F vs ultrasonic Power for Consolidate status in direct measure



crack was done and consolidated with different types/problems of consolidation: no consolidation, poor adherence, incomplete filling and complete filling.

Thanks to ultrasounds are a non-destructive testing, all the probes were measured in all states (sound, unsound and repaired) and ultrasound power and velocity were compared against destructive testing. We have demonstrate that ultrasound power is a high sensitive parameter to detect defects and to estimate the degree of consolidation because it is correlated quite well with R_F. By other and, velocity requires larger defects to suffer significant deviations. Despite of this, velocity has lower variance than power.

Therefore, ultrasound non-destructive testing is capable to detect defects and correlate with destructive testing parameters offering an alternative to these ones.

As future work, the research equipment is preparing an ultrasonic evaluation by means phased array and time diffraction technique that are novelty techniques in heritage applications and it is hoped that this methods can provide punctual information of the consolidated crack.

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Ray Tracing Study of the Effectiveness of Acoustic Intervention in the Church of Santa Maria De La Valldigna Monastery

P. Serrano, I. Guillem and V. Gómez

Abstract Nowadays many ecclesiastical enclosures are not in use and therefore they present an important state of deterioration. To prevent this and trying them to remain part of our heritage, we propose to give them some different uses from those for which they were initially projected. In this study, we research the possibility as concert hall areas.

In this paper, we study the acoustic parameters of the "Monestir cistercenc de la Mare de Déu de la Valldigna" Church through simulation methods by Ray Tracing techniques. This study was performed before and after an ephemeral planned acoustic preparation in order to be able to host a concert series of chamber music, with a relatively low economic cost. The main paper objective is to test the suitability of the proposed intervention to convert the church into a place to perform actions of different musical groups.

Keywords Simulation • Acoustic • Church

1 Introduction

Currently it is very common to find old ecclesiastical buildings, which are obsolete, and therefore, unused. These big and important buildings usually with a high degree of heritage protection should be kept in good condition for the future. It does so by harboring a different use for which they were designed.

This work shows how the group of Acústica Arquitectónica y del Medio Ambiente of the Universitad Politécnica de Valencia contributes to the heritage conservation. A temporary intervention was project to adapt the main church of the Monestir for planning sacred, choral or chamber music concerts with a reasonable cost and heritage friendly.

The main challenge for the churches acoustic design are their own architectural features. Mainly the high ratio main volume to surface and the stone and painted

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surfaces are the reason for a high reverberation time with an insufficient musical clarity and a low intelligibility.

The work focuses on the results obtained by the simulation software ODEON future opportunities on further works.

2 Method

This study is based on the acoustic simulation like a virtual environment in which the acoustic performance is simulated with a high degree of reliability. Here we use the simulation like an analysis tool who let us know the effects on the acoustic performance before work begins. The effects of different configurations would be evaluated.

The first was the realization of a simplified 3d cad model (Fig. 1) for the church. Then he model was transferred to the simulation software. On the acoustic model the absorption and diffusion coefficients were assigned to the interior surfaces.

A validation model was run. The acoustics measurements were compared to the results for the simulation model under the same acoustics and architectural conditions. An iterative simulation procedure was needed to match the results between the virtual environment and the real performance of the building.

Once the model and method were validated, three different simulation scenarios were performed. Before intervention (Sit 0), empty hall after the intervention (Sit 1) (Fig. 2) and the last one, the hall full of public and musicians on the stage (Sit 2).

All scenarios were simulated under the same conditions:

Interior temperature:	20 °C
Relative Humidity:	50 %
Air density:	standard
Impulsive response length:	9.000 ms
Number of rays:	50.680
Scattering method:	Lambert

The source was placed on the stage with a high 1.5 m and on the axis of symmetry. The onmidirectional source was defined with an overall gain of 90 dB, and pink noise signal.

The five receivers were placed within the public area. Four of them were fixed on the symmetry axis 5 m interval. And the last one was placed on the lateral axis. The height was fixed to 1.2 m above the floor.

The proposal consist on the placement of carpet on the public area and corridors. Velvet curtains covering the side chapels and a wood stage complete the intervention.

The absorption coefficients used for each material [1] on the simulation are shown in the Table 1.

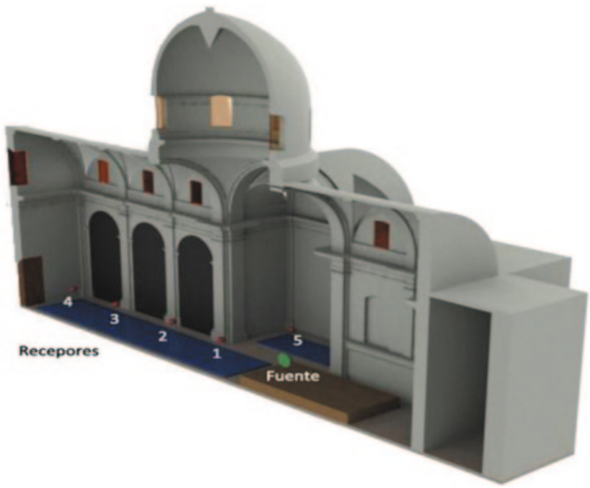

Fig. 1 Simplified 3d cad model. [5]

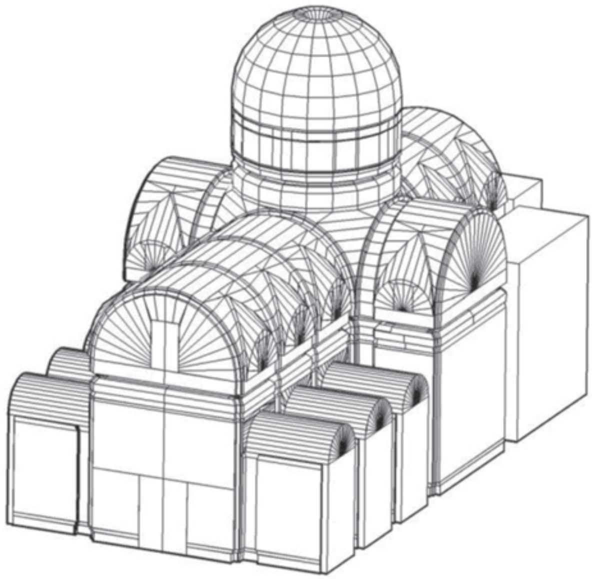

Fig. 2 Simulation scene Sit 1. [5]

3 Results

The parameters obtained for the tree scenarios were: RT30 (RT_{mid}; BR; Br), EDT, Ts, SPL, C80, D50, LF80 y STI. The following analysis focus only on the musical performance parameters, the intelligibility parameters were left.

Table 1 Coefficients used for each material. [5]

Description	Code	Frequency							
		63	125	250	500	1000	2000	4000	8000
Walls	14301	0.05	0.05	0.06	0.08	0.095	0.095	0.065	0.035
Single glass	10001	0.18	0.18	0.06	0.040	0.030	0.020	0.020	0.020
Wood door	10007	0.14	0.14	0.10	0.060	0.080	0.100	0.100	0.100
Marble	2001	0.01	0.01	0.01	0.010	0.010	0.020	0.020	0.020
Wood stage	3000	0.40	0.40	0.30	0.200	0.170	0.150	0.100	0.100
Empty church pews	14302	0.37	0.55	0.50	0.150	0.100	0.050	0.050	0.050
Velvet curtains	8010	0.14	0.14	0.35	0.550	0.720	0.700	0.650	0.650
Occupied church pews	14303	0.57	0.57	0.61	0.750	0.860	0.910	0.860	0.860
Musicians on stage	11000	0.27	0.27	0.53	0.670	0.930	0.870	0.800	0.800

Table 2 Temporal parameters. [5]

Parameter	RT_{mid} (s)	BR	Br
Sit 0	4.44	1.49	0.72
Sit 1	3.29	1.25	0.8
Sit 2	2.35	1.69	0.8

Table 3 EDT_{mid} values. [5]

Parameter	Sit 0	Sit 1	Sit 2
RT_{mid} *(s)*	4.44	3.29	2.35
EDT_{mid} *(s)*	4.53	3.39	2.39

3.1 Temporal Parameters

The parameters referred to RT are shown on Table 2 for the three scenarios:

We can see that a noticeable improvement on the $\mathbf{RT_{mid}}$ values with the proposal. Although it has not succeeded in reaching the optimum values ranging between 1.3 and 1.8 s [2] for baroque and chamber music.

On the **BR** values we can notice that not further improvement were reached. In this case, for high RT values the BR value is desirable to be around 1.25 [2]. For example in the Sit 2 we obtain. A higher value tan on the scenario Sit 1 (BR = 1.25). This may be due to the absorption on the public area for medium and high frequencies without modify the low frequencies absorption. The hall low frequencies response result excessive.

On **Br** values, the hall conditioning approach enough to the recommended values (0.87) [2], we obtain for the different scenarios from 0.72 to 0.80 for Br values. We can affirm then the harmonics richness will be short but, but sufficient. We can see that the presence of public not affect like on the BR value.

The results for $\mathbf{EDT_{mid}}$ (Table 3) are similar to the RT_{mid} values for each scenario. We can see that the diffusion of the hall is not affected by the proposal and remain into the optimum range [3].

Table 4 SPL values. The difference between receptor 1 and 4. [5]

Frequency (Hz)	63	125	250	500	1.000	2.000	4.000	8000
Receiver 1 Max(dB)	69.4	69.5	67.8	66.5	65.1	65.1	64.9	62.9
Receiver 4 Min (dB)	66.4	66.9	64.1	61.6	59.4	59.2	58.5	54
Difference (dB)	3	2.6	3.7	4.9	5.7	5.9	6.4	8.9

Table 5 C_{80} values [5]

Parameter	Sit 0	Sit 1	Sit 2
C_{80} *(dB)*	−5.73	−4.02	−0.8

Table 6 LF_{80} values. [5]

Parameter	Sit 0	Sit 1	Sit 2
LF_{E4} *(%)*	16.50	−17.20	16.37

3.2 Energetic Paramaters

The **SPL** values registered (Table 4), shown that the differences between receivers increase with the distance from source. The differences between receptor 1 and 4 (more distant) are in some frequencies above the just noticeable difference for SPL with values around 5 dB. The difference increase with the frequency. This can cause the sensation of hearing in the last rows of the audience is smaller than near the stage.

The $\mathbf{C_{80}}$ values obtained fall within the recommendations once the refurbishment of the church will be completed (Table 5). Very right for the empty room scenario ($-4 \geq C80\ (3) \geq 0$ dB) [2], and better for the occupied room ($-2 \geq C80\ (3) \geq 2$ dB) [4].

3.3 Special Parameters

Finally we detail the data obtained for $\mathbf{LF_{80}}$ (Table 6). We note that none of the simulations to arrive at the minimum recommended value of 19 % [4].

The percentage of this parameter increases as the amount of lateral early reflections arriving at each receiver. For the values in each of receivers, in all simulations, only two of them satisfy this parameter, the receivers 2 and 5. The rest of them do not receive sufficient early lateral reflections for the following reason in each scenario

- Sit 0. When the direct sound reach the side chapels, the first and second reflections are lose, coming back the sound to the nave with an important delay.
- Sit 1 and Sit 2. The placement of the velvet curtains, acoustically high absorbing material, to avoid excessive reverberation time in the churches, cause that the first lateral reflections are attenuated excessively and result in LF values for receiver 1, 3 and 4 are too low.

This effect can be seen on the following color map (Fig. 3):

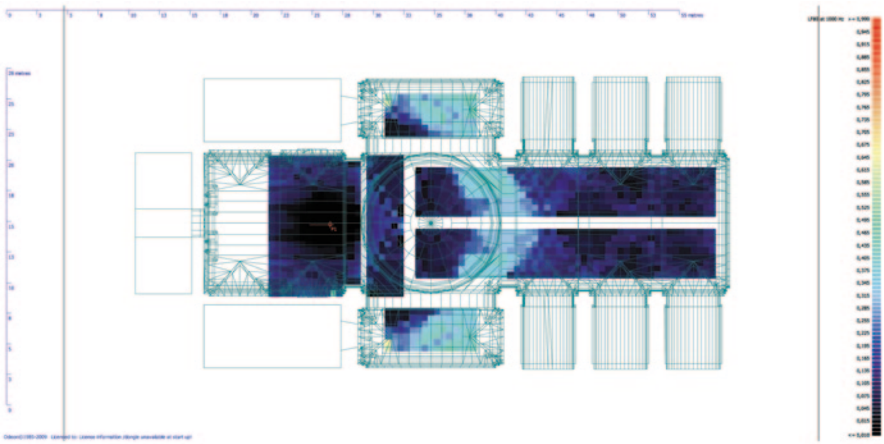

Fig. 3 LF_{80} color map Sit 1. 1000 Hz. [5]

4 Conclusions

As overall conclusion, is exposed that with the proposed intervention, simple, practical and relatively low economic cost, we can improve the acoustic conditions for the "Monestir cistercenc de la Mare de Déu de la Valldigna" Church. In this case the difficulty concerns to work on a type of buildings with heritage conditions.

It has been found that we can enhance the values of acoustic parameters in churches, but also is reflected the difficulty of reaching results within the optimum range for music listening.

The reflective materials that cover up the inner surfaces of the church, cause the high values for RT. These very high RT values makes it can easy to reduce the reverberation. This value is even higher for proper quality musical performances, and thus other values of BR and the EDT. In contrast, the opposite situation appears for musical parameters such as clarity or definition with values that do not reach the recommended minimum. Although, if it is true that the subjective feeling of improvement in the quality of the enclosure is largely perceived by the public.

So, mainly for this reason it is difficult to get accurate optimal settings for the type of music that can be interpreted in the church. There are not more places for increase the absorption of the hall as the audience surface without damaging or changing the architectural and artistic features of the church apart of hanging curtains on lateral chapels.

Should be taken in mind that although you get to have perfect hearing, with small actions we can make the room sound better. Probably these small gaps in the acoustic parameters obtained are offset by the beautiful space of the concert hall and the audience is likely to offset this difference, thus, give functionality to these buildings and get conservation of an important part of our heritage.

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Architectural Heritage as a Source for Development. The Need for Indicators to Recognize Its Contribution

J. Monfort i Signes, I. Tort Ausina and M. J. Vidal Lucas

Abstract The international cooperation for development has been reducing inequalities between individuals and peoples for five decades. In this context, the architectural heritage has a great potential for the development of communities. However, cooperation projects related to architectural heritage present sometimes a problem, which is the evaluation of their results, because, in many cases, the degree in which the objectives have been achieved is hard to assess. This handicap contributes significantly to question the effectiveness of this type of projects over others. This difficulty in assessment is due to the lack of indicators that should quantify how the intervention contributes to the development and promotes economic growth but also helping individuals and communities to expand their life choices and adapt to change. In short, to demonstrate how the architectural heritage is integrated into the sustainable human development.

Keywords Development • Cooperation • Architectural heritage • Indicators

1 Introduction

For more than five decades, international development cooperation has been combining efforts to reduce inequalities among people worldwide. The earliest conceptions exclusively focused on economic development have evolved to a developing idea more focused on human aspect, which not only provides an economic process. Above the material well-being, a more satisfactory and more valuable existence of individuals must be added.

In this broadest concept of development, what is called sustainable human development is where culture plays an important role. Cultural cooperation on the one hand is able to improve the living conditions of a community from an economic

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aspect, but it is also a way to preserve the values and traditions, promoting access to knowledge and building capacity of action by the people in community cultural life. So if culture is a valid instrument for the human development, architectural heritage has great potential as a resource to generate the community development.

This heritage can be analysed as a resource for development and as an element from which to formulate Development Cooperation Projects. The analysis is made in order to know which way the project formulation and implementation take into account the Millennium Development Goals [1].

2 How to Generate Architectural Heritage Development?

According to UNESCO, Heritage is our legacy from the past, with what we live today and what we will pass on to future generations. The Krakow Charter adds that Heritage is the set of the works of human beings in which a community recognizes its particular and specific values and with whom he identifies [2]. We tend to associate the idea of heritage with material culture and on the contrary we are interested to understand, preserve and spread the intangible aspects of the past. The real heritage is in the system of ideas, in the philosophy that inspires and supports the materiality of objects and buildings [3].

In its broadest sense, heritage is the set of goods inherited from the past. Therefore, the architectural heritage can be defined as the set of built assets of any nature, to which each society attributes or recognizes a value culture [4]. But this is a dynamic definition, as cultural values are changing, this implies that the concept of architectural heritage is constantly building and the objects that make up this heritage are an open set, subject to change and especially open to new additions.

Traditionally the idea of architectural heritage has been assimilated with the idea of "monument" for its historical, artistic and abstract worth preserving for their usefulness or potential use. Today the concept has been expanded to include other properties and buildings so far not considered. An example is the traditional architecture, buildings related to craft activities or industrial buildings. Another aspect, as important as the one previously mentioned, is the architectural heritage, which is conceived as a part of a whole, that is, groups of buildings that form urban historical centers, monumental sets, urban weaves, gardens, etc.

Heritage in general, and therefore architectural heritage, is in itself a priceless treasure that gives consistency to the idiosyncrasies of people and, at the same time, it is a reference for the interpretation of history. That is because heritage concentrates three types of values: The first one, social value, is useful to identify with other people, internal cohesion and a collective representation. The second one is the scientific value, for its potential to generate historical and cultural knowledge. The last of the values, the economic one, is today more apparent since the heritage is becoming one of the most important driving forces of local and regional economic growth through tourism.

These three values that are attributed to the architectural heritage are the ones that have to exercise to generate development. As an important factor in economic development, it is well known that the strengthening of cultural industries or heritage conservation through cooperation is an element that can improve the lives of a community. A new cultural cooperation element has to be considered to a greater extent today because of the cultural tourism.

Despite this economic factors are not, or should not be the only ones to take into account cultural cooperation, this could lead to a vision of architectural heritage not as a means but as a purpose. If we recognize the instrumental role of culture in the development of societies, then this cannot simply be a factor of economic progress. It must also reassert itself as a way of preserving values and traditions give access to knowledge and increase the people capacity intervention in community cultural life. It is, in short, that intervention in the architectural heritage act as a factor of empowerment of the society.

We can say that the intervention in the architectural heritage can contribute to improve the lives of people. So the performances should go beyond the mere physical intervention, promoting and facilitating socio-economic structures by sustainable use of heritage. Thus, the general objective is further complemented by cross-cutting objectives to promote equality between men and women, respect for the environment, contribute to democratic governance, promote human rights and respect for cultural diversity. Therefore, the appreciation of heritage involves cultural, economic and social aspects, which are also complemented by institutional strengthening, valuation, social ownership and training.

3 Why Do We Need Indicators?

When we deal with a Development Cooperation Project (DCP) for an intervention in architectural heritage. The purpose of cooperation should not be the intervention itself. The overall objective is to aim at a solution to a situation that can improve, trying to transform a reality that presents a problem or need which has been identified previously. In short, the objective is the development of an impoverished community in the broadest sense. As we have already mentioned before the heritage can solve the equity in two ways, both desirable. First of all, as an important factor of economic growth, and secondly as a means of preserving values and traditions, giving access to knowledge and increase the people capacity of intervention in community cultural life. Ultimately what we call sustainable human development. This is the reason why intervention in architectural heritage becomes the strategy to achieve the overall objective of the DCP.

The biggest problem we find in the DCP in architectural heritage interventions is the evaluation of results. While the objectives are properly defined, it is not always easy to verify that these objectives have materialized once the project ends. This has contributed markedly to question the effectiveness of interventions in heritage as a source of development and consequently its convenience over other types of interventions. There is a difficulty in the evaluation by the lack of indicators. These should explain how the intervention in heritage contributes to development, fostering economic growth but also helping individuals and communities to expand their life choices and adapting to change. In short, how the heritage as cultural value is integrated into the sustainable human development [5].

According to UNESCO, although in recent years increasing attention has been paid to the role of culture as a vital element of development processes, policies and programs still face an important challenge: the lack of data and indicators that measure the relationship between culture and development. This has led to a certain marginalization of culture in international cooperation programs and national development strategies [6].

For this reason it is necessary to look for indicators that allow us to assess the achievement of the objectives set out in the DCP, and demonstrate how culture fosters the development in an effective and sustainable way, adding value at the same time to exposing the potential and value of culture in order to be recognized as a development priority in itself.

4 What Should Indicators Measure?

The assessment is the systematic and objective study of a project, program or policy in progress or completed, its design, implementation and results. An assessment will need to provide credible and useful information, enabling the incorporation of lessons learned into the decision making process.

It is, therefore, the analysis of the results and effects of a project, during or after the execution. It is essential to learn from experience. Therefore, the evaluation must be conducted in each phase of the project, from identification to its effects and after its conclusion. The indicators must be used with their respective sources for verification in order to evaluate each characteristic aspect of the project.

The sources we use to obtain verification indicators will be appropriate and defined. For information check these sources need to use the necessary techniques. These techniques can be quantitative or qualitative, as the indicator. Quantitative techniques give us a set of values with which it is easy to make a synthetic and numerical analysis and are useful for validation of hypotheses. Qualitative techniques, on the other hand, are used to analyse processes, dynamics of action and behaviour that can not be quantified with numbers, as well as help to relate the quantitative variables, with them we can assess attitudes and motivations.

In the area of cooperation there is a general consensus in reference to the aspects that must be evaluated from a Development Cooperation Project, these are:

- Effectiveness: it measures whether the objective and the results have been or may be achieved. This attribute refers to the level to which the objective of the project has been completed. That is, the goal has been successful in the population and time defined during the project design. This criterion does not value the resources spent to achieve the objective.

- Efficiency: analysis of the results in relation to the effort. Measures the relationship between inputs or resources expended and results. It is to say, the efficiency with which resources are spent must be assessed.
- Impact: the changes and effects, both positive and negative, intended or not intended project in relation to beneficiaries and other stakeholders. This criterion measures the effect that the project has on the environment in the broadest sense. It is to identify the net effects and check the causal link between the project and impact. It is the most difficult and laborious criterion to evaluate. In order to be measurable in a clear way, it must always be done after a while of the completion of the project.
- Relevance: to what extent the project is justified in relation to the priorities of local and national development. Analysing the relevance it must be assessed if the project is within the overall objective, policy and strategy of the donor and the counterparty and the needs and priorities.
- Feasibility: to analyse to what extent the positive effects of the project will continue after the end of foreign aid. For this last criterion it has to be evaluated if the sustainability of the project in time is taken into account and if the effects produced by the project are maintained independently. It must assess the chances of success, risks of failure and the difficulties to be avoided.

5 Conclusions

Given the challenges of poverty and the urgency of action on specific regions, it seems that to deal with the architectural heritage is not very appropriate comparing with priorities such as hunger and health. But we must emphasize that the heritage is not the subject of development cooperation, but it is the resource whose aim should be to contribute to sustainable human development in these communities.

This paper tries to stress the need to find a number of indicators relating the development and heritage. These indicators should demonstrate the impact and extent of the valuing architectural heritage and emphasize the potential of its management as a generator of development.

This approach to heritage, as a tool for cooperation for development, has been also widely discussed in this paper.

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System of Barracks and Military Areas as an Opportunity for Urban Regeneration

A. Tartaglia, M. Gambaro and J. Stanojev

Abstract Urban development of the city Novara (Italy), as for the other medium-sized Italian cities, was characterized with the presence of architectural complexes intended for military activities and functions.

Nowadays, activities by the local administration have been oriented in two directions: one direction is to promote procedures and applicable tools of PRG (General Plan of Urban Regulation) in order to make possible functional transformations (program "Città della Salute e della Scienza di Novara" and PPE "Polo di Innovazione") and the second direction is creating specific protocols with Agenzia del Demanio (Agency of the State Property) to establish criteria and regulations for cultural, economical, social and environmental valorization of public properties (program "Valore Paese").

Starting from the case study of Novara the paper develops and establishes a model and criteria for valorization of state-owned properties, also for other Italian contexts, with particular attention to the concept of social housing and developing sustainable hypothesis of valorization.

Keywords Valorization • Public private partnership • Urban regeneration • Architectural technology • Environmental design

1 Introduction

Urban development of the city Novara, as for the other medium-sized Italian cities, was characterized with the presence of architectural complexes, intended for military activities and functions. Located in central areas or very close to the historic center, those complexes have been considered as an anomaly in planning and development processes. They are important for the volumetric consistency and very often present inherent limitations to the same function that led to the hesitation and lack of strategies and regulations. This situation, without doubts, has been a limit for the

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Fig. 1 The military areas in Novara

development and transformation of important urban areas, still characterized by the presence of these isolated and unknown parts.

The problem of renovation and reuse has attracted attention of residents. Administrators have used that problem to construct scenarios of transformation and urban regeneration. Usually, those, often exercise, projects were only oriented to the building manufacturing and quality of single architectural project and design. That approach had presumption that the work of architecture could, by itself, constitute and serve as a basis for the urban rehabilitation of the entire isolated part, able to attract investors and develop processes of social and economical valorization. Naturally, there were no results and numerous studies had just preference to the technical and cultural approach.

2 Main Military Areas

The case of Novara represents an interesting experiment for some processes already realized and processes which are under implementation and planning.

The system of barracks and military areas are organized inside the urban structure in four areas (Fig. 1).

2.1 Barrack Perrone

The former Barrack Perrone is in the historical center. It was abandoned by military use already in July 1945 and used as a transit camp for soldiers and former prisoners of the war. After that period it was used for years as a shelter for Dalmatian refugees.

Nowadays, Barrack Perrone, is seat of the Facoltà di Economia dell'Università degli Studi del Piemonte Orientale Amedeo Avogadro di Novara (Faculty of Economics, University of Eastern Piedmont Amedeo Avogadro, Novara). In 2006, University promoted international design competition, for transformation into university campus, with residence for students, teachers and related services. This intervention is in phase of realization [1].

2.2 Piazza d'armi and Former Polveriera

The buildings formerly known as Piazza d'armi (Square of arms) and former Polveriera, are on the south part of the city, located on the edge of the urban built environment. This area includes large open area and 18 buildings used as military depots. The complex is included in the program "Città della Salute e della Scienza di Novara" (City of Health) [2] and it will be transformed into the new hospital in Novara and the seat of the Faculty of Medicine and Surgery, University of Eastern Piedmont Amedeo Avogadro. l'Azienda Ospedaliero Universitaria Maggiore della Carità di Novara promoted international competition for preliminary and final design of the new complex in 2009. The project is currently in phase of preparation for final draft [3]. This property has passed transition from l'Agenzia del Demanio to the jurisdiction of Piemonte Region, as a supervising body.

2.3 Barracks Passalacqua, Barracks of Gherzi and Barracks of Horses

The complex consists of the Barracks Passalacqua, Barracks of Gherzi and Barracks of Horses, located on the southern edge of the historical center. Each of this barracks occupies an entire block, forming a barrier between building of the higher school and the large residential area to the south. Barracks of Horses is still under responsibility of Ministero della Difesa (Ministry of Defence) and it is partly used, while Barracks Passalacqua and Barracks of Gherzi are abandoned and unused for many years and today they are under the responsibility l'Agenzia del Demanio. Also, they are included in the program "Città della Salute e della Scienza di Novara".

2.4 V Central Warehouse

The complex of former V Central Warehouse, is located in a district of Sant' Agabio and it can be considered as a link area between Quintino Sella Channel and industrial chemical center. It is consisted of nine buildings with depot function. Buildings are in the state of obsolescence and unused for many years, and under the responsibility l'Agenzia del Demanio. The properties are in area of intervention from Piano Particolareggiato Esecutivo, PPE (*Detailed Executive Plan*) public initiative called "Polo di Innovazione" (*Innovation Centre*), adopted by City Council in 2010 [4].

3 Current State of Valorization Process

Activities undertaken by the Administration to valorize properties have been oriented in two directions: one direction is to promote procedures and applicable tools of PRG (General Plan of Regulation) in order to make possible functional transformations (program "Città della Salute e della Scienza di Novara" and PPE "Polo di Innovazione"). The second direction is creating specific protocols with l'Agenzia del Demanio (Agency of the State Property) to establish criteria and regulations for cultural, economical, social and environmental valorization of public properties (program "Valore Paese"). Former Barracks Perrone is exception, because it is the seat of the University from 2001 year and therefore is already the subject of a project for reconstruction and reuse. Process of valorization for all other properties has started.

Protocol of City of Health [5] provides a set of activities in order to implement new university hospital center of regional importance and services connected to it, that are integrated with the program of reorganization for "Centro integrato servizi sanitari territoriali dell'ASL" (Centre for territorial integrated health services of Local Health Trust). The main institutional actors of the area signed the protocol on January 2008. The general strategy includes area of new hospital (former Piazza d'armi and Polveriera) and agricultural areas inside the Parco della Battaglia. Beside that area, strategy includes participation in interventions of single program and complementary interventions. Interventions of single program are planned for the area of the historical hospital site San Giuliano, as well as, areas near large military properties (Barracks Passalacqua and Barracks of Gherzi) and complementary interventions are planned for abandoned or partially used municipal properties (former Macello, Marcato all'ingrosso, Centro Sociale, Area Assa).

Municipality of Novara has signed a Protocol of Understanding (Protocollo d'Intesa) with the Agenzia del Demanio, in the same year, under the program "Valore Paese" [6]. Protocol considers valorization for four former properties of the Ministry of Defense (former Piazza d'armi and Polveriera, Barracks Passalacqua, Barracks Gherzi and former V Central Warehouse). Those properties are under the responsibility Agency of the State Property with the law 27 from December 2006, no. 296 finance law 2007.

Project “Valore Paese” introduces model of “concessione di valorizzazione” (concession for valorization) with long-term rental, even 50 year, to local administrations and private entities. Main aim of that approach is to initiate processes of renovation and restructure of the properties with its cultural, social or business functions and consistent with the strategies of local communities. Programmi Unitari di Valorizzazione, PUV (Valorization Unitary Programs) also were included under the same project, as institutional instruments of governance with aim to valorize former properties of Defense.

Implementation has been inhomogeneous in different geographical areas, without definition of real intervention strategies. In this way, mechanism for creating list of prosperities that can get concession was degraded.

The analysis of the case Novara, allows us to develop and establish a model and criteria for valorization of state-owned properties, also for other Italian contexts. First, it appears that only economic valorization is made at the end of the program and that is realized through the sale of properties with the classical logic of the beneficial position. This choice might seem theoretically reasonable, especially considering, that majority of the properties are located in the strategic zone of the city. However, this approach is challenged within two factors: the size and characteristics of the heritage and demand in the real estate market.

4 Relevant Aspects in Valorization Process

The properties involved in process of valorization that would be uneconomic to recover are the ones in a state of degradation and functional as well as advanced physical obsolescence. Exceptions can be made only in cases of buildings subjected to bond, which will be subject to restructuring and recovery. Diversity of typology (barracks or warehouse, distributive schemes rather than rigid) makes difficulties to get the idea for restructuring and reuse. To these considerations is added the low quality of individual buildings and the system of volumetric plan, typically military, which does not allow adaptation. Therefore, an initial cost appears for transformation of area. Costs are sometimes so high that could destabilize the economic and financial sustainability of the intervention. Characteristics of Novara context (the typical Italian capital of the Province) are also the reason why rent of properties does not reach the high speculative values of large urban centers. The debate has been “misleading” with the approach that should consider mainly the state-owned properties, as a sum of individual buildings that have to be recovered. That approach avoids the perceptions of the whole complex and the integration with the urban fabric of the city. How approach can be proper with the projects that have as priority the building scale and not the urban?

Another reason for the failure of the initiatives, undertaken up to now, can be founded in the demand on the real estate market. Available volumetric quantity is higher than those that market could absorb. Physical dimension of the recovered buildings is bigger than dimension that market needs and demands. Public interest of community is the only necessary usage capable to support that volume but only with consistent economic support from private investors or forms of mixed financing with long-term concessions.

Further criticisms of cultural approach refer to the assumption of having income from real estate. It has been considered that properties resigned from military activities should generate economic value corresponding to the location and the quantity strictly measured from existing developed. It is not difficult to guess that in many cases, transformed spaces of deposits and warehouses, or barracks, into potential exploitable spaces, generate high amount of income equally to high expectations. Such logic for transformation, purely keeping quantities, is detached from reasoning of the urban redevelopment and redesign of large parts of the city. It is necessary to ask if it is correct to attribute an economic value to market properties that have exhausted their function over the years and now represent a cost to the community. Another possibilities is to consider them as a "fixed social capital", assumption for the implementation of urban regeneration strategy for achieving the goals and needs of the community, stimulating, due to external economies, the direct involvement of private investors.

The problem of housing is one urgent problem that reappears today. One important percentage of the population is unable to access to the offers of free rent or to buy in the open market. Thus, it is the manifest of need for houses at agreed prices, outside the rules of the speculative market, achievable by the cooperative system, or institutions or agencies for construction and management of public housing. This logic has been adopted for the Novara context. The state-owned property could be involved through competitions under control by the implementing bodies for the construction of social housing; the criteria of the Law of 18 April 1962 no. 167 "Disposizioni per favorire l'acquisizione di aree per l'edilizia economica e popolare" (Regulations to foster the acquisition of areas for council houses), that has characterized an entire period of planning for social housing in Italy and by now has become exhausted.

Therefore, plan for social housing might include identification of areas, defining selection criteria and technical specifications. Also, it might contain construction costs and prices of rental as well as management. Management should consider advantages determined by the presence of the plans for implementation and municipal programs already adopted and approved in difference expectation of current Piano regolatore generale (Urban Regulation Plan of the City). Without prejudice to the existing initiative the new hospital and the university with the context allow the implementation of some isolated parts of significant value for residential social areas with related services and public spaces. It is acting to release land and reduce size with rationalization of the system and consolidations aimed towards open spaces for the community and implementing the necessary changes between historically isolated areas within the urban fabric.

5 Furthers steps and Conclusions

The organization of the area needs the improvement of the strategic planning, capacity of pushing the local resources and identities outside the local communities, so to support the agreements and concretize the principles for the development.

The awareness of the need for planned continuity to lead the processes of transformation and coordination on urban level is extremely important. A plan, not only for public operators, but also directed to the social housing from private operators, in this particular historical moment which is characterized by the contraction of expenditure of authorities. Therefore, a new market should be oriented to those individuals who set their objectives into fair gain, working with the logic of public policies for social housing, but giving priority to the long-lasting location, with social or agreed fees and control of sales figure. There are also significant forms of funding and networks of cooperation that have considered the involvement of bank foundations active in the sector of Private social housing of the Cassa Depositi e Prestiti (Public Bank property of the Ministry of Economy and Finance) as well as the real estate funds established just for the social housing-innovative real estate financial instruments that provide participation of public and private.

Research group, Governance, project and valorization for the built environment [7] of the BEST Department, from Politecnico di Milano, has established with the ANCI (National Association of Italian Municipalities) a Framework Convention with the aim to promote and develop projects for valorization of heritage public buildings of small municipalities. It is established as one of the steps and tools of our consideration and with the reference to context of Novara and in particular to the north Italy. Main objectives are strategic tools for increasing potential for collaboration between public and privates entities in work realization of public utility, with significant attention to the opportunities offered by the PPP (Public and Private Partnership) [8–12].

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Diagnose and Repair of Domed Elements of Masonry

Manuel Fortea Luna and René Machado López

Abstract In this work there is exposed a method of repair of domed elements of Masonry consists of an analysis of its current and initial state; an analysis tensional by means of the software CARYBO; a diagnosis; and a treatment based on application of a special mortar of base NHL.

The object of the repair is not to return it to the damaged element its initial geometry, but simply its initial presentations, though for it one relies on a different geometry.

For the check of the same one two models have realized to scale, one with a leaf of brick and exactly equal other one more a reinforcement based on the mentioned mortar. Both have been submitted to extreme actions up to the collapse in order to verify its behavior.

The method consists of implementing basically in the factory a product, that though new, it has the same mechanical and chemical characteristics that the proper factory. And to implement it in those places where it is necessary and with the necessary dose, according to a rigorous analysis.

Keywords Masonry • Building maintenance • NHL mortar

1 Introduction

The earthquakes happened recently so much in Spain (Lorca) as in Italy (Bologna and Aquila) have stated the inefficiency of the repairs effected in the masonry with current technology (reinforced concrete), revealing the incompatibility between constructive technologies of different nature. The buildings in critical situations, since it is an earthquake, reject violently what they consider to be a foreign body. A behavior similar to the human body, a "very natural" behavior, in the sense that is own of the nature.

The proposed method is based in disturbing as little as possible to the structure, it helping to satisfy the presentations that request him without forcing it with strange protheses and with materials and products compatible with its nature.

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Fig. 1 Sample Arch 01

Fig. 2 Sample Arch 02

2 Methodology

It appears as methodology, the construction of two arches (Figs. 1 and 2)—manometers of identical constructive and geometric characteristics, with the only difference, which the second one (Arch 02) is reinforcing by means of the increase of section of the leaf with mortar of lime NHL.

The above mentioned mortar has the singularity of which the same mechanical resistance and density has that the proper one of the factory with the one that is constructed the arch.

The realized test consists of displacing horizontally the supports of the arch. This one is the most common pathology in this type of structures. This displacement is realized slowly at the time that the information of reading is taking, up to coming to the point of collapse. The test is realized on both manometers.

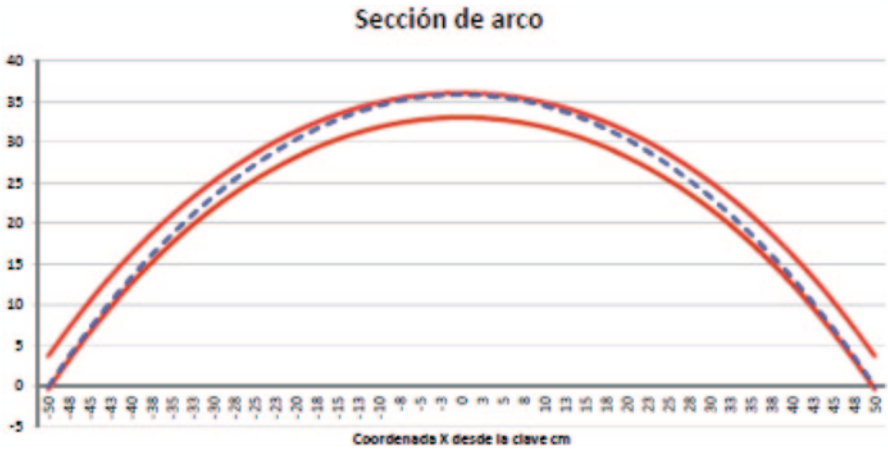

Fig. 3 Arch chain

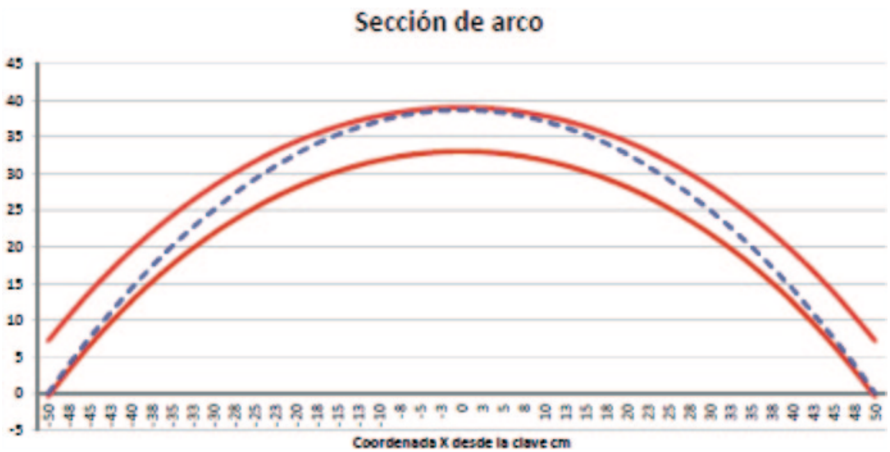

Fig. 4 Arch chain reinforced

3 Discussion and Development

RESULTS OF THE TEST

The analysis departs from the following element:

Chain Arch bases (Fig. 3). Singing of the leaf(sheet) 3 cm.
Width 47 cm.
Apparent density 13 kN/m^3
Maximum admissible tension 2.7 N/mm^2

The element reinforced with the following information of beginning:

Chain Arch reinforced (Fig. 4). Singing of the leaf 6 cm.
Width: 47 cm.

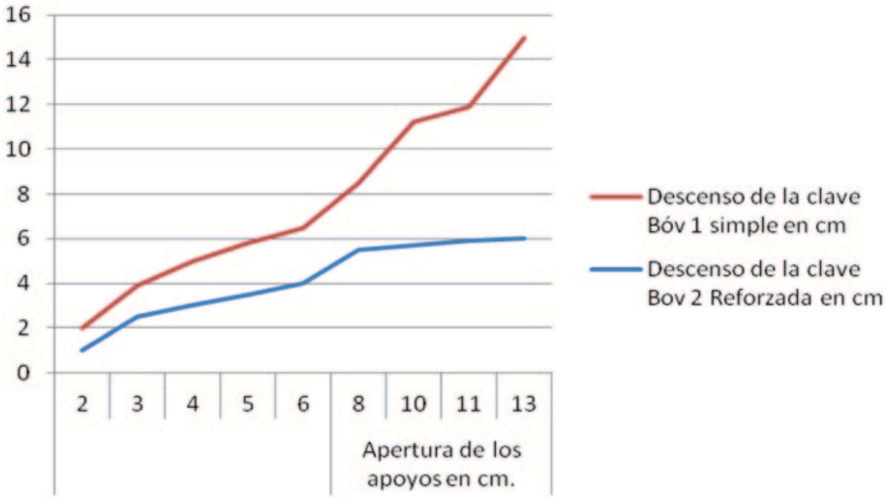

Fig. 5 Comparative of behavior of the arches

Apparent density 13 kN/m^3
Maximum admissible tension 2.7 N/mm^2

The theoretical information of these elements, considering its geometry and the information of the used materials, is those who are described later. The graphs (Figs. 3 and 4) they show the step of the line of efforts along the effective section:

The following graph (Fig. 5) represents the behavior of both vaults during the process of the test.

From this test and the geometric analysis, one manages to demonstrate not only the functioning of the structural element of masonry, but also it demonstrates the efficiency of the system of reinforcement, as well as of the systems of repair that later will be exposed.

The systems and methods will be detailed for the repair of the cracks and fissures in the elements, by means of the utilization of mortars of lime NHL, before the accomplishment of the necessary reinforcements, if out.

Finally there will be realized the presentation of the development of the mortar of lime NHL Tectoria BVD, developed specifically for this purpose, of which its individuals will be detailed characteristics and of because of its compatibility and efficiency in the elaboration of this system.

4 Conclusions

1. The behavior of the model corresponds with the behavior foreseen by the software, producing the joints to it in the same places distinguished by the calculation.

Fig. 6 Arch 01, broken

Fig. 7. Arch 02, broken

2. The behavior of the model corresponds with the behavior foreseen by the software as for the minimal necessary displacement in the supports for the collapse.
3. The manometer with the reinforcement has a behavior similar to the manometer without reinforcement, appearing the joints in the same places. The reinforcement does not lead him to a behavior different from the original one (Fig. 6).
4. The manometer with the reinforcement has less deformation than the original one when both surrender to the same effort. To equal displacement of the supports the key of the reinforced arch descends less than the original one (Fig. 7).

Part V
Materials and Construction Systems

Isabel Tort-Ausina

Abstract There is a real need to apply the principles of sustainability to industry, especially the construction industry that is a major consumer of resources. In this section, papers present a variety of building materials alternatives and solutions , such as: reducing high levels of greenhouse gas (GHG) emissions in the cement industry by adding natural stone waste; rice husk is an abundant and renewable waste, which can be used as alternative building material; the prepared concrete industry and concrete technology sector is very competitive and constantly evolving and self-compacting concrete is emerging as an effective solution for lower skilled workers; the feasibility of recycling fibres from construction and demolition waste (C&DW) as an alternative material to the chopped glass fibres currently used as reinforcing elements in prefabricated plaster.

Also, experimental curves of temperature evolution over time for masonry elements exposed to a non-stationary temperature law are analysed, as well as the effects of type of cement selection or metakaolin (MK) and sepiolite (SP) addition on cement pastes foamed by aluminum powder, for determining the properties of fresh and hardened mortar. A comparison of delamination resistance by peeling tests after laboratory ageing and real exposure has been shown in order to confirm achievable durability of at least 25 years, provided that decay of initial delamination resistance of panel is less than 25% when exposed to heat or moisture ageing in laboratory conditions. A thermal survey carried out in 3 representative classrooms of a college in Bolzano, Italy is also shown.

Properties of Lightweight Plaster Materials Made With Expanded Polystyrene Foam (EPS)

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Abstract Gypsum is a natural material commonly used in building construction and its most often use is still in the form of interior plasters and plasterboards. However, during the last years several studies dealing with the reduction of density have arisen and new gypsum composites have being developed in response to enable quicker and easier installation.

Former research results have shown that the most favourable material to produce lightweight plaster composites is expanded polystyrene beads (EPS). But, apart from density reduction, it involves an important mechanical strength decrease.

The reinforcement of plaster composites can be accomplished by incorporating additives, such as fibres, plasticizers and bonding agents. In the EPS plaster composite the best results are achieved by adding bonding agents. Moreover in a water to binder ratio of 0.8 and 2 % EPS with bonding agent, the decline in density achieved is at least 44 % while mechanical strength of the composite improves in comparison to and EPS plaster composite without the addition of any other additive.

Keywords Lightweight gypsum • Lightweight plaster • Plaster composites • Lightweight aggregates

1 Introduction

Lightweight plaster has been widely known and developed in order to enable quicker and easier installation, but also to improve gypsum characteristics such as thermal behaviour, acoustic performance or fire resistance properties [1].

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Table 1 Density, flexural and compressive strength and shore C hardness increments of composites made with plaster and different additives (W/B = 0.8) in comparison to a reference sample made with no additives and same water to plaster ratio. [1, 4–8]

Additives	Percent by weight	Δ Density (%)	Δ Flexural strength (%)	Δ Compressive strength (%)	Δ Shore C Hardness (%)
Foam additive[a]	1	−26.18	–	–	−40.74
Expanded clay	60	−20.45	−45.82	–	−31.40
Perlite	20	−23.49	−38.39	−14.44	+3.70
Vermiculite	20	−13.39	−25.69	−34.86	−25.93
EPS	3	−42.91	−67.80	−62.68	−64.15
Cork	15.5	−38.40	−53.56	−59.51	+18.52
Cellular glass	30	−16.85	−29.72	−47.36	+19.26

[a] Specimens made with foam additive got no representative results for mechanical strength due to cohesion deficiency

Plaster is a material with a relatively small weight per unit volume under normal conditions, and its density can be slightly decreased by keeping a high water/binder ratio (W/B). Lightweight plaster, with a further reduced density, can be made by introducing gassing agents, lightweight mineral aggregates or plastic granules [2, 3].

There are many studies considering different lightweight plaster composites and their physical and mechanical properties. These research works generally consist of the progressive addition of aggregates or additives such as foaming agents, expanded clay, perlite, vermiculite, cork, cellular glass or expanded polystyrene foam (EPS). The most representative results for these studies are shown in Table 1.

It can be concluded, from the increments shown in Table 1, that the most suitable additive/aggregate to reduce density is EPS, but it involves a significant mechanical strength decrease.

This paper evaluates physical and mechanical properties of EPS lightweight plaster composites, with the aim of improving their mechanical strength through the incorporation of additives and other aggregates, such as fibres.

2 Methodology

In order to analyse gypsum composites with EPS aggregates two conditions were set. The first condition was to fix an acceptable mixture consistency according to the standard EN 13279-2 [9] for both the reference specimens and those with different doses of EPS. This mixture consistency determined the water to plaster ratio (W/B) to obtain good workability and plasticity in the samples. A higher W/B ratio improves workability and produces a slightly reduction of the density of plaster, but it also means a mechanical strength decrease, so it was essential to find the most suitable W/B ratio. The second condition was related to the materials involved; for all studies the type of gypsum used was characterised as A1 according to European Norm EN13279-1 [10], and the additives added to the EPS plaster composites due

Table 2 Density, flexural and compressive strength and Shore C hardness of different plaster samples with different W/B

W/B	Density (gr/cm^3)	Flexural strength (N/mm^2)	Compressive strength (N/mm^2)	Hardness (Shore C)
0.6	1.13	5.11	9.65	80
0.8	0.95	3.23	5.68	67.50
1.1	0.82	2.16	4.44	50
1.2	0.48	0.57	0.74	12.50

to improve mechanical strength were: fibres, which are commonly used to reinforce plasterboards; plastizicers, that improve workability and bonding agents, that may help increasing the cohesion of EPS with plaster.

The different physical and mechanical properties were measured in prismatic specimens ($160 \times 40 \times 40$) mm^3. All the specimens were characterised by their density in dry state, their mechanical strength after 7 days and their Shore C hardness. Flexural strength was determined by the load needed to break prismatic specimens supported on rollers positioned at 100 mm intervals, according with standard EN 13279-2 [9]. Compressive strength was determined by the load needed to break the broken sections of the specimens previously tested to flexural failure, according with standard EN 13279-2 [9] and Shore C hardness was determined by establishing the indent left by an exerted force on each test specimen, measured in Shore C units, from 0 (softest) to 100 (hardest), according with standard UNE 102039 [11]. The results were compared amongst the gypsum composites analyzed and they were all defined based on their comparison to a reference sample made with no additives or aggregates.

3 Results and Discussion

The results obtained for specimens at water to binder ratio of 0.6, 0.8, 1.1 and 1.2 are given in Table 2. The maximum EPS ratio was found at 2 % for all cases, according to workability. Plaster with W/B = 0.6 was thick and was difficult to cast into mould, while plaster with W/B = 1.1 and 1.2 were too thin. With higher W/B a non representative reduction of density is achieved and in term of strength, the low W/B gave better results, but when adding aggregates, a higher W/B would make it more workable. Plaster made with W/B = 0.8 gave good consistency and was suitable for sample preparation, so the consistency is chosen by the W/B = 0.8 for all samples.

The analysis of the different EPS plaster composites is given in Table 3 and results show that the incorporation of fibres to EPS plaster composite does not improve mechanical strength, in comparison to the EPS plaster composite with no fibres, due to inadequate mixing. However, the addition of plastizicers and bonding agents improves mechanical strength in comparison to the EPS plaster composite with no more additives. This is owing to the fact that both additives permit to control setting time making it possible to allow EPS floatability. Nevertheless, the

Table 3 Density and flexural and compressive strength increments of composites made with plaster and EPS (W/B = 0.8) in comparison to a reference sample made with no additives

Additives	W/B	Δ Density (%)	Δ Flexural strength (%)	Δ Compressive strength (%)
1 %EPS	0.8	−33.46	−42.78	−55.55
2 %EPS	0.8	−50.60	−60.30	−73.07
3 %EPS	0.8	−59.32	−67.05	−82.07
2 %EPS + fibres	0.8	−48.50	−65.48	−78.51
2 %EPS + plastizicers	0.8	−33.95	−44.20	−54.18
2 %EPS + bonding agent	0.8	−44.10	−20.65	−44.22

bonding agent and EPS plaster sample is the one that gets better density and mechanical strength results.

4 Conclusions

The incorporation of EPS in plaster composites make it possible to reduce density of plaster materials, although, the maximum EPS ratio is 2 % due to workability. The composites made with EPS and plaster, and also every lightweight plaster composite, have an important disadvantage which is the mechanical strength decrease involved.

From the experimental studies it can concluded that the mechanical strength of plaster composites with EPS can be improved by adding bonding agents, that improve cohesion of EPS with plaster with a similar density reduction.

Further work will focus on the analysis of bonding agents and EPS plaster composites properties, with the aim of determining their potential applications to create lightweight prefabricated materials for construction use.

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Plaster Reinforcement with Fibers Obtained from the Recycle of Construction and Demolition Waste

S. Romaniega Piñeiro and M. Del Rio Merino

Abstract The main objective of this research is to study the feasibility of recycling fibres from construction and demolition waste (C&DW) as an alternative material to chopped glass fibres which are used today as reinforcing elements in the prefabricated plaster. To do this, sets of samples are made with rockwool and different percentages of combinations between water/plaster. These series are repeated by changing the additive E glass fibre length of 25 mm to make a comparative analysis with respect to the series infused with rockwool.

Keywords Fibres • Rockwool • Recycling • C&DW • Plaster

1 Introduction

1.1 Construction, Environment and Sustainability

The First Earth Summit was an important milestone in the field of the environment. This meeting represents a reference to a new way of perceiving the future and also incorporates awareness about the sustainability in broader terms. A key contribution of the meeting is called Agenda 21, which we consider today a reference for the implementation of sustainable development.

The Johannesburg Reunion 2002 was presented as a great opportunity to assess progress in the actions for the implementation of national strategies for sustainable development, as established by aforementioned Agenda 21. The most notable difference between the previous meetings and Johannesburg, experts say, is that in 2002 the knowledge of our planet was broader, so we should be more aware of the damage caused to it. Nevertheless, the success or failure of the meeting is under discussion.

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1.2 Construction and Demolition Waste

The document that currently regulates the construction and demolition of waste at a national level is the Royal Decree 105/2008, of February 1, by regulating the production and management of construction and demolition waste [1].

This Royal Decree was established as a cornerstone of Spanish policy on C&DW. It is expected to contribute to sustainable development in the construction sector, which is an important sector for the Spanish economy.

2 Objective

The main goal of this research is to study the feasibility of using fibres from the recycling of C&DW (with the intention to exploit the properties that the fibres have when they are sent to the flow of construction and demolition waste) as an alternative material to the fibres currently used as reinforcing elements in the prefabricated plaster.

3 Background

3.1 Reinforced Plaster

The fibres are used from years ago to strengthen brittle materials (mud bricks). In general, strengthening of materials works by improving physical-mechanical behavior of the matrix. The behaviour of these compounds depends, firstly, on the type of fibre added, and then on other factors such as percentage of fibre, fibre length, orientation, surface of the fibre.

3.1.1 Reinforced Plaster with Natural Fibres

Several references have been found concerning the addition of plaster reinforced with natural fibre [2, 3, 4]. The short fibres used are cellulose, sisal and hemp, but in all of them, the best results were obtained with sisal fibre [5].

3.1.2 Reinforced Plaster with Artificial Fibres

Of the aforementioned fibres, the polymeric fibres [6, 7] and the glass fibres [8, 9, 10, 11] are the more suitable for addition to the plaster as reinforcement. The rest of them are excessively expensive and they have higher mechanical properties than plaster. Furthermore, glass fibres are the most commonly used fibres as reinforcement in the prefabricated plaster.

3.2 Infused Plaster with Fibres that Come from Recycling

Previous references were found regarding the addition of materials that come from recycling in a plaster matrix [12, 13]; but no references have been found regarding to the use of fibres from recycling, specifically in a plaster matrix.

4 Experimental Method

4.1 Materials Used

Different test plaster pieces are made using the following materials: plaster E-35, rockwool from the recycling process and fibreglass of 25 mm. Rockwool is marketed primarily as sheet panel, rigid, or semirigid, joined with different types of resins such as phenolic resins or thermosetting or fireproof, with or without coating. They can also be found supplied in roll form or in bulk. This rockwool obtained from recycling is made with a plate shape of 5.4 mm thickness and bonded with resin.

4.2 Preparation of Plaster Samples

In the first phase, two series of plaster samples for reference are made of plaster E-35, with a relation between water/plaster = 0.6.

Subsequently, in a second phase, series of plaster samples are made with plaster E-35 and relation W/P = 0.6 and the following proportions of rockwool that come from recycling, 1, 1.5, 2, 2.5, 3, 3.5 and 4 %.

Finally, in third step, and to achieve the main objective, the results obtained with plaster series E-35, W/P = 0.6 and different percentages of rockwool from the recycling (1, 1.5, 2, 2.5, 3, 3.5 and 4 %), are compared with the series of plaster obtained with E-35, the ratio W/P = 0.6 and different percentages of fibreglass of 25 mm (0.5, 1, 1.5, 2.5, 3, 3.5 and 4 %).

4.3 Tests Carried Out

There are two types of tests: mechanical tests for determining the resistance to bending and compression of the plaster samples, and a test for determining the surface hardness of them, called Shore C. All of them are following the Spanish standards [14].

Table 1 Results of the samples for reference

Relation W/P	Hardness "Shore C"	Weight	Bending strengh	Compressive strenght
0.6	92.1	309.99	7,514	17,788

5 Results

5.1 1st Phase: Reference Samples

The following Table (Table 1) shows the average results obtained for the series of tests in the four types of tests performed.

5.2 2nd Phase: Plaster Samples Infused with Rockwool that Comes from Recycling

"Shore C" hardness is increased till around 8 % with 1, 1.5, 2 and 2.5 % of addition. After addition of 2.5 % the hardness begins to descend as it increases the% addition.

The weight falls with respect to the reference series. This decrease increases as the percentage of addition of rockwool gets bigger.

The bending strength is decreased by about 5 % for the percentages of adding rock wool of 2.5, 3 and 3.5 %.

The value of results average of compressive strength obtained exceeds the compressive strength of the reference series, reaching the maximum value with addition of 3 % increasing in this case 12.51 %.

5.3 3rd Phase: Plaster Series Additived with E Glass Fibre

Finally the results of the series infused with glass fibre are analyzed, comparing these results with the series of reference.

The results of the surface hardness obtained are lower than the ones obtained for the series of reference. They decrease by 6–1.5 % addition. The weight is bigger for all the percentages of addition, reaching a 3.5 % of increase for the series infused with 2.5 % of fibreglass.

The results obtained in the testing of bending strength are increasing as it increases the percentage of addition. Adding a percentage of E-glass fibre 4 %, the bending strength is increased by 50 %. Furthermore, after done the bending strength test, the fracture surface is completely sewn with the fibres.

The results obtained in the compression test are lower than the ones obtained for the series for reference. The maximum value is obtained by adding 4 % which is a decrease of 10 %.

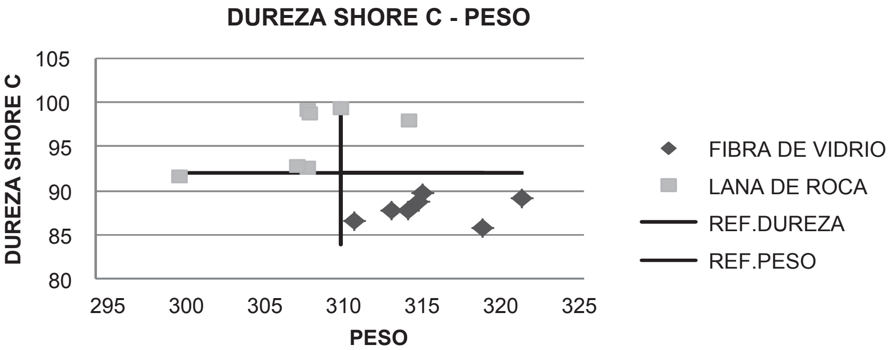

Fig. 1 Comparative hardness shore C- weight

6 Conclusion

This chapter discusses the differences and similarities between sets of plaster tests infused with rockwool and series infused with E glass fibre of 25 mm, all of them made with a relation between W/P = 0,6.

6.1 Workability

During the production of the series of plaster tests infused with E glass fibre of 25 mm, it is observed that from 2 % addition the workability of the paste decreases.

The workability of the plaster tests infused with rockwool is good even for an addition rate of 4 %. Therefore it can be concluded that this property improves with the addition of rockwool, with respect to addition of E-glass fibre of 25 mm.

6.2 Hardness Shore C

This shows that, for less weight, higher values of surface hardness are obtained in the series made with rockwool (that comes from recycling) than in the series made with the E-glass fibre (Fig. 1).

6.3 Bending Strength

The plaster tests, infused with E glass fibre, have more flexure strength than the infused with rockwool that comes from recycling (Fig. 2). Test series infused with rockwool have less weight than the ones with E glass fibre.

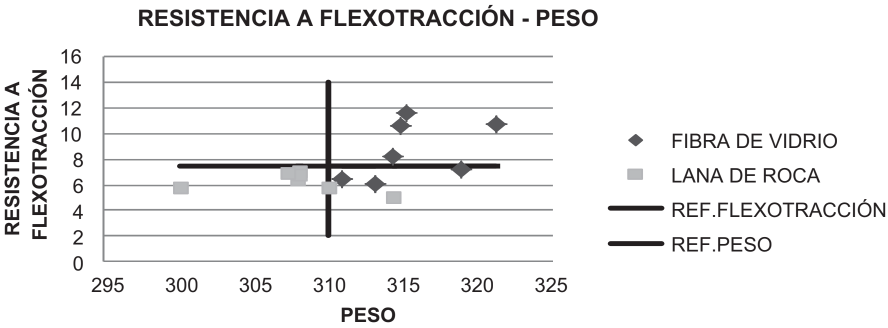

Fig. 2 Comparative flexural strength- weight

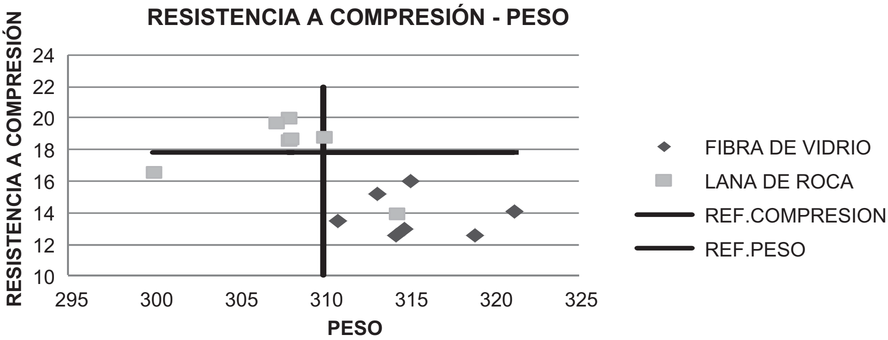

Fig. 3 Comparative compressive strength—weight

6.4 Compressive Strength

The series infused with rockwool from the recycling are more resistant to compression than the ones infused with glass fibre E. These ones have higher weight (Fig. 3).

As a general conclusion it should be noted that the plaster tests infused with E glass fibre of 25 mm resist more than 62.87 % in bend strength than those added with rockwool that comes from recycling with a percentage of addition of 4 %. Besides the two sides of the fracture surface are sewn, but it does not happen with the ones infused with rockwool.

By contrast, plaster samples with rockwool show better results than the ones that are added with E-glass fibre of 25 mm in Shore C hardness, weight and resistance to compression.

Hardness Shore C: increases by almost 10 % to the rates of addition of 1, 1.5 and 2.5 %, with a lower weight in at all.

Weight: decreases to 3.63 % for an addition rate of 4 %.

Compressive strength: increased up to 20.07 % for an addition rate of 3 %, also with a minor weight

7 Future Research

- Higher percentage of additives.
- Work with longer fibres.
- Study on adding other formats of rockwool (dust …)
- Work with other tissue types from the C&DW
- Mixture ventures between different types of fibres.

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Temperature Profile Analysis of Masonry Elements Subjected to High Temperatures

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Abstract The objective of this work is to obtain **experimental curves of evolution of temperature with time for masonry elements exposed to a non-stationary temperature law**. It has been designed an experimental device to subject the samples to a uniform non-stationary evolution of the temperature field. Through this testing device is possible to evaluate the structural and mechanical characteristics of the element and calculate the effective cross section of the masonry element which has been subjected to thermal action. Thus it is possible to know the **last residual strength of the element by the simplified calculation method** that Eurocode sets for masonry structures subjected to the action of fire.

Keywords Temperature profiles • Masonry elements • High temperatures • Non destructive technique

1 Introduction

To study the temperature profiles in a brickwork wallet at high temperatures is desirable to **establish a protocol to ensure the reliability of results** in obtaining time-temperature curves. Because the trials are conducted without a specific testing standard that defines (for the development of time-temperature graphs of a given material at high temperatures), it is proposed to establish a **working methodology** to study the thermal behaviour of ceramic specimens.

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2 Materials and Methods

The objective of this work is to obtain experimental time-temperature curves of evolution for brickwork wallets exposed to non-stationary temperature law. We have designed an **experimental device** to subject the samples to a uniform non-stationary evolution of the temperature field. It has been subjected one side to a heat flow imposed by a refractory ceramic hot plate while the other face is exposed to ambient temperature. Through a set of thermocouples located in the interior of the wallet various temperature curves versus time are measured.

To ensure that the results obtained in these tests can be successfully implemented, it should be achieved the following objectives:

1. Establish a protocol to ensure the reliability of results.
2. Ensuring the one-dimensional heat transfer test.
3. Design the experimental test device.
4. Validate the results of the test device.

The one-dimensional nature of the problem has been ensured through a design that does not allow transversal heat transfer. Validation of the one-dimensional character of the problem has been checked through the measure of different temperatures in a plane at an equal distance from the face exposed to heat flow of the plate. It has also been the subject of this paper the validation and tuning of the experimental device.

2.1 Brickwork Wallets Implementation

The test wallets were made of pieces of clay bricks commercial format providing the material with the same characteristics. The mortar used is a pre-dosed mortar M7, five commonly used in ceramic masonry and mechanically mixed.

The dimensions of the ceramic bricks are 11.4 to 11.6 × 5 × 24 cm while the thickness of the mortar joints are between 0.9 and 1.1 cm. The bricks were of perforated face side and metric format.

The wallets made were obtained from commercial format pieces subject to cut to carry out series of similar wallets. In the cutting operation a water cooled diamond wheel DB TN35 NE23 type cutter was used.

The implementation of the **masonry prisms** was conducted very rigorously. The first layer of the walls is placed on a bed of mortar aligned and vertically aligned by a level. Then central brick and lateral half brick were placed taking care to keep the joint of the masonry bond close to 1 cm and filling up 2/3 of mortar holes in the masonry. Finally the third row is positioned on the bed of mortar and rectified by the level. On the last course is placed another mortar joint to help the later facing (Fig. 1).

Fig. 1 Preparation and final appearance of wallets

2.2 Measuring System and Temperature Control

For the adoption of a **system of measurement** has been performed a literature search and attempted to reproduce the systems of some authors [1–11], in order to optimize the technique.

Several thermocouples were placed in between the walls, practicing drills at certain distances and depths to obtain data on the temperature inside the masonry wallets.

In order to obtain reliable data, we proceeded to fill of plaster the interstitial spaces between the masonry and the thermocouple (because it creates a small air chamber that distorts the data).

It should be noted that during the preparation of the samples was important to ensure the distance of the thermocouples to the unexposed face. Although perforation could reach a gap that was not filled with mortar (the first results were highly variable due to this inaccuracy), we proceeded to filling with plaster, which facilitated his reading. Thanks to the flexibility of thermocouple chosen (wide long and low section) it could be possible to adjust the distances the measures were to be taken.

The **temperature control system** was centred on a data acquisition system receiving the signal from the thermocouples that were placed inside of the wall and

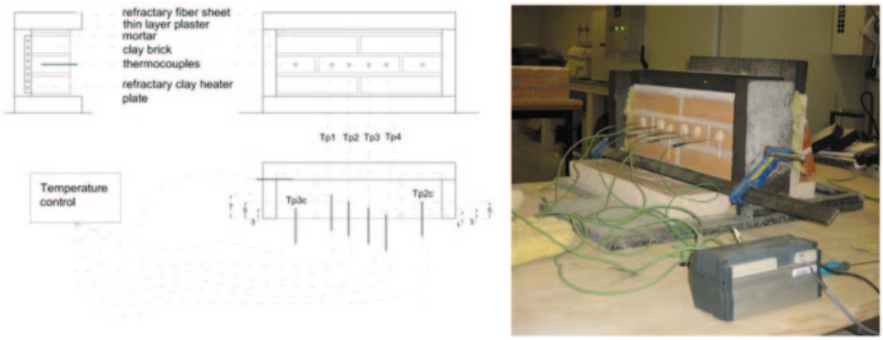

Fig. 2 Experimental geometry and arrangement of test. View the complete device (perimetraly insulation and thermocouples) and connections between thermocouples and temperature controller

from an additional thermocouple receiving the signal from the heating plate that transferred the temperature to the element.

2.3 The Experimental Geometry

Since there is no specific test for obtaining temperature profiles it is **designed a device** for this purpose. Wallets were placed on a horizontal surface, were perimetraly isolated leaving a face in contact with the ambient temperature and subjected to the heat transfer on one side via a heating resistor. The one-dimensional nature of the problem had been ensured through a design that does not allow transversal heat transfer.

In order to conveniently isolate the wallet it has a base of insulating material composed of refractory fibbers on which the specimen is placed. This plate is highly versatile and allows its use where it is required a rigid, self-supporting insulator material having a good physical erosion resistance (insulation of furnaces in ceramic industry, thermal barriers, high temperatures insulators …). This board is best for all applications that are subjected to temperatures above 1,000 °C and where there may be exposure to direct flame or hot gases. The maximum temperature for continuous use is 1,260 °C.

Then it was surrounded at the sides, top and one side of insulating material (in this case cellular glass due to cutting workability, treatment, and replacement of the work piece in case of breakage by expansion due to temperature and to allow better management and adequacy of insulation in the trials). This ensures that the **thermal process** that will be subjected the specimens to be an **adiabatic process** since the perimetraly recess of the specimens should minimize the lateral losses (Fig. 2).

The temperature profile in the elements was determined by placing four thermocouples located in the central part of the specimen at different distance from the unexposed side. Besides these temperature measuring thermocouples, were added two control thermocouples. Also was used an additional thermocouple to measure temperature of the heating plate. The thermal profile of the element was obtained for different control temperatures of the plate, from 50 to 700 °C.

2.4 The Experimental Geometry

The devices have been used to make the measurements with the aim of finding the temperature profiles were the next:

- A programmable temperature controller OSAKA Mod OS48 ECORAM with analogy output and Type K thermocouple built in for reading.
- A Gantner Instruments IDL 101 data logger and its corresponding ICP 100 software program compatible with spreadsheets in Excel.
- A laptop HP Compaq nc8430.
- A refractory ceramic hotplate of 1,500 W of power. Canalled ceramic plate 490 × 150 × 25 mm (1,500 W and 230 V) mounted and prepared with plugs and cables anticaloric cables.
- Refractory fibbers Ceraboard 100 rigid plate, with high cohesion and low thermal conductivity.
- Mineral insulated K type thermocouples suitable for high temperatures (−200 to +1,100 °C) 3 mm in diameter and 150 mm in length.
- A digital thermometer CRISON Mod. 638 pt with contact sound (with temperature range −199.9 to +850 °C).
- A heat gun RAYTEK Mod. Raynger ST ProPlus (infrared precision thermometer with laser sighting eye of a point).
- Rigid insulations (cellular glass) and flexible (rock wool) as support for the sealing of certain joints.

After placing the wallet according the trial set we proceeded to heat the wallet on one side for at least 210 min at different steps of temperature (50 to 700 °C). During the experiment we measured the temperature reached in the wallet at different points. The trial ended after three hours and a half of heating when the higher temperature profile is stabilized.

3 Discussion and Conclusions

The exact determination of the **temperature profile in the masonry wallet** is a key to obtain a suitable result in the measurement of stress and strain in the specimen in the case that the item is being affected by high temperatures and for the knowledge of the heat transfer through the isotherms study (Fig. 3).

Thanks to obtain **time-temperature curves** in the wallets subjected to different thermal steps is possible by reverse engineering techniques to obtain different temperature profiles which will indicate which part of the element section affected by the thermal action is not effective.

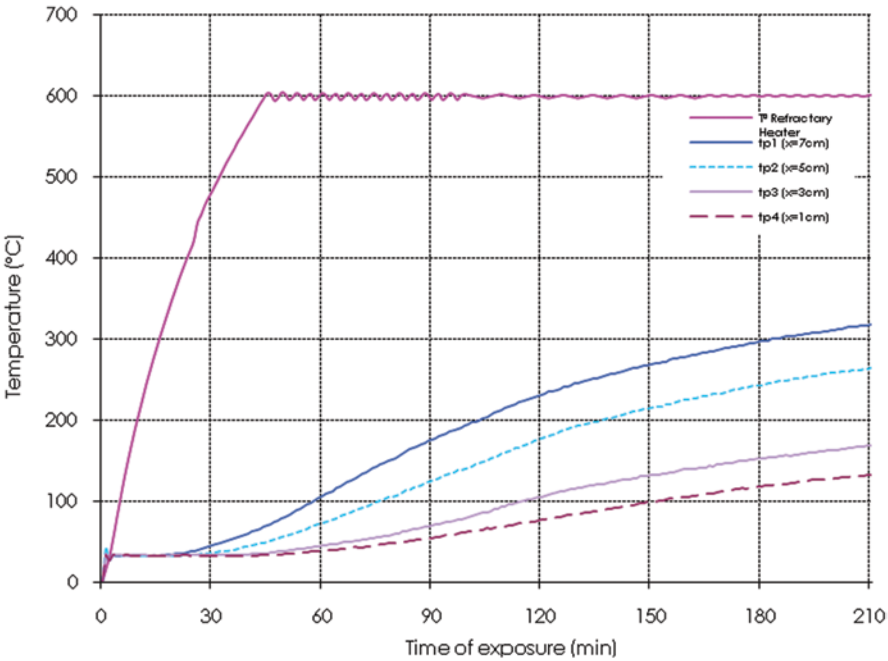

Fig. 3 Time-temperature curves of specimens subjected at 600 °C

We can calculated if the **effective section** of the element, after being subjected to thermal action, is sufficient to **maintain its mechanical and structural properties** or its bearing capacity is so deteriorated that it is necessary to demolish it (Fig. 4).

Through non-destructive techniques as set forth in this article is possible to **analyze ceramic brick masonry subjected to high temperatures** without altering their physical, chemical, mechanical or dimensional properties.

Although there are some studies that define the profiles of temperatures of several masonry elements, because the **heterogeneity** of them is not possible to make a direct comparison between them while although similarities are evident.

This type of testing allows non-invasively and indirectly assesses the structural and mechanical characteristics of the element. In this way we can calculate the **effective cross section of the element that has been subjected to high temperatures** in order to know their **last residual strength through the simplified calculation method set out in Eurocode 1996-1-2**.

It is also possible to establish the **degree of heat transfer** through the element and the layout of the isotherms **according to the temperature range** that has been subjected or exposed the element.

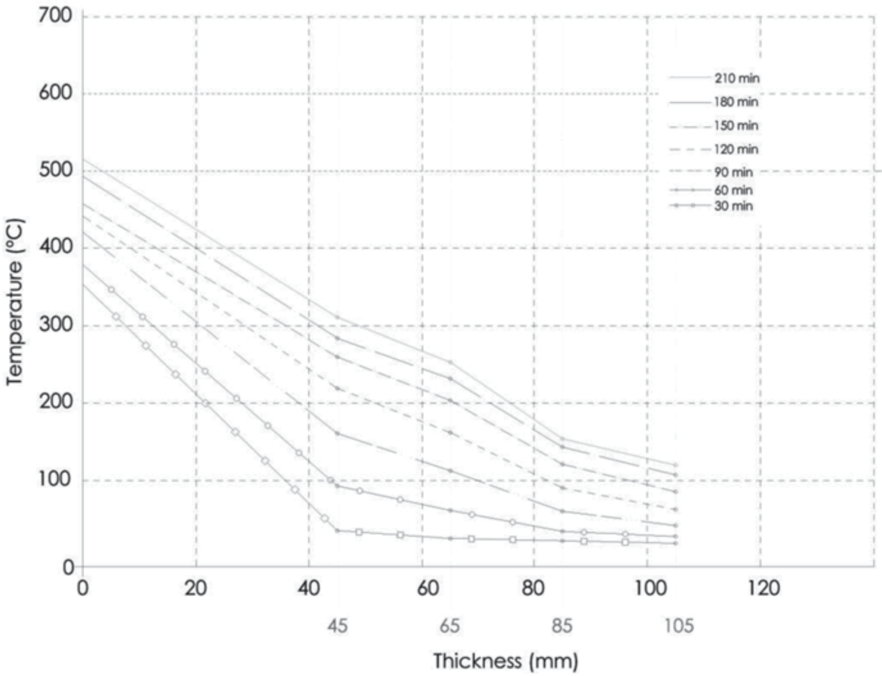

Fig. 4 Profiles of temperature at the specimens at 600 °C

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Greenhouse Gases in the Production of Cement Using Marble Dust as Raw Material

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Abstract There is a real need to apply the principles of sustainability to the industry, and specifically the construction sector that consumes high resources. Within the same, the cement industry generates high levels of emissions of greenhouse gases (GHG) emissions to the atmosphere, and there are a large number of research lines to reduce the CO_2. The option that has been followed in this research is the replacement of cement raw materials, where the reduction of GHG emissions is achieved by adding the residue from the manufacturing of natural stone, the cement manufacturing process. The relevance of this exhibition lies in the different scenarios that arise in the implementation of the waste and the effects of reducing emissions as well as recovery of waste.

Keywords Materials and Construction Systems • GHG • Cement

1 Introduction

The carried out investigation has as objective to determine the decrease in the consumption of the fossil main fuels, atmospheric emissions, effluents discharges and solid residuals associated to the traditional production of cement Portland and its comparison when incorporating a residual coming from the factory of the marble, so much in the stage of elaboration of the raw one, like in the one of addition to the clinker.

The industry of the cement has a contribution of 5–7 % of the global emissions of CO_2, being the process of calcination the one that contributes half of emitted CO_2 [1, 2], estimating that 850 kg. of CO_2 they are emitted by each ton of produced

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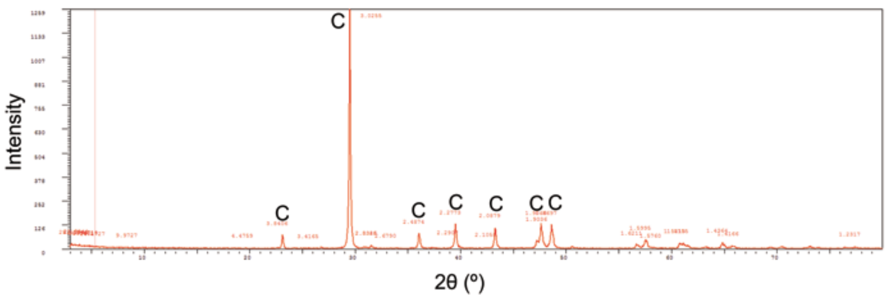

Fig. 1 XRD Marble dust. C-calcite

clinker [3] it is hence that it is important to center the decrease efforts, not only in the one mentioned process of calcination, but also in the rest of processes that they participate in the other 50 % emission, as well as to consider the decrease of the consumption of raw materials, since for the production of 1 t of clinker they are used 1.7 t of raw materials (limestone, clay, etc.) [3]

The processes of industrial metabolism have been frequent for the industry of the cement, where variables of economic nature and environment should be conjugated so that they can be carried out the recovery of residuals, although frequently this recovery have been of energy type, example is that in Spain the substitution of fossil fuels for residuals has ended up almost reaching the 16 % [4].

Regarding the use of alternative raw materials and additions, the normative own European favors this processes [5], but in the case that occupies us, the scientific literature, it approached for several decades the possibility from the use of limestone additions to the cement and the concrete [6].

Although the characterization and study of the properties of cements and mortars with incorporation of marble dust have been frequent in these last years [7–11], this investigations have been centered in the normative execution of composition and mechanical resistances [12, 13], without approaching the analysis of the contribution of the residual of the marble from the optics of the reduction of CO_2.

2 Materials and Methods

2.1 Materials

The used residual is a marble dust coming from the manufacturing of marble industry in the province of Almería (Spain). Their origin is in the refrigeration of the cutting and polishing of marble blocks and slabs, removing the resulting water by centrifugation, and the rest, the marble dust itself is deposited in a public settling basin. Mineralogical characterization throws a residue which is inert, composed mainly of Calcite (Fig. 1), alkaline pH and particle size less than 1 μ.

The samples of mud were picked up at a distance of 100 km of the factory where it is elaborated the clinker and the cement of reference of this investigation.

To check the technological validity of this proposal, got ready with the marble dust six cements type CEM II, assisting to the European norm UNE EN 197-1, where the percentage of addition of marble dust was increased and diminished that of the clinker of the reference factory. It exists in the literature scientific examples of the viability of this possibility for the production of mixed cement [14].

2.2 LCA Methodology

The methodology used in the assessment of environmental impact reduction in cement production, is the Life Cycle Analysis, In This study, the whole production system cement was considered following a cradle-to-gate approach.

The ISO 14040-2006 standard methodology was adapted to suit the aims of this assessment [15]. Primary data on energy consumption and GHG emissions during marble stone cutting, transport and cement manufacturing was complemented with European average data from Ecoinvent database, with the use of a software commercial [16], which was one of the most widely used and accepted methodologies in Europe.

The LCA methodology has been used for decades to understand and analyze the processes of cement production from the standpoint of sustainability [17], but by itself is not automatically a tool to facilitate process improvement, if not that lets us know the implications of it.

The environmental impact categories considered here are global warming potential (GWP), and primary energy demand. The former is quantified as kg CO_2 equivalent, using the IPCC 100 years GWP model [18], whereas the latter is expressed in terms of MJ-equivalent, as cumulative energy demand (CED). The CED of a product represents the direct and indirect energy use throughout the life cycle, including the energy consumed during the extraction, manufacturing, and disposal of the raw and auxiliary materials [19].

The outline bases of our investigation it will be the synthesis of the processes carried out in the reference cement factory (Fig. 2), which applies a process of via dry in the cement production.

Using as criteria the supply of inputs and emissions, we get four stages: input and raw material preparation, mixing and blending, clinkering, and finally, grinding and blending clinker and additions.

The scope of this paper is from the cradle to the door; therefore, the processes associated with the production of such services are included in the inventory. In the case of the marble dust, it is generated in a process and categorize considered as waste, therefore does not take into account the environmental burden. The functional unit is defined as 1 kg (kg) of cement placed on the door of the factory.

The potential case studies are the percentages of limestone, sand and iron slag as raw materials provided at the beginning of the base schema, and the percentage of clinker needed to form the cement, this in turn function of the additions to be added.

So that within the percentages allowed the UNE EN 197-1, the most permissive is to replace the supply of limestone to marble dust in the crude of cement, and add up to 35 % of marble dust to obtain a CEM II/B-L. The process is described in Fig. 3.

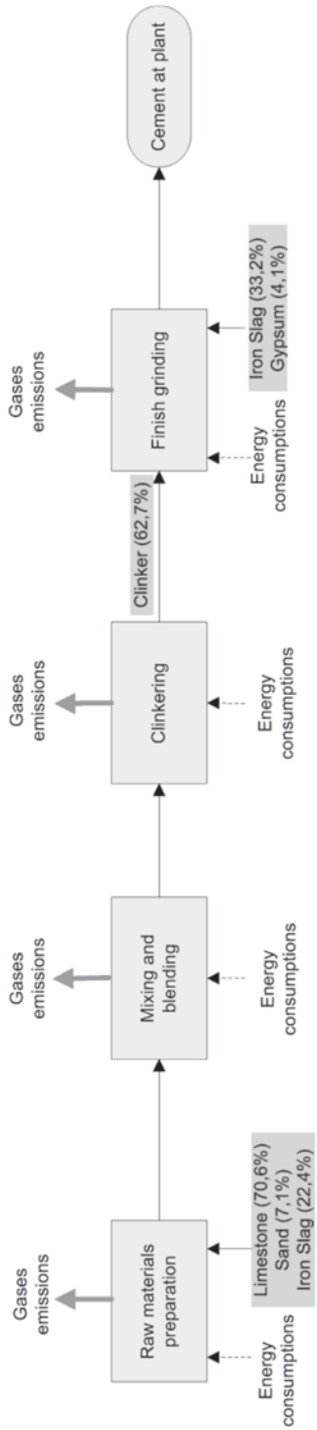

Fig. 2 Basic process

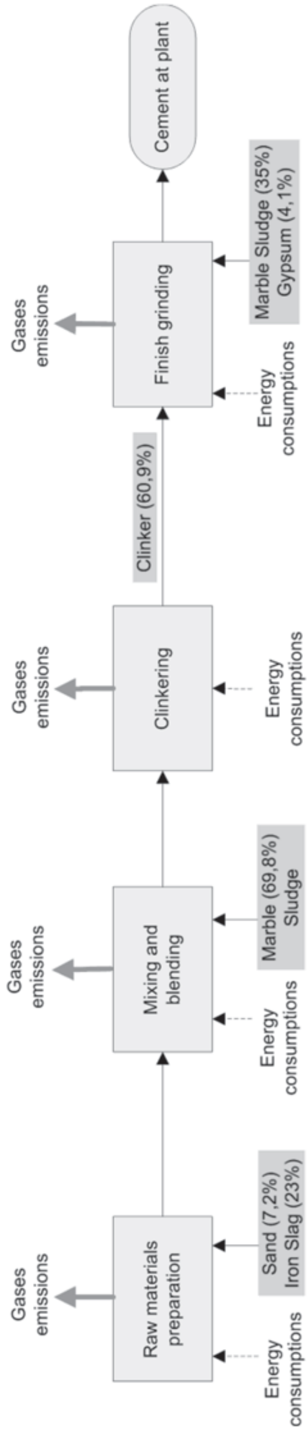

Fig. 3 Process substitution and addition of 35%

Table 1 Basic process inventory (1) and substitution and addition process (2)

	Basic process	Substitution and addition process
	Clinker-1	Clinker-2
Coal	$4.90·10^{-2}$ kg/kg	$4.90·10^{-2}$ kg/kg
Petroleum coke	$6.50·10^{-2}$ kg/kg	$6.50·10^{-2}$ kg/kg
Fuel oil	$1.22·10^{-2}$ kg/kg	$1.22·10^{-2}$ kg/kg
Diesel	$0.01·10^{-2}$ kg/kg	$0.01·10^{-2}$ kg/kg
Natural gas	$1.06·10^{-4}$ MJ/kg	$1.06·10^{-4\,MJ}$/kg
CO_2 from fuels	$0.39·10^{-1}$ kg/kg	$0.39·10^{-1}$ kg/kg
CO_2 from lime	–	–
Slag	$2.13·10^{-1}$ kg/kg	$2.18·10^{-1}$ kg/kg
Sandstone	$7.10·10^{-2}$ kg/kg	$7.10·10^{-2}$ kg/kg
Iron foil	$1.20·10^{-2}$ kg/kg	$1.20·10^{-2}$ kg/kg
Limestone/marble slug	$7.05·10^{-1}$ kg/kg	$6.98·10^{-1}$ kg/kg
EE	$4.80·10^{-2}$ KWh/kg	$1.20·10^{-2}$ KWh/kg
Process water	$5.90·10^{-4}$ m^3/kg	$5.90·10^{-4}$ m^3/kg
Agua	$4.47·10^{-4}$ t/kg	$4.47·10^{-4}$ t/kg
Trucking	$1.88·10^{-1}$ tkm/kg	$2.24·10^{-1}$ tkm/kg
Boat transport	$1.70·10^{-1}$ tkm/kg	− tkm/kg
	Cement-1	*Cement−2*
Trucking	$6.06·10^{-2}$ tkm/kg	$1.225·10^{-1}$ tkm/kg
Total clinker consumed	$9.50·10^{-1}$ kg/kg	$6.03·10^{-1}$ kg/kg
Gypsum	$5.00·10^{-2}$ kg/kg	$4.10·10^{-2}$ kg/kg
Marble Dust	– kg/kg	$3.55·10^{-1}$ kg/kg
Electric Power	$5.20·10^{-2}$ KWh/kg	$3.38·10^{-2}$ KWh/kg

Table 2 GEI emitted

Substance	Compartment	Ud	Basic process	Substitution and addition process
GHG	Air	kg	$8.56\ 10^{-1}$	$5.65\ 10^{-1}$

Because the percentage of $CaCO_3$ marble dust is 98.52 % versus 95 % of the lime supplied to the process, the required input marble dust to the formation of crude of cement is lower. Regarding the percentage of gypsum, is a function of the limit established by the UNE EN 197-1 for the content of sulfate (SO_3) less than 3.5 % by weight of the final cement.

The inventory (Table 1) is based on consultations with the factory, complemented by the ecoinvent database, and corrections existing in the scientific [20].

3 Results

The percentages of marble dust that is added has varied from 5 to 35 %, although the results are provided in this article (Table 2) refer to the course of further addition, 35 %, and complete replacement of the limestone crude cement.

The percentages of reduction of GHG emitted in the process to replace the limestone of the cement crude and addition of 35 %, are hovering around 34 % compared to the percentages emitted in the production of commercial cement.

4 Conclusions

This paper discussed a choice of industrial metabolism from the perspective of the impact of greenhouse gases. The most important aspects of this research are:

- In the case of replacement of the limestone by marble dust in the step of forming the cement crude, there are three steps are eliminated: the extraction process in mine, the associated transport, and the roller grinding mill.
- In the stage of production of cement by the addition of marble dust to the clinker, it avoids the ball mill grinding.
- Also, at this stage, with increasing the percentage of the addition of marble dust, the amount of clinker required is less, also reducing the greenhouse gases emitted in the clinkering.
- The decrease in GHG emissions is mainly due to the reduction in electricity consumption and transportation.

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Cement Paste Foamed by the Addition of Aluminiun Powder with Metakaolin and Sepiolite

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Abstract Spanish Technical Building Code requires thermal insulating materials inside the vent cameras of buildings façades, having low fire reaction (for instance, belonging to class A). Current thermal insulating materials are usually based on polymer foams, with the added disadvantage of producing toxic gases in case of fire. So, it's necessary to develop new incombustible materials of low density for insulating which can be sprayed. Cement mortar based foams are good candidates.

This paper analyzes the effects of type of cement selection or metakaolin (MK) and sepiolite (SP) addition on cement pastes foamed by aluminum powder, for determining the properties of fresh and hardened mortar. The water retention and the rheology of the fresh foamed cement pastes were studied to characterize the fresh mortar. Finally, pore network in the hardened foamed mortar was studied by imbibition methods. It is concluding that incorporating siliceous fly ashes (SFA) in ordinary Portland cement besides additions of MK or/and SP, the foamed mortar have lower bulk density and higher closed porosity. These properties are important for the thermal insulation materials applying in the vent cameras of building façades

Keywords Sprayed mortar • Cement • Fly ash • Metakaolín • Sepiolite • Aluminum powder

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1 Introduction

Aerated concrete is a mortar with filler, with voids generated by inorganic agents that react between each other (e.g. $Ca(ClO)_2$ with H_2O_2 producing O_2) or with the binder material (e.g. metallic powder with lime for producing H_2). Other option is reactions with organic agents undergoing a fermentation process.

Autoclaved Aerated Concrete is made with aluminum powder, based first on the reaction (1) to produce gas, and autoclaving to thermally activate the silica fraction in the aggregate. This make the silica sand to react with portlandite producing C–S–H, with varying C/S ratios, such as C_2SH, C_2SH (B) and C_2SH (D) what contributes to strength development [1].

$$2Al + 3Ca(OH)_2 + 6H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 6H_2O + 3H_2 \uparrow \quad (1)$$

The use of pozzolanic additions as MK, in lime-based mortars is a common practice in restoration works. Hydraulic phases are produced during pozzolanic reaction between lime and MK.

Sepiolite is a clay with thixotropic behavior, used as a thickener for cement slurry, paint and additives. In cement investigation, has been used as a carrier agent of biocide products for restoration purposes, due to its zeolitic behavior [2].

2 Materials

2.1 Binders

Cements used in this investigation were Calcium Aluminate Cement (CAC) from Kerneos Aluminates (France), White Portland Cement (WPC) and Ordinary Portland Cement with Fly Ash (OPC), (designated as BL II 52.5 R and CEM II A/V 42.5 R respectively according to the European Standard UNE-EN 197-1) both from Tudela Veguin (Spain).

Aerial binder used was high calcium lime (CH), (classified as CL-90-S according to the European Standard ENV 459-1) from Calcasa (Madrid). See Table 1 for chemical composition.

2.2 Additions

Pozzolanic material used was metakaolin (MK) from Grace, S. A. As viscosity modifiers dry micronized sepiolite (SP) Pansil from Tolsa, S. L. (Madrid) were also used. See Table 1 for chemical composition.

Table 1 Chemical composition of the materials used for this research

Oxides (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	TiO_2	Na_2O	MgO	K_2O	L.O.I. 1,000 °C
Metakaolin	52.00	44.00	1.40	0.10	0.10	3.00	0.05	0.10	0.40	1.07
Sepiolite	63.18	3.95	0.54	0.63		0.13	0.67	20.23	1.38	
CAC	6.00	37.00	18.50	39.80	0.40	4.00	0.2	1.50	0.2	
CH				93.00				0.50		

Table 2 Mix proportion

Mix	w/p ratio	BL I 52.5 R (%)	CEM II A/V (%)	CAC (%)	CH (%)	Al (%)	Addition	
							MK (%)	SP (%)
WPC/CAC/CH/H-80	0.80	50.00	0.00	9.20	40.00	0.80	0.00	0.00
WPC/CAC/CH/SP-1/H-80	0.80	50.00	0.00	9.20	39.00	0.80	0.00	1.00
WPC/CAC/CH/SP-2,5/H-80	0.80	50.00	0.00	9.20	37.50	0.80	0.00	2.50
WPC/CAC/CH/MK-10/H-80	0.80	45.00	0.00	9.20	35.00	0.80	10.00	0.00
WPC/CAC/CH/MK-20/H-80	0.80	40.00	0.00	9.20	30.00	0.80	20.00	0.00
OPC/CH/H-80	0.80	0.00	80.00	0.00	19.20	0.80	0.00	0.00
OPC/CH/SP-1/H-80	0.80	0.00	79.00	0.00	19.20	0.80	0.00	1.00
OPC/CH/SP-2/H-80	0.80	0.00	78.00	0.00	19.20	0.80	0.00	2.00
OPC/CH/MK-10/H-80	0.80	0.00	70.00	0.00	19.20	0.80	10.00	0.00
OPC/CH/MK-20/H-80	0.80	0.00	60.00	0.00	19.20	0.80	20.00	0.00

3 Methodology

The purpose of this investigation was to analyze the effect of the addition of MK and SP in the expansion of aerated concrete. With this aim, this research focuses on the study of properties of fresh and hardened mortar.

3.1 Production of the pastes

Pastes were mixed with a mechanical kneading. Two reference pastes were designed, the first one with WPC/CAC/CH in the ratio 5:1:4, and the second one with OPC/CH in the ratio 4:1. All mixes have 0.8 % of aluminum powder content. Water was mixed by weight, mixing proportions of this research are given in Table 2.

3.2 Viscosity of the Paste

European Standard UNE-EN 1015-3 is the reference used to determine the consistency and viscosity of the paste. Aluminum powder was removed from the mix to avoid the expansion effect. Pastes were poured into a truncated cone cast ($D_1 = 100$ mm, $D_2 = 70$ mm, $h = 60$ mm) over a shacking table. 15 shocks in the table and 10 stings in the fresh pastes were applied before demolding. Two perpendicular spread diameters were recorded, the procedure was repeated after each 10 min.

3.3 Water Retention of the Paste

Water retention of pastes without aluminum powder was tested according to European Standard UNE-EN 83-816-93. Fresh pastes were poured 10 min after blending into a cylindrical cast ($D = 70$ mm, $h = 2$ cm) on the top of two absorbent papers and a cotton gauze, to measure the weight of water absorbed by the paper in correspondence with the water content in the mix after 5 min.

3.4 Density and Porosity

Archimedes method was used to calculate bulk density, samples of $50 \times 50 \times 50$ mm^3 were weighed after drying for 24 h in an furnace at 105 °C. Then, samples were fully saturated with water in a vacuum chamber equipped with precision instruments that supplied subatmospheric pressures between 380 and 450 mmHg and finally suspended in water. Le Chatelier flasks were used to calculate true density after crushing 80 g. of samples.

4 Results and Discussion

4.1 Viscosity of the Paste

Viscosity is an important factor in sprayed materials. Pastes should be fluid enough when flowing through a hose, and stiffer once sprayed over vertical surfaces to avoid material slipping down. A render of a layer of paste of 2 cm thickness over a ceramic support was used to check material flowing. Foaming is originated by hydrogen produced in reaction (1). Pastes should be as consistent to entrap gas bubbles and fluid enough to allow deformation of the paste (Fig. 1).

Viscosity depends on water/powder ratio and powder greediness of water, e.g. lime absorbs water with great avidity [3]. Figure 3 show that OPC/CH series have a low consistency due to the lower lime ratio. All series show that small amounts

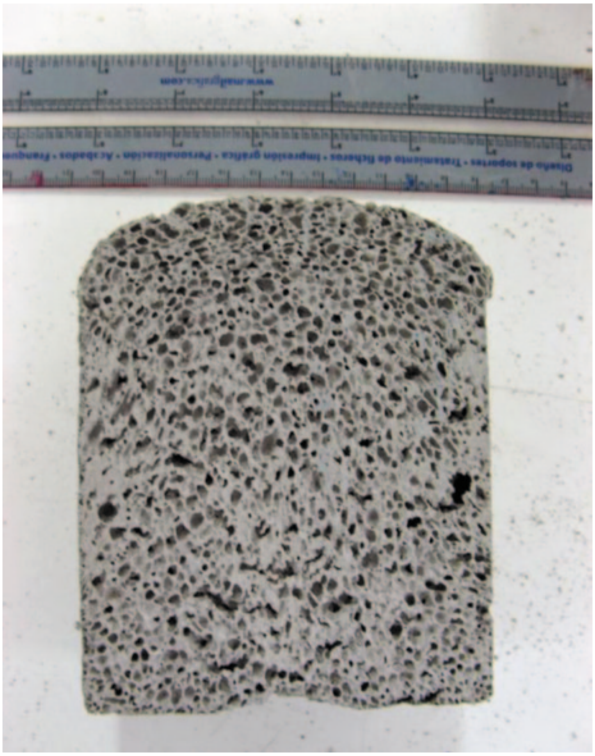


Fig. 1 Cross section OPC/CH/H-80

of SP increase pastes consistency as well as MK. It also improves consistency, as Caldarone et al. observed [4].

Cement pastes become rigid over time regardless of the addition of SP or MK. All pastes in WPC/CAC/CH series became plastic after 10 min, due to the higher lime ratio. Unlike in OPC/CH series, with the same water/powder ratio, only mixes with higher amounts of SP or MK became plastic after 10 min due to higher starting consistency.

4.2 Water Retention of the Paste

Water retention is a mortar property that prevents the rapid loss of water due to the absorption of supporting materials. Water loss in foamed cements affects to hydration of cement, viscosity of paste and production of gas. In other words, it determine foaming and paste mechanical performance.

Lime contribution to water retention capacity is widely accepted [5], this effect is highlighted in Fig. 4, WPC/CAC/CH series, containing large amounts of lime has higher water retention. SP is a hydrophilic material which retains a large amount of water [6]. That's why small amounts of lime replacement with SP in blended pastes,

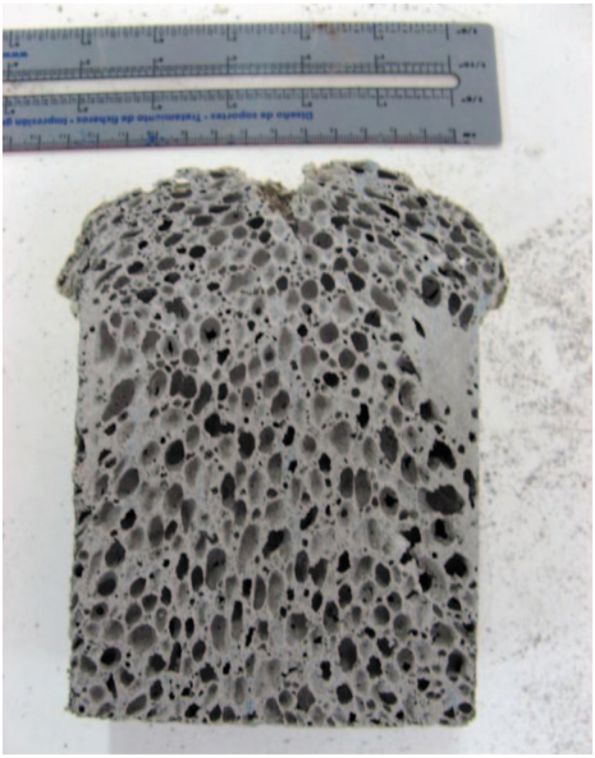


Fig. 2 Cross section OPC/CH/MK-10

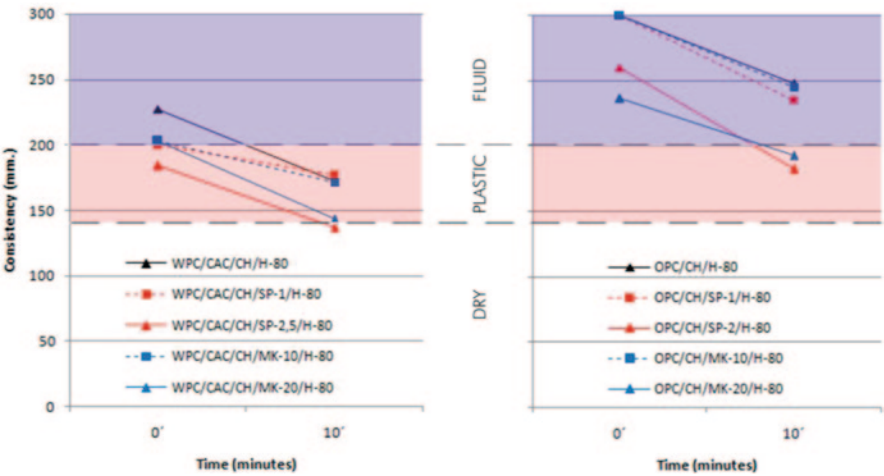


Fig. 3 Evolution of consistency

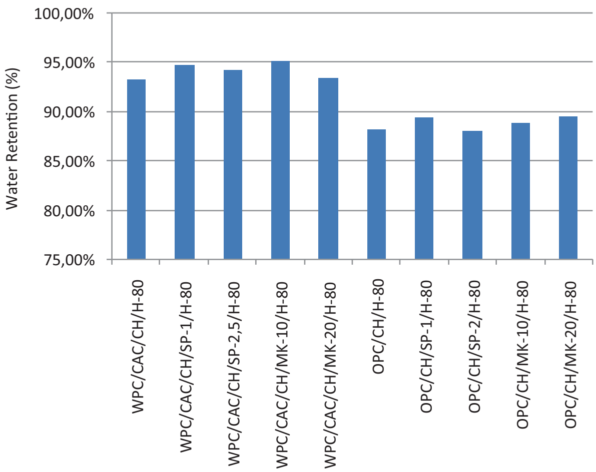


Fig. 4 Water retention

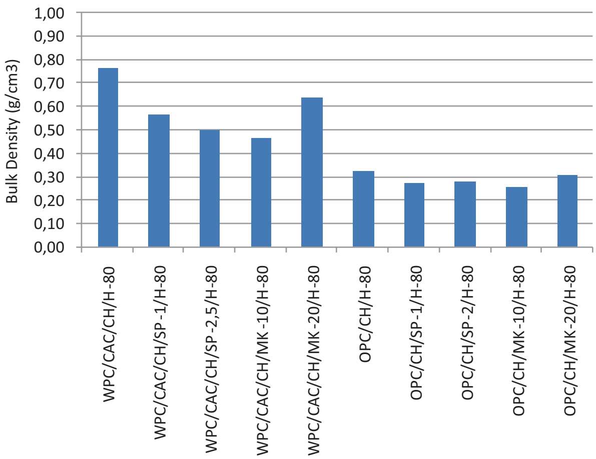


Fig. 5 Bulk density

improves water retention. Water requirement increase owed to MK presence, attributed to its high fineness [7].

4.3 Density and Porosity

Thermal conductivity in foamed cement pastes is consequence of the hydrogen bubbles retained by the cement paste, which is defined by the bulk density. Figure 5 shows that pastes with siliceous fly ash cements, OPC/CH series, have lower bulk density. In all series, lower densities are found out with SP and MK addition, best values are achieved with 2 % of SP content or 10 % of MK content.

Fig. 6 Open porosity

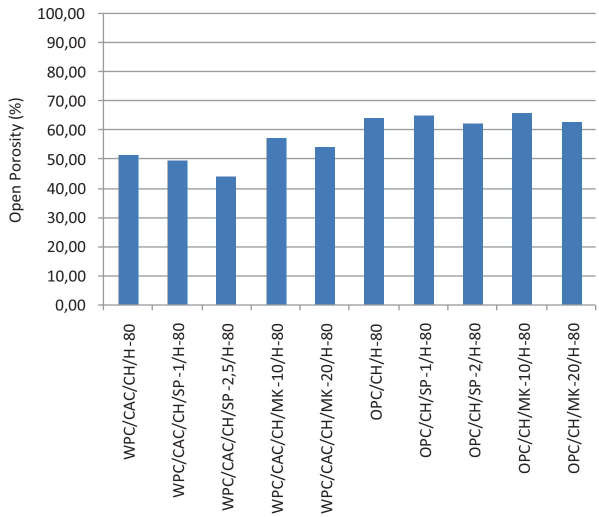
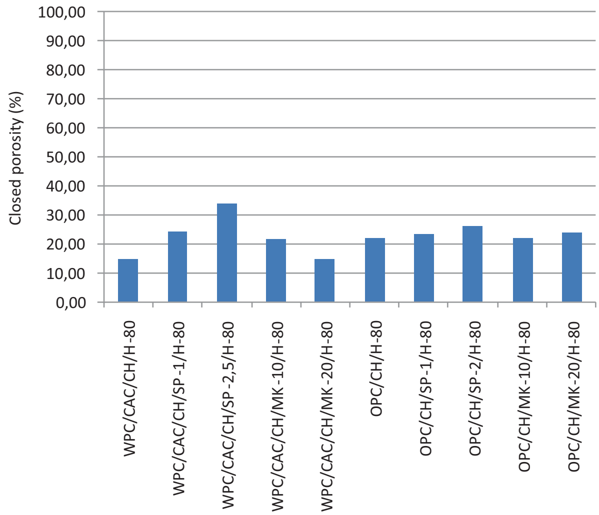


Fig. 7 Closed porosity



Closed porosity produces higher isolation behaviour due to lack of air circulation through pores network. Closed porosity is mainly increased with SP addition, even without SFA, as can be seen in Fig. 7.

Open porosity is the feature best improved by cement with SFA; as is highlighted in Fig. 6.

5 Conclusions

This work presents a research in cement pastes foamed with aluminum powder, in order to achieve a composition which can be pneumatically sprayed. Pastes were made using cement with siliceous fly ash, and metakaolín or sepiolite addition to check effects on fresh pastes properties and foamed hardened pastes features.

Based on the results of this work, the following conclusions can be pointed out:

- Sepiolite and metakaolin addition improve viscosity and water retention of cement pastes designed to be foamed with aluminum powder and water.
- The use of cement with siliceous fly ash achieves a large reduction of bulk density of foamed cement pastes.
- Sepiolite and metakaolin addition reduced bulk density regardless of the type of cement used.
- Sepiolite is the addition which provides a largest increase of closed porosity in foamed cement pastes.

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Preliminar Assessment of Durability for Aluminium Composite Panels

E. Lahoz and F. Hernández de Olivares

Abstract Aluminium composite panels (ACP) are thin and lightweight sandwich panels composed usually by two alloyed aluminium sheets bonded to a non insulating core made of low density polyethylene, with or without added fire retardant substances (currently named as type FR or PE respectively). Cladding kits based on ACP are considered as repairable or replaceable with some more efforts. It is assumed that its intended working life will reach at least 25 years. Experimental studios on ACP degradation are based on the decay of delamination resistance by peeling test before and after artificial ageing, but there is a gap of correlation between artificial ageing procedure and real experience, which does not allow to confirm if durability is similar to the expected working life. Comparation of delamination resistance by peeling tests after laboratory ageing and real exposure has been carried out in order to confirm that durability of at least 25 years can be reached, provided that decay of initial delamination resistance of panel does not reach 25 % when exposed to heat or moisture ageing in laboratory conditions.

Keywords Aluminium composite panels • Durability • Delamination resistance • Peeling test

1 Introduction

Even now, both aluminium composite panels (hereafter ACP) and cladding kits based on ACP (e.g. cassette shown in Fig. 1) are considered as innovative products in Europe. ACP are thin and lightweight sandwich panels composed usually by two alloyed aluminium sheets bonded by a film adhesive to a non insulating core made of low density polyethylene (hereafter LDPE) plus with or without added fire retardant substances, named currently as type FR or PE respectively (Fig. 2).

Until now, in some Member States, only innovative products favourably assessed through the national Approval procedure are accepted by the market. For

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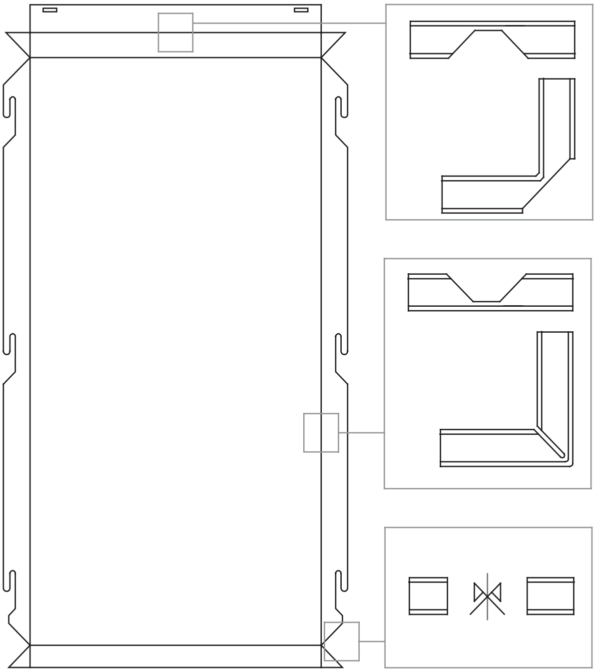

Fig. 1 Flat ACP pattern for cassette

example, in France it was in 1995 when first national Approvals (Avis Technique 2/94-388 [1] and 2/94-389 [2]) were issued iby Centre Scientifique et Technique du Bâtiment (hereafter CSTB) for respectively cladding kits based on riveted boards and on suspended cassettes made from ACP ALUCOBOND, delivered then by Société ALUSSUISSE). In Spain, Instituto de Ciencias de Construcción Eduardo Torroja (hereafter IETcc) issued DIT 345 [3] and 346 [4] for these same ACP in 2000. In 2003, IETcc issued DIT 405 [5] for similar cladding kits based on ACP LARSON (first ACP manufactured in Spain by ALUCOIL S.L.)

In all of those documents, delamination resistance was determined through peeling test according to ASTM D 1781 as a factory production control and not as a durability parameter. In fact, as minimum manufacturers declares an acceptance value of 52 N.mm/mm. And for example in relation to durability, Avis Technique concluded without testing that due to the intrinsic durability of the components and its compatibility, it can be expected a 30 years durability can be reasonably expected. According to recently approved European Technical Approval Guideline (hereafter ETAG) n. 034 [6] for cladding kits, an expected working life 25 years should be considered for cladding kits as they are expected to be easily reparable or replaceable with some efforts. Nevertheless, there is a gap of correlation between artificial ageing procedure and real experience, which does not allow to confirm if durability is similar to the expected working life. This paper focuses on save this gap for ACP type PE.

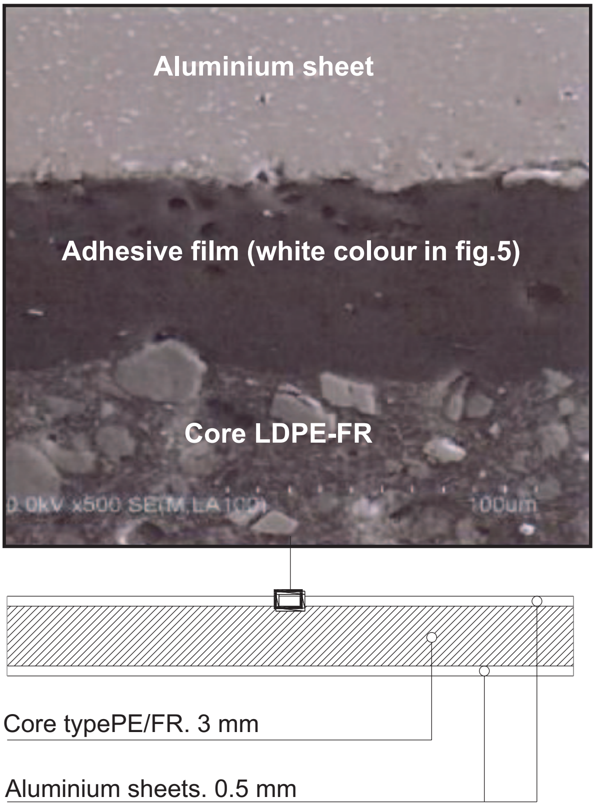

Fig. 2 Example of ACP composition

2 State of Art

First experience from manufacture was carried out for ALUCOBOND in 1992 [7]. Then, it was determined the decay of delamination resistance by peeling test according to standard ASTM D 1781-76 [8] before and after exposition to Cycle B of Standard ASTM C 481 [9]. This ageing consists on six repetitions of the following steps:

- 1. Total immersion in water (1 h. 50 ± 3 °C)
- 2. Exposure to dry air (3 h. 70 ± 3 °C)
- 3. Sprayed hot water (3 h at 70 ± 3 °C)
- 4. Exposure to dry air for (18 h at 70 ± 3 °C)

And following results were obtained on specimens made of ACP ALUCOBOND type PE Figure 4 and figure 5,

- Peeling strength (initial state): 163,6 N.mm/mm
- Peeling strength (front sheet) after Cycle B: 154,1 N.mm/mm

There was a decay of approximately 6 %, but no correspondence is expressed in this Report of Test between Cycle B ageing and a determined period of time. Comparation to minimum declared valued (52 N.mm/mm) considered valid for "as deliver state" does not clarify which is the limit between acceptable and inacceptable durability.

Delamination resistance obtained by peeling test was researched by some authors like John A. Wiliams and James J. Kauzlarich [10], which pointed out that maintaining a constant angle when applying the peeling force (like the procedure described at ASTM D 1781) was the critical variable for a reliable determination of this resistance, but also announced that temperature (and perhaps also humidity) were important variables for many tape/adhesive combinations.

Heat and moisture can be the main ageing agents causing the decay of bonding performance of a determined adhesive. This is one of the conclusions pointed out by Lucas F.M. da Silva et al [11], who researched on the influence of several factors on the tensile strength of some adhesives all of them different than, before and after the exposition of single lap joints at 50 °C and 80 % RH along 1 and 4 weeks. Moisture influence alone was also studied more than twenty years ago by H.M. Hand et al. [12]. They pointed out that bonding strength of some adhesives (e.g. those based on a hydrophilic matrix) may become seriously affected when exposed to humidity.

3 Methodology

3.1 General

It is based on ISO 15686-2:2012 [13], and has been divided into three parts (Fig. 3):

- Initial, comprising the hypothesis (step 1): Durability of ACP as part of external cladding kit is at least 25 years.
- Principal, composed by a definition of theoretical items (steps 2–5) plus experimental tasks defined below, based on artificial and real exposures (steps 6–9). As objectives, it is proposed to research the degradations of delamination resistance under appropriate ageing exposures.
- Final, comprising a proposed estimation of durability expressed in years (step 10).

3.2 Experimental

3.2.1 Tests Program

According to steps 6–7 (Fig. 3), it was compared in first place existing data from ALUCOBOND samples (size 305 × 76 × 4 mm) aged in real conditions (façade "A"). Then, there were carried out new tests on samples of ACP LARSON, supplied by ALUCOIL, exposed to ageing procedures in laboratory (based on Draft 06 of EOTA TR [14]), and on samples exposed to available real ageing conditions

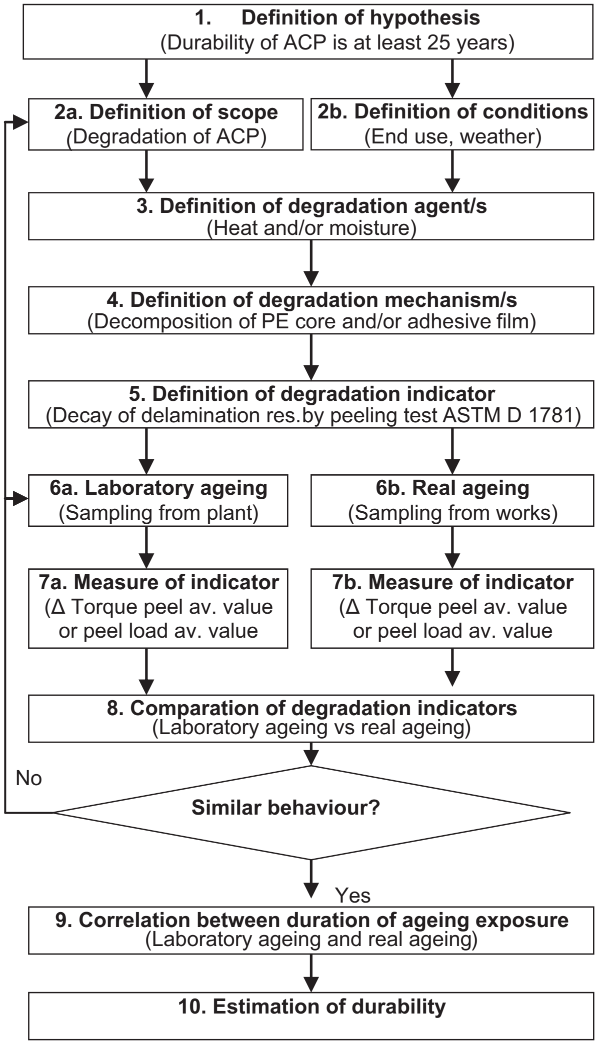

Fig. 3 Scheme of methodology

(façade "B"). For identification, samples were named as "PE-1" (if they came from ACP ALUCOBOND, or as "PE-2" (if they came from ACP LARSON). Indicator variable depends on manufacturer control procedures (Tables 1 and 2).

4 Results

Following tables show results from laboratory and real exposures.

Table 1 Ageing program

Agent	Mechanism (Procedure)	Indicator (units)	Laboratory ageing (Sample)	Real ageing (Sample)
Heat and/or Moisture	Decay of delamination resistance *(ASTM D 1781)*	Torque peel *(N.mm/mm)*	Cycle B ASTM C 481 *(PE-1) See §. 2*	Façade A *(PE-1)*
		Load *(N)*	36 days (~2500 h/3) 80 °C *(PE-2)*	Façade B *(PE-2)*
		Load *(N)*	Water immersion 20 °C 21 d *(PE-2)*	Façade B *(PE-2)*

Table 2 Real ageing conditions

Façade	Location	Built (year)	ACP	Colour	Or	Temperature		Precipitation (P. days)
						ΔT_{av}	$T_{max\ av}$	
A	Balsicas (Murcia)	2003	PE-1	Black	West	9.5 °C[a]	22 °C[a]	5.5[a]
B	Miranda de Ebro (Burgos)	2006	PE-2	Silver	Northwest	11.5 °C[b]	16 °C[b]	8.8[b]

ΔT_{av} = Month average (maximum—minimum) temperature difference
$T_{max\ av}$ = Month average maximum temperature
P. days = Average number of days per month in which precipitation occurs
[a] Available data from Murcia Airport meteorological station.50 years period: 1962–2012 [15]
[b] Available data from Burgos Airport meteorological station.50 years period: 1962–2012 [16]

4.1 Comparation Between Laboratory and Real Ageing Exposures for ACP "PE-1" (Table 3)

Although range of initial values for specific samples exposed to real ageing in façade A is unknown, it seems that a more severe decay of delamination resistance is obtained after a real exposure of 8.33 years rather than according to Cycle B of ASTM C 481.

4.2 Comparation Between Laboratory and Real Ageing Exposures for ACP "PE-2" (Table 4)

PE-2 manufacturer's declared range for initial values raises from 550 to 850 N. Therefore, real exposure value of 751.2 N can not be interpreted as an increase of delamination resistance due to exposure to heat. On the other hand, procedure for laboratory ageing by exposure to heat (80 °C) is foreseen to last 2,500 h. according to Draft 06 EOTA TR in order to demonstrate a 25 years durability. Due to time limitations, a reduced exposure of 35 days (840 h) approximately the 1/3 of 2,500 h, was carried out for this preliminary assessment.

Table 3 Decay of delamination resistance by peeling test of ACP "PE-1"

Laboratory exposure: Cycle B ASTM C 481						Real exposure (8.33 years on façade A)					
Initial av.value		Aged av.value		Decay		Initial av.value		Aged av.value		Decay	
Torque peel (N.mm/mm)	Breakage	Torque peel (N.mm/mm)	Breakage	Δ Peeling (%)	Variation breakage	Torque peel (N.mm/mm)	Type of breakage	Torque peel (N.mm/mm)	Type of breakage	Δ Peeling (%)	Variation breakage
163.6	Cohesive, inside adhesive	154.1	Cohesive inside adhe-sive	5.80	No	Unknown		113.1 (ext. sheet-core) 139.8 (rear sheet-core)	Cohesive, inside adhesive	Unknown	

Table 4 Decay of delamination resistance by peeling test external sheet-core of ACP "PE-2"

Laboratory exposure: 35 d. at 80 °C						Real exposure (6 years on façade B)					
Initial av.value		Aged av.value		Decay		Initial av.value		Aged av.value		Decay	
Load (N)	Breakage	Load (N)	Breakage	Δ Peeling (%)	Variation breakage	Load (N)	Type of breakage	Load (N)	Type of breakage	Δ Peeling (%)	Variation breakage
648.3	Cohesive, inside adhesive	591.5	Cohesive inside adhesive	8.75	No	Unknown		751.2	Cohesive, inside adhe-sive	Unknown	
Laboratory ex: Water immersion 21 d 20 °C											
Initial av.value		Aged av.value		Decay							
Load (N)	Breakage	Load (N)	Breakage	Δ Peeling (%)	Variation breakage						
648.3	Cohesive, inside adhesive	654.3	Cohesive, inside adhesive	−0.75	No						

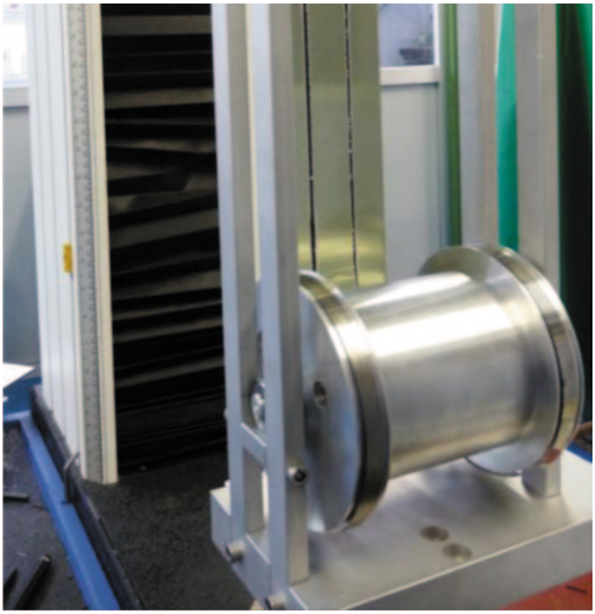

Fig. 4 Specimen during peeling test

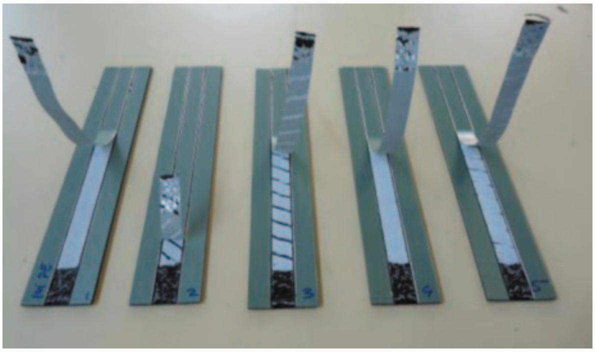

Fig. 5 Specimens after peeling test

5 Conclussions

Following conclusions are presented:

1. Real exposure results after 8.33 years (Table 3) are more severe than laboratory aged results based on heat and moisture exposure according to Cycle B of ASTM C-481. Therefore this particular ageing procedure is not reliable for demonstrate that durability of ACP is at least 25 years when they are foreseen to be used as part of external claddings.

2. Exposure to heat, and in particular orientation and colour of cladding will bring a decay of delamination resistance. On the other hand, moisture, will not influence on the decay of delamination resistance provided that ACP panels, like PE-1 and PE-2, are composed by non porous cores and by non hydrophilic adhesive films.
3. Preliminary decay of delamination resistance after 35 days of heat exposure in laboratory conditions, confirms reliability of methodology and requirement (25 % after 2,500 h) proposed by Draft 06 EOTA TR for an estimated durability of 25 years of ACP.

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Additived Plaster with Rice Husk Waste

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Abstract The rice husk is an abundant and renewable waste, which can be used as alternative building material instead of those which are commercialized today. The main purpose of this work raises as a study of the behavior of a new material resulting from the mix of plaster and the mentioned waste in different percentages, in order to analyze the results and the feasibility of this new building material "cast-rice husk", which would reduce the waste and use of raw materials, thus contributing to environmental improvement.

For this purpose, specimen test with different percentages of the rice hulls will take place, besides, tests in order to analyze their behavior by comparison with the matrix.

The conclusion of these tests are:

- The addition of rice husk reduces the density of the plaster although it generates a loss of value in the bending strength and compressive strength.
- This new material can be used as material for the manufacture of prefabricated elements and other structural elements that require low weight.

Keywords Husk rise • Plaster • Hardness • Flexural strength and compressive strength

1 Introduction

The rice husk is the biggest waste resulting from cereal grains' agricultural production, and its final destination is one of the biggest problems facing rice-producing countries. Each 4 t of rice produced, generates a ton of husk. In the EU the third largest producer of rice is Spain with a production of 926,400 t in 2010 (FAOTAST).

Fertilizers, herbicides, insecticides and fungicides, are used in the rice production, transforming the husk in a highly polluted waste. We must avoid burning this waste, as it releases toxic that may cause respiratory problems.

Once we realize the problem that this waste generates the uses that are being given to it and the research regarding its use [6], this study is proposed to provide other solutions to the rice husk generated in the cultivation of this cereal.

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The rice husk is an abundant and renewable waste, which can be used as alternative building material instead of those which are commercialized today by reducing the human consumption and the use of raw materials, helping to minimize environmental problems generated by the improper elimination of this waste.

The main objective of this study proposes to study the viability of the mix of the waste already mentioned with plaster, in different percentages.

1.1 Lightly Plaster's Background

To lighten the plaster it has been used:

- Occlusion of air mass: increasing the A/E, by using carbonated water, air entraining, and foaming.
- Addition of light loads: expanded clay, perlite, vermiculite, expanded polystyrene, EPS waste, natural cork, foam glass.

Several researchers have joined to the plaster, lightweight aggregate to reduce its density. Regarding these studies, we should highlight the study of Oteiza San José I. [1] as in his study he incorporates rice husk with water/plaster 0.6 and additions of 1 and 2 % of fiber on dry weight of the plaster.

The results and conclusions of the author about the incorporation of the fiber are: good workability, reduction of the flexural strength in a 25 % compared with the reference, densities similar to those of the plaster with no additions and the increasing of the resistance of compressive strength by 12 % compared to the reference. Therefore, the study concludes that this fiber, with the percentages used in his study, does not provide significant improvements in relation to the plaster without additions.

Rio Merino M. [2] has performed several studies to ease up the plaster based on: the occlusion of air mass and the incorporation of light loads such as expanded clay, expanded perlite, vermiculite, expanded polystyrene, cellular glass and cork waste granules [3]. Their findings support the composites consisting of plaster and plaster-cork-EPS.

Gonzalez Madariaga F.J. [4] works on how to recycle the EPS' waste. Through its experimental studies, he confirms the possibility of using these residues, and asserts that the plates and panels with these wastes can meet the uses of laminated plasterboard and EPS panels for the building trade but with minor requests for some of its characteristics [5].

Jobbins F. [6] has a patent which suggests an alternative material to the addition of expanded vermiculite, perlite and more recently thermoplastic particles, incorporating a natural or synthetic latex to the mass of plaster in combination with a nonionic surfactant.

Sumin Kim [7] has performed a study with plaster's panels manufactured with addition of rice husk up to 40 % on the weight of the plaster. It is concluded that rice husk is a good reinforcement material, with some resistance effect regarding water and humidity absorption.

By taking into consideration all the literature reviewed, we can conclude that there are many researchers who have worked incorporating to the plaster, different additions to improve some of its features (reducing its density, improving its toughness, etc…) Or just to save in raw materials and reduce the spilt of waste (rubber, EPS from recycling, etc) Apart of Oteiza's investigations regarding the addition of rice husk, and the studies done by Sumin Kim, no more references can be found in the literature regarding to the addition of this residue in any binder. Therefore, it has been decided to continue this study (1 and 2 % and A/E = 0.6) to compare results and to study the viability of incorporating such waste in larger quantities.

2 Methodology

- Study and analysis of the materials used in this research.
- Experimental plan: materials, standards and tests.
- Analysis of results.
- Conclusions.

3 Materials Used

Plaster using in experimental studies is Iberplaco E-35

Husk rice: husk rice is a short fiber, which covers grain in natural state, for protect it against environment. It appears in milling process in the cultivation of this cereal. Its length varies between 5 and 11 mm according species considered; its structure is wavy and irregular superficial appearance [8]. Husk rise has highest abrasives properties and 6 in Mohs scale in natural state. Its structure has a porous volume about 54 %, and cavities which stay close until combustion process [9].

Husk rice used coming from San Juan de Aznalfarache, Seville (Spain) and it belongs to Herba Ricemills Company.

4 Experimental Plan

The tests have being made in Materials Laboratory of Technique Architecture University of Madrid. The temperature of Laboratory is 73.4 °F (23 °C) and relative moisture is 26.4 %.

Specimen test with references dimensions (40 × 40 × 160 mm) will take place using international rule UNE-EN 13279-2 and plaster E-35 and A/E = 0,6 and A/E = 0,8.

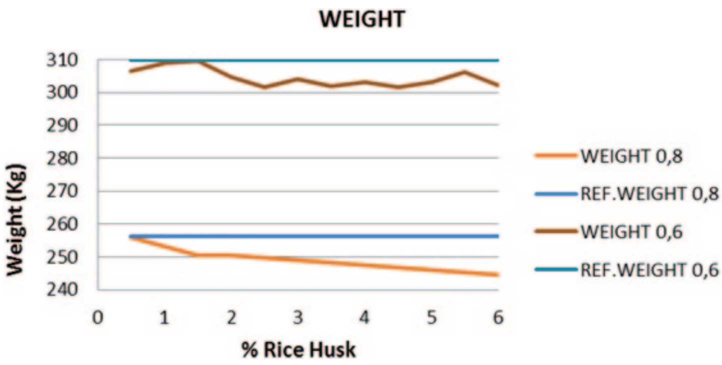

Fig. 1 Determination of Weigh specimen test with mix plaster and husk rise in different percentages and reference line

5 Analysis of Results

5.1 Workability

Tests with relation A/E = 0.6 showed good workability, whenever percentages of rice husk should not be higher than 6 %. Testing with ratio A/E = 0.8 show good workability independently from waste addition.

5.2 Density

The Fig. 1 represents results of Weigh Test. It compared laboratory tests, with mix plaster and husk rise in different percentages, with reference line. The specimen test mix plaster and husk rise don't show a significant increment of density, because all density measures are below reference line.

5.3 Shore C Hardness

The Fig. 2 represents results of Shore C Hardness Test. Those laboratory tests with ratio A/E = 0.6 with waste incorporated about 4 % and higher, showed hardness values above line reference. Specimen test with ratio A/E = 0.8 have hardness values similar to reference line, reaching decrease about 3 % in those tests with 8 % of waste incorporated.

5.4 Flexural Strength

The Fig. 3 represents results of Flexural Strength Test. Those specimen test with ratio A/E = 0.6 showed a reduction of flexural strength in a 43 % compared with the

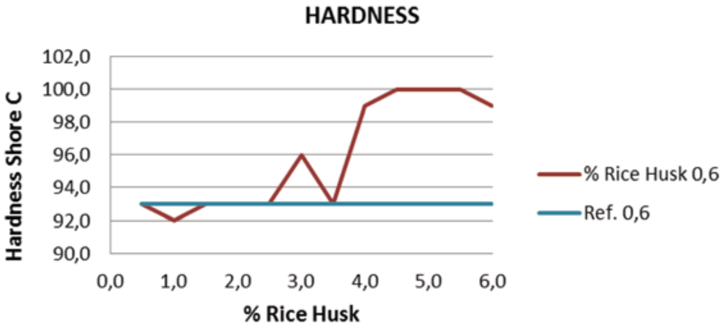

Fig. 2 Determination of Shore C Hardness with mix plaster and husk rise in different percentages and reference line

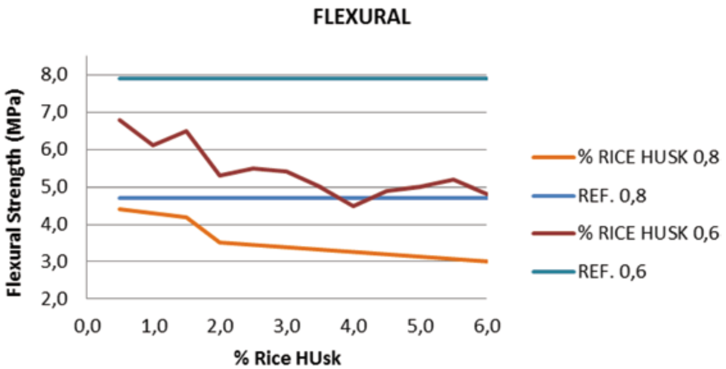

Fig. 3 Determination of Flexural Strength with mix plaster and husk rise in different percentages and reference line

reference (7.9 MPa). However specimen test with ratio A/E = 0.8 showed a reduction of flexural strength in a 43 % compared with the reference line (4.7 MPa).

5.5 *Compression Strength*

The Fig. 4 represents results of Compression Strength Test. Compression Strength decrease slower than Flexural Strength. Compression Strength is 43 % lower than reference value (17,4 MPa) for those specimen test with ratio A/E = 0,6 and 6 % waste incorporated. However for those specimen test with ratio A/E = 0,8 and 8 % waste incorporated, the decrease is about 57 % versus reference (10,4 MPa)

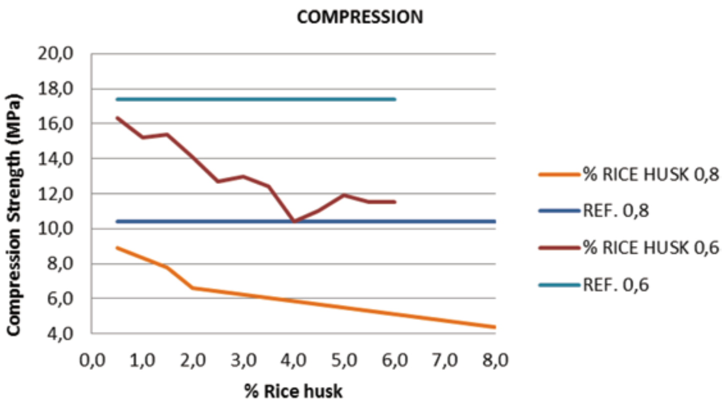

Fig. 4 Compression Strength with mix plaster and husk rise in different percentages and reference line

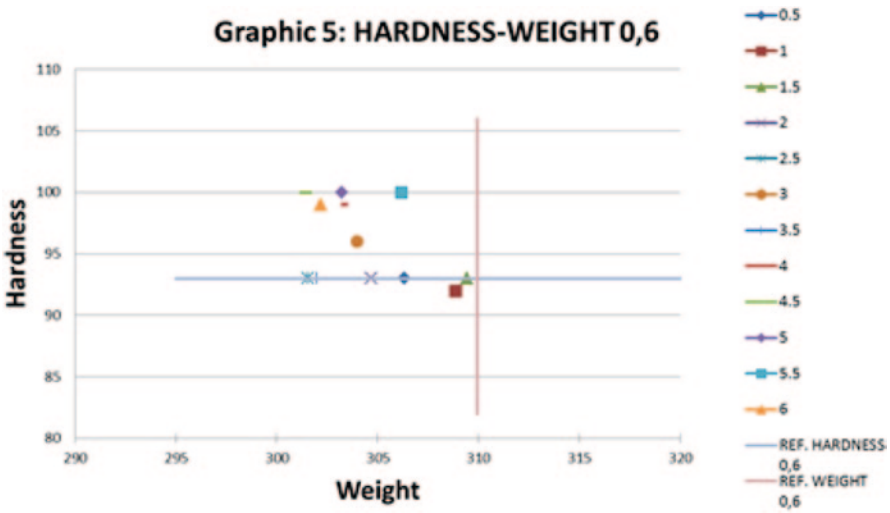

Fig. 5 Comparative hardness- weight in laboratory test with ratio A/E = 0.6 and A/E = 0.8

6 Conclusions

The present study concludes that this fiber, with the percentages used in his study, does not provide significant improvements in relation to the plaster without additions for the weight loss (Fig. 1). For studying possibility to use this component in low weight building material and so increase this effect, it should be necessary using higher husk rice addition, however we take into account the addition of rice husk reduces the density of the plaster although it generates a loss of value in the bending strength, compressive strength and workability. In laboratory tests with

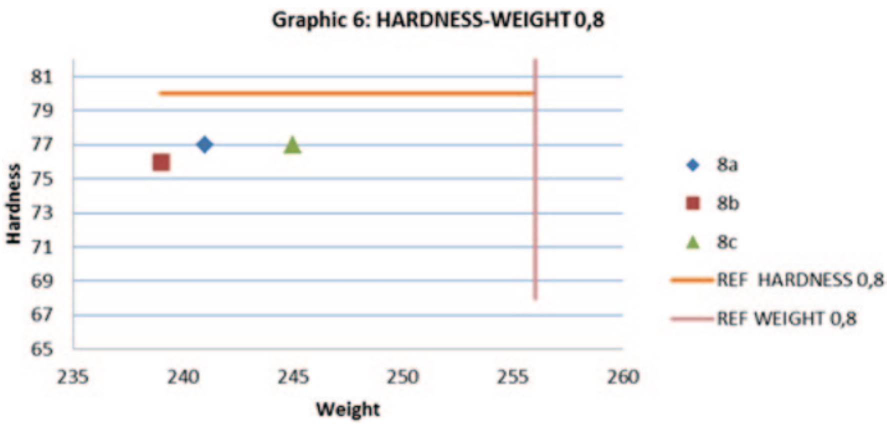

Fig. 6 Comparative strength bending-weigh in laboratory test with ratio A/E = 0.6 and A/E = 0.8

A/E = 0.8 were used additions of 8 % of fiber on dry weight of the plaster so for testing material behavior is necessary increase percentage load versus workability.

About Strength (Fig. 5) appeared two perpendicular lines which define the reference values. The components in the left side have lower density values and the components in the up side have higher hardness. Husk rice additions below 4 % showed an increase hardness, however additions about 8 % and ratio A/E = 0.8 have hardness lower than reference value.

The Fig. 6 represents results of strength bending-weight in specimen test with ratio A/E = 0.6 and 0.8. The components in the left side of the vertical reference line have lower density and the components in the up side of the horizontal reference line have better strength bending. It is concluded that loss strength bending is not a regular patron; it due to heterogeneous distribution of husk rice inside laboratory tests observed in rupture tests and it produces a dispersion of data.

The Fig. 7 represents decrease of Strength Compressive versus decrease waste addition in plaster. The exceptions are addition 4 and 4.5 % which have lower Strength Compressive than those with higher husk rice addition.

Decreases of 58 % of strength compression is produced in specimen test with 8 % of husk rice addition.

This study concludes that plaster with husk rice addition reduce its mechanical strength significantly, in relation to the plaster without additions. This point will be important aspect if components loss required properties. In this case would have to analyze using reinforcing commercial material that several researchers have joined to the plaster.

The final product has a wrinkled aspect in part which is not in contact with the mold when husk rise percentages are high. So if we use this product like coating this aspect will improve adherence but previous analyses are required for choosing appropriate products.

Plaster mix husk rice could be an viable alternative building material instead of those which are commercialized today.

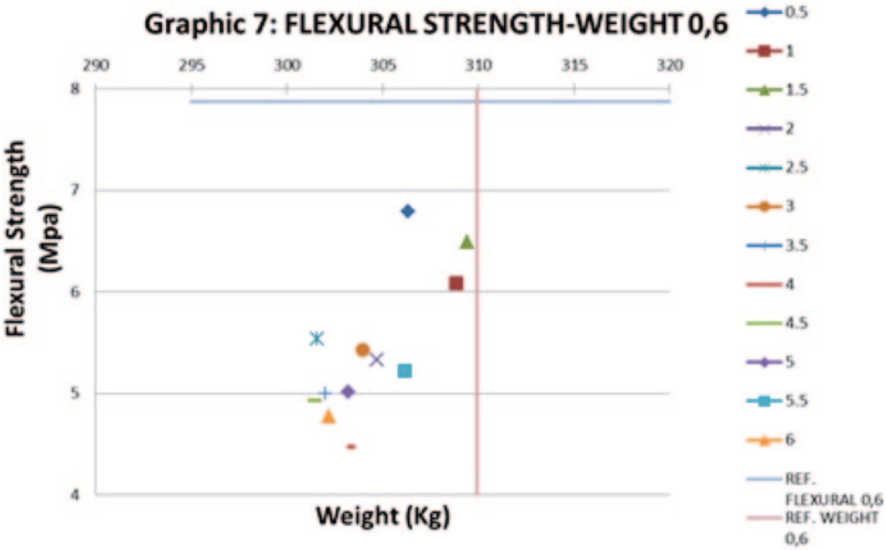

Fig. 7 Comparative strength compression-weigh in laboratory test with ratio A/E = 0.6 and A/E = 0.8

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Study and Improvement of SCC Mixtures of Concrete Industry

A. Navarro

Abstract The prepared concrete industry and the technology sector of the concrete is very competitive and constantly evolving. [Roncero et al., Empleo de hormigones autocompactantes con bajos contenidos de finos en el sector del hormigón preparado: algunas experiencias prácticas. 1st Spanish Congress on Self-Compacting Concrete. Valencia, 2008; Walraven, Self compacting concrete: Challenge for designer and researcher. 1st Spanish Congress on Self-Compacting Concrete. Valencia, 2008]. The self-compacting concrete is emerging as an effective solution for lower skilled workers. So getting the best performance concretes, reduce costs, is the day to manufacturers. [Lasala, Empleo de hormigón autocompactante en prefabricación. 1st Spanish Congress on Self-Compacting Concrete. Valencia, 2008; Galán Sánchez, Hormigón autocompactante: una apuesta para la disminución de los niveles de ruido y mejoramiento de la calidad en la producción de elementos prefabricados. 1st Spanish Congress on Self-Compacting Concrete. Valencia, 2008]

The purpose of this paper is to analyze the qualities of a SCC is currently taking to try to improve their properties and try to reduce costs.

Dosage is taken as a starting point a real that is used in Central and according to the specifications recommended in "European guidelines for self-compacting concrete", paragraph 8.2 [EFNARC, Specifiction And Guidelines for Self-Compacting Concrete: Febrero 2002. http://www.enfrac.org, 2002] and Annex 17 of the EHE 08.[Ministerio de Fomento, Instrucción de Hormigón Estructural EHE 08, 2 edición: Febrero 2009] There will be a preliminary study paste the best compatibility between the portland cement used several brands of additives and superplasticizers in the markets.

Keywords Concrete • Autocompressible • Superplasticizers • Rheology

1 Materials Used

The materials used in this study consisted of a cement type CEM-52, 5R, water of network Township, crushed gravel from 0.5/12.5 (aggregate 1), two sand 0/4 (arid 2 and 3, the latter to correct the final mixture) and another 0/8 (arid 4), all washed. Just

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as two nature polycarboxylate superplasticizers additives, Sika Visco Crete 5920 and Glenium C303-SCC. All aggregates used met the physico-chemical, physical and mechanical and granulometric specified in Article 28 of the instruction EHE08 [6].

2 Procedures and Results

Since this work is about improving the dosage of a HAC used, start from the characterization of the same parameters to analyze and try to improve it. To this end, study the composition of their skeleton granular additives studied thermogravimetry and paste composition, analyzing and superplasticizer fine dosage through fine/cement relations by Mini Slump test. And the Marsh cone for connection superplasticizer/cement based on a water/cement ratio given. To conclude, analyze its mechanical parameters of the dosages used.

2.1 Granular Skeleton

In Attachment 17 of the instruction EHE 08, it is said that the HAC have a higher percentage of fines than conventional concrete. This shows that the HAC concrete, according to the mentioned in said schedule, you can not apply the same restrictions to conventional concrete. In starting the HAC, the percentage of the relationship between the coarse aggregate and sand at this dosage is 0.98. Regarding the resulting granular skeleton, the percentage of the relationship between the coarse aggregate and sand at this dosage is 0.66, has been reduced from the initial composition and is closer to the ratio recommended by the literature [7]. This can be seen in Fig. 1, where the curve starting granular skeleton, comparing curves Bolomey Fuller and is located halfway between the two. While the final dosage, is closest to the Bolomey curve is corrected at the top of the same, reducing the particle size, making this a finer granular skeleton, eliminating the use of the aggregate 4 by the 3 position that 4 possessed coarser particles for use in large sizes.

2.2 Pulp Composition

The amount of fines that would be involved in the initial composition of cubic meter HAC (Understanding how fine-grained those ≤ 0.125 mm.), 313.09 kg, which added to the cement, would amount to 723.09 kg/m3 and the relationship fine/cement ratio is 0.76, as the recommended range should be between 0.80 and 1.10 [1]. According to the points made by Okamura [8], a test was performed with Mini-Slump test, Table 1 shows the study of the mobility of the paste for SCC starting and Marsh cone [9].

Given this, and then compare these results with those obtained in the granular skeleton came to the following conclusions:

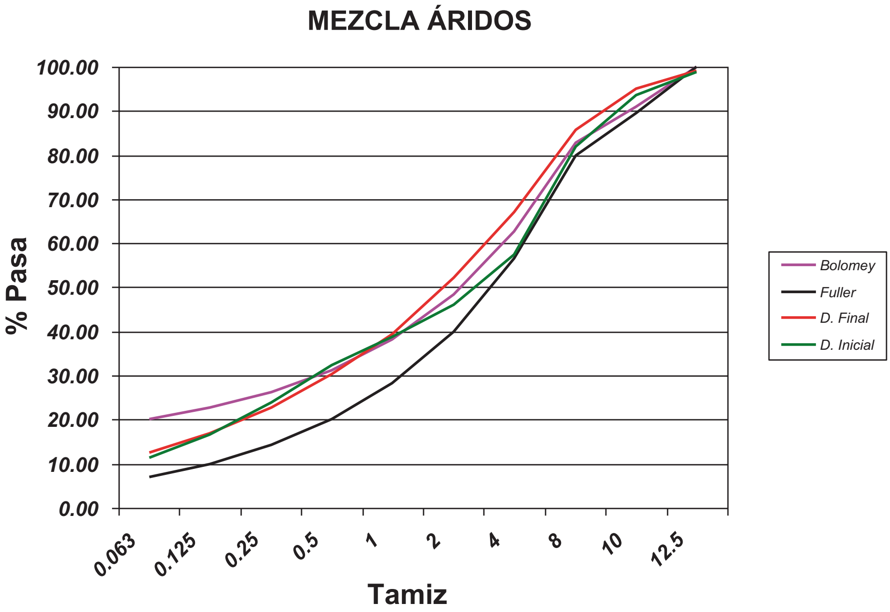


Fig. 1 Comparison of the skeletons granular

Table 1 Mini-Slump Test and Marsh cone (W/C = 0.46)

Cement (gr)	Fine (gr)	Water (gr)	Additives (%)	Fine/Cem	Mini Slump (mm)	T Marsh cone 500 ml (seg)	T Marsh cone 1000 ml (seg)
1200	960	552	1.46	0.80	–	–	–
2000	0	920	1.46	0	145	10	20
2000	0	920	1.75	0	150	7	19

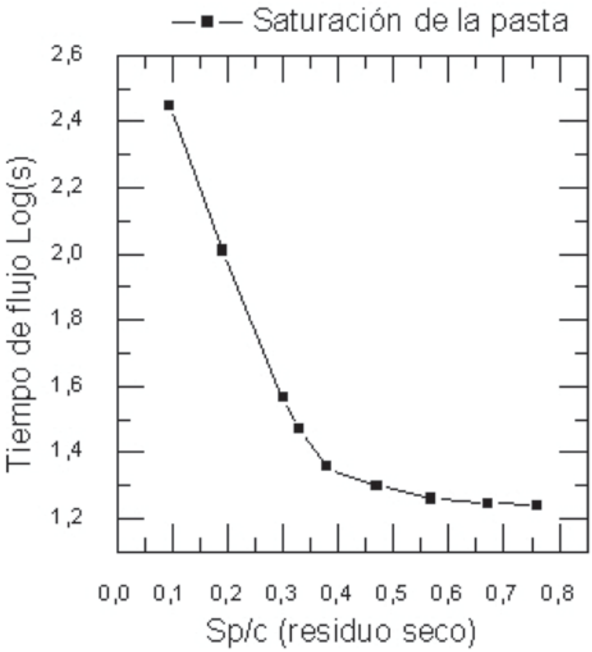
Manufacturer's recommended range, 0.5–1.5 % by weight of cement

According to the test data and Mini-Slump Marsh cone, it can be seen that the additive does not get enough fluidize proportional cement paste. And it can be seen that the range of use in the dosage pattern is in the approximate area of saturation of the additive. Add to that the amount of fines of dosage pattern and coarser size fractions of "coarse aggregate", along with a water/cement ratio of 0.46, we can conclude that the skeleton could be improved mix granular pattern, reducing the ratio between the fine and coarse aggregates and try to improve the ratio of additive/cement attempting to reduce the amount of cement, without impairing the inherent characteristics of durability HAC itself. While the use arises another superplasticizer additive.

The amount of fines that would be involved in the composition of SCC final (minimum particle size 0.125 mm.), would be 309.26 kg, which added to the cement, would add 684.26 Kg/m^3 within the recommended range [4]. The relationship fines/cement is 0.82, understood as valid parameter in paragraph 2.5.8 EFNARC method [5].

A factor to take into account also the water/fines in volume, which should be between 0.80 and 1.10. In our case, we have a ratio of 1.16.

Fig. 2 curve log(T)-sp/c



Different mixtures were tested additive and cement up to determine the most suitable. Getting Fig. 2 (curve log (T)-sp/ c) to less time, greater fluidity of the paste.

The test temperature was controlled around 24 ± 2 °C, which is very important parameter to study the rheology of cement pastes [10, 11]. It can be understood that the point of saturation corresponds to the maximum absorption capacity of the cement, although the temperature increase for a given dose of superplasticizer, the fluidity of cement paste increases [12]. The additive manufacturer provides a recommended dosage of between 0.9 to 2.50 % by weight of cement.

2.3 *Thermogravimetry Additives Used*

By DSC, were analyzed in this paper additives used to quantify and verify their properties regarding feature polymeric base in aqueous suspension, giving an idea of the amount of available polycarboxylate, aqueous base and solid residue.

According to Fig. 3, the red DSC additive belonging to the observed ViscoCrete 60.12 % is simply the aqueous base and a 38.96 % by weight of the sample would be the active components of polycarboxylates, obtaining a residue 0.90 % solid.

Analysing the weight derivative, the red curve is drawn on the bottom of the graph, we can find the maximum temperature after which begins to occur mass losses of the components. Would have a maximum at 55 °C, after which it begins

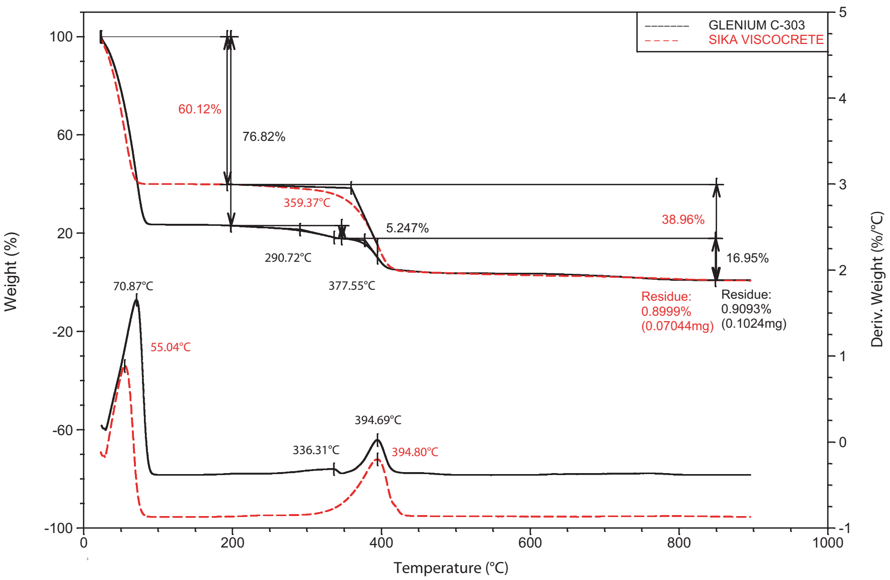


Fig. 3 DSC of the additives studied

to lose mass of the aqueous base, and another peak at 394.80 ° C is supposed to be the temperature at which it begins to lose mass of active ingredient of the additive.

By contrast, the solid residue of another additive is 0.91 %, its aqueous base is around 76.82 %, and the associated percentage is 22.27 % polycarboxylate.

If we focus on the derivative curve (graph black) can be seen, the existence of a trace where the maximum temperature is from about 336.31 ° C. on the other thermogram of additive employed, was not. This must be due to a different compound of the active polycarboxylate or other polycarboxylate superplasticizer lower rate.

Therefore, as in the study of the additive used in the initial dosing, we saw that the additive does not get enough fluidize proportional cement paste and the range of use in the dosage pattern in the area is approximately the same saturation. Using this other additives, although use more, we improve the end SCC mix possibly new additive to possess some other component in addition to the main base, with a higher performance range.

2.4 Mechanical Parameters

To further characterize each of the six batches were made concretes broken to 28 days and at 7 days for each dosage, as well as parameters of the Slump Flow autocompactabilidad and Safety in L. It has taken into account the statistical calculation parameters according to EHE 08, as shown in the summary tables (Table 2 and 3).

Table 2 HAC breaking initial data (*left*) and final (*right*) at 28 days

x1	x2	xi	r.r (%)
49.50	51.90	50.70	5.00
51.70	53.00	52.35	2.00
59.50	56.00	57.75	6.00
62.40	62.00	62.20	1.00
57.6	54.6	56.1	5.00
58.9	59.9	59.4	2.00
Media	**Amasada**	**56.42**	**Mpa**
	F(x)	**48.83**	**Mpa**

x1	x2	xi	r.r (%)
59.50	58.60	59.05	2.00
73.00	65.60	69.30	11.00
61.20	65.30	63.25	6.00
63.70	69.90	66.80	9.00
70.20	75.60	72.90	7.00
79.50	79.80	79.65	0.00
Media	**Amasada**	**68.49**	**Mpa**
	F(x)	**54.90**	**Mpa**

Table 3 Facts and break to 7 days mobility initial HAC dough (*left*) and final (*right*)

x1	x2	xi	r.r (%)
38.57	40.09	39.33	4.00
Slump Flow		**71 cm**	
L Box			
T20		**1,20 s**	
T40		**2,70 s**	
h2/h1		**0,85**	

x1	x2	xi	r.r (%)
43.40	46.47	44.93	7.00
Slump Flow		**70 cm**	
L Box			
T20		**1,10**	
T40		**2,75**	
h2/h1		**0,83**	

3 Conclusions

With the above, shows an improved initial HAC, achieving resistance increase due to a granulometry most studied, increasing the amount of sand gravel by reducing, as a result, has been reduced by 35 kg final amount of cement cubic meters as can be seen in Fig. 4, assuming a saving of € 1.05 per cubic meter, in addition to reducing CO_2 emissions. As regards the additive, the new used seems to have a greater range of action and greater effectiveness, while even having fewer elements nonaqueous properties are greater.

As for the laying of the new HAC, largely unchanged properties, although at early times have improved mobility dough no major achievements in this regard, we should study all this new dosage in plant itself, since the results obtained were conducted in a controlled environment while many factors that influence the concrete in the factory, would be more difficult to control (aggregate moisture, humidity, temperature…).

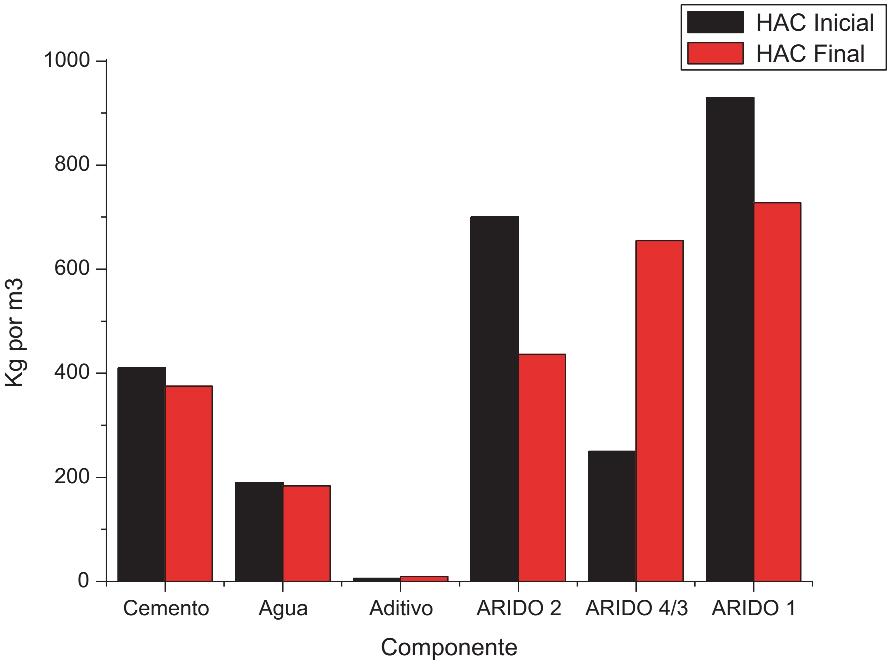


Fig. 4 Comparison between the initial and final HAC

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A Study of Foundations on Expansive Soils

R. Galindo and C. Sanchez

Abstract The design of stiffened slabs involves an assessment of the range of deflections under the applied structural loads and the various environmental conditions likely to arise during the life of the building. In countries whose regions experience a wide range of climatic conditions, large seasonal soil deformations can occur. As differing soils react to widely varying degrees, a problem exists for the foundations in designing economical. The problem is most important for the most expansive soils. This paper describes a method for designing stiffened slabs for expansive soils, based on an analysis of soil-structure interaction. The method increases the understanding of slab behavior and allows an improvement on the empirical methods in use.

Keywords Foundation • Expansive • Soil

1 Introduction

A common approach for designing stiffened slabs for expansive soils has been to develop suites of standard designs each member of which is intended to cater for a specified range of soil conditions. Common design practice for selecting a particular slab design characterizes the soil using the in situ moisture content, Atterberg indices and the depths and thicknesses of the layers of expansive soil. The use of index tests at best produces only a qualitative measurement of soil properties, and requires the application of empirical judgment to categorise the soil for design purposes. This leads to widely varying boundaries between categories of the standard design suites and to quite different designs for similar ranges of soil conditions. It considered more realistic to characterize soils by directly measuring responses to changes in applied load and suction [1].

Several semi-rational design methods have been published. A general feature of such methods is that, based on the soil characteristics appropriately expressed, a

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deformed shape is adopted for the soil surface beneath the covered area. Foundation loads are assumed to modify this shape. The deformed shape and an assigned modulus of subgrade reaction are used to obtain a support indices have been established using computer modeling of the soil-structure interaction, the accuracy of the design process in assessing the actual interaction between the real slab and real soil, responding to the expected variations in environmental conditions, depends critically on the accuracy of an initial assumed edge distance *e* which defines the slab support conditions. A realistic assessment of this interaction is necessary to avoid overly conservative designs.

2 Model of Soil Behavior

The three main causes of volumetric change in an element of clayey soil are the applied stresses and the matrix and solute suction stresses. The applied stresses consist of the weight of overlying soil and any externally applied loads. Matrix suction is the pressure applied to the soil skeleton arising from negative pore water pressure. Solute suction is caused by the chemical solutes in the water and is equal to the pressure difference that would exist between a fluid of the same composition as the pore water and pure water separated by a membrane permeable only to water molecules. The matrix and solute suction stresses in combination form the total suction stresses acting on the soil.

Researchers [2, 3] into the stress-deformation response of expansive soils attempted to use the concept of a unified effective stress based on the equation developed for saturated soils. Specifically, the relationship was $\sigma' = (\sigma - u_a) + \chi(u_a - u_w)$, where:

σ' is the effective stress on the soil skeleton
σ is the total stress on the soil mass
u_a y u_w is the pore air pressure and the pore water
χ was called the suction parameter which ranged from 0 to 1.

Many experiments were made to measure the parameter χ and it was found that it depends on both the soil suction and soil type. Therefore, without extensive laboratory testing, it is difficult to define χ adequately for design calculations.

Later work showed that the nature of soil responses to changes in applied and suction stresses were fundamentally different. Increases in applied stress are inherently anisotropic and tend to increase the continuity of the soil mass and eventually induce shear in preferential directions [4] Soil suction acts isotropically and tends to decrease the effective continuity of the soil by producing tension cracks.

Direct measurement with a membrane oedometer of the deformation of soils in response to changes in applied stress and both components of the total suction stresses have shown that the responses to changes in any one of these stresses are dependent on the ambient values of the other two. Figure 1 shows the results of some tests on a Pleistocene clay.

Such experimental work has shown that within a wide range of suction values, the deformation responses can be approximated satisfactorily by straight lines on semi-log plots. Outside this range the response becomes non-linear and much

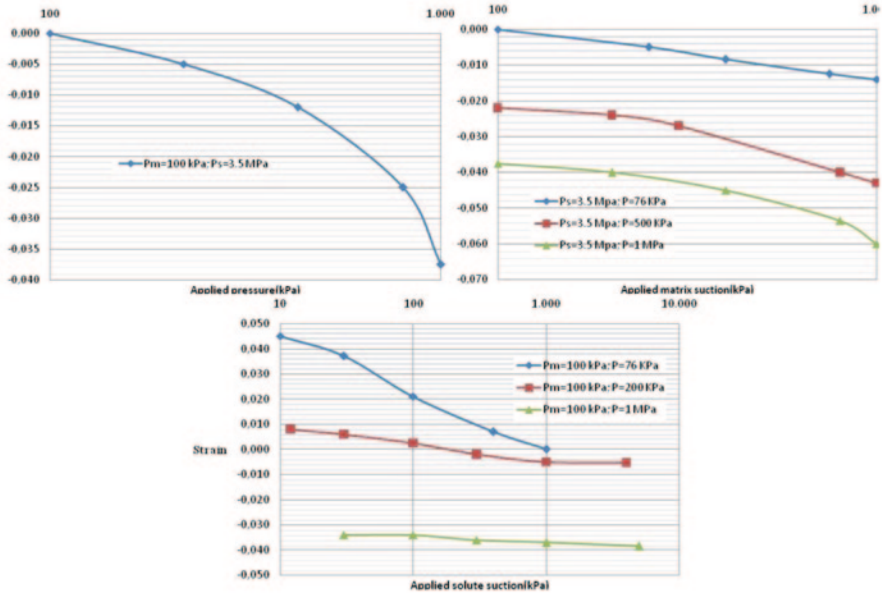

Fig. 1 Results of tests with oedometer (Fargher et al. 1979) [5]

reduced. This linearity allows the definition of instability indices, I, with respect to suction changes which are complementary to the familiar compression index C_C describing response to changes in applied stress. Specifically, for changes in matrix suction, S_m, solute suction, S_s and applied stress p,

$$I_m = \{\text{for given } p, S_s\} = \frac{\Delta\varepsilon_m}{\Delta \log S_m}; I_s = \{\text{for given } p, S_m\} = \frac{\Delta\varepsilon_s}{\Delta \log S_s}; C_c = \{\text{for given } S_m, S_s\} = \frac{\Delta\varepsilon'_p}{\Delta \log p}$$

Thus, with sufficient laboratory testing the effective stress-deformation testing the effective stress-deformation characteristics of a soil can be quantified within the limits of applied and suction stresses likely to obtain at a particular site. Fortunately the proportion of the deformation response which occurs outside the log linear region is generally negligible.

3 Measurement of Soil Characteristics

The laboratory testing techniques are well recognized [5, 6]. Nevertheless, the cost and time involved with this scale of testing renders its use prohibitive for individual house or small factory developments. A less rigorous approach is needed.

One approach is to use typical values of instability and compression indices for soils of varying reactivity. The main deficiency of this approach is that it depends on a reliable categorization of soils based on more readily determined characteristics. As indicated above, plasticity indices are not a reliable indicator.

A more direct approach is to use laboratory measurements of deformations of soil samples in response to changes in suction and applied load. The response of the soil to changes in suction may represent a response to either matrix or solute components or both, for which the individual instability indices can differ widely. By assigning suitable specific values of suction to extreme test conditions and assuming that between these the deformation response is log-linear, the suction deformation response can be quantified adequately.

If volume change characteristics can be assumed to be the same for both swelling and shrinking within the same limits of stress change, and if the stress-deformation response can be considered to have two independent components: applied stress and total suction, then the following stress-deformation characteristics can be calculated from the results of simple tests in which undisturbed soil samples are wetted and dried, from the sampled state under chosen external loads:

$$I = \{\text{for } p \text{ constant}\} = \frac{\Delta \varepsilon}{\Delta \log s}$$

Where s is total suction, p is applied vertical pressure and ε is measured vertical strain.

It is possible to sufficiently characterize the soil by measuring the deformation of a sample under two applied stresses as the sample is taken from an intermediate to extreme dry and from intermediate to extreme wet conditions. Figure 2 shows graphically the form the results of such tests might take with applied pressures of 10 and 50 kPa.

Below, it is showed the development of the following expression using such results linking the change in vertical strain or the soil with changes between two stress and soil suction states denoted p_a, s_a and p_b, s_b.

$$\Delta \varepsilon = \left(A + B \log p_a\right) \Delta \log s + \left(C + B \log s_b\right) \Delta \log p$$

This expression can be written as:

$$\Delta \varepsilon = M + N\left(\Delta \log p\right)$$

Where, for each layer:

$$M = \left(A + B \log p_a\right) \log \frac{s_b}{s_a}; N = C + B \log s_b; A = I_{p_1} - B \log p_1; C = Cc_{s_1} - B \log s_1; B = \frac{I_{p_2} - I_{p_1}}{\log {p_2}/{p}}$$

With the laboratory data p_1, p_2 (for applied stress) and s_1, s_2 (for total suction).

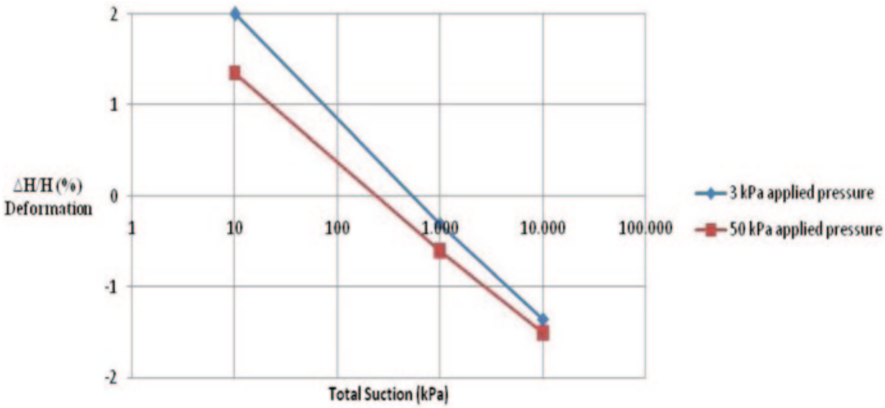

Fig. 2 Representation of laboratory test results

4 Suction Changes in Foundations Soils

It is now necessary to consider the range of field soil suction profiles that are likely to exist. The soil suction at any point within a soil mass represents a state of dynamic equilibrium between the various processes which can cause change. These include the effects of fluctuations of the water table, applied stresses, air humidity, temperature and pressure, soil temperature, soil structure and composition, chemical composition of the pore water, drainage characteristics and seasonal variations in precipitation and evaporation.

If the surface of the soil is extensively covered then in the absence of any other changes the environmental controls become heavily damped and the two components of suctions tend towards equilibrium values. In these circumstances the equilibrium values are determined mainly by the depth to the water table or in dry areas by the balance between precipitation and evaporation. Clearly at the edge of a covered area the soil remains more responsive to natural environmental fluctuations, wherein lies the problem to be solved.

In addition, such artificial influences as tree planting, subsurface drains or leaking pipes can cause pronounced changes in the suction profile. Consequently from either natural or manmade influences, the soil may become either extremely wetted or extremely dry on occasions.

A rigorous analysis of soil movements beneath a foundation slab would involve the measurement of the in situ soil suction profile with additional observations and experiments over a long time span to determine the likely range of soil suction profiles under operational conditions. The techniques required are well established, but generally involve too much time and expense for individual house or similar scale foundation designs.

A less expensive approach would be to cater for changes in soil suction between estimated equilibrium and the extreme conditions. This would allow the use of explicit design or assumed soil suction profiles and obviate the need for extensive soil testing for the majority of situations.

The choice of design soil suction profile depends on the engineer's assessment of the likely variations in conditions under the centre and the edge of the building following construction. For example, if the preconstruction profile is judged to be near either the extreme dry or extreme wet conditions then the change between the two extreme conditions should be used. Otherwise the change from equilibrium to either extreme may be appropriate.

A good design of the slabs consists of a reinforced concrete slab provided with thickened beams around the perimeter and in some grid pattern internally. The beams and slab are continuous one with the other this slab deforms in response to the building loads and pattern of soil reaction stresses acting on it.

Finite element or numerical analyses which can account for complete compatibility and some simplifications are necessary for design purposes.

The slab is idealized as an assemblage of "T" beams acting in a unified manner. As a design criterion, the deflection of a unit width central strip is calculated and compared with that tolerable by the superstructure. It is assumed that the strip acts as a beam spanning between the external walls of the house, partially restrained by the effect of the edge beams and acted on by the structural loads and soil reaction stresses. The shear and normal stresses along its sides are ignored. The pattern of soil reaction stresses are simplified into a number of rectangular stress blocks. Elastic analysis then gives the central deflection and bending moment. The strip is assigned a moment of inertia per unit width equal to the moment of inertia of each "T" beam divided by the beam spacing. The portion of the slab between the T beams is ignored.

The structural capacity of the slab is assessed using yield line analysis of the complete slab simply supported at the four edges. The moment capacities per unit width in the two principal directions are taken to be those of the component "T" beams divided by the beam spacing.

5 Outline of Design Method

The slab and foundation soils are an interactive system. The slab deforms in response to the building loads and soil reaction stresses. The soil deforms in response to the applied and soil suction stresses.

The design proceeds by searching for a pattern of soil reaction stresses that is in equilibrium width the building loads and which, in combination with the soil suction stresses, produces compatibility of deformation at the interface between the slab and soil. The tolerance of the superstructure to the imposed deformations and the capacity of the slab for the maximum imposed bending moments are then checked.

The previous sections have described certain assumptions made to render the design process amenable to hand calculation:

- The development of log-linear stress-deformation equations from laboratory test results to characterize layers of the foundations soils.
- The use of design soil suction profiles.
- The simplification of the soil reaction stresses into a pattern of rectangular blocks for the elastic analysis of a central strip of the slab to obtain the central deflection and bending moment.
- The use of yield line analysis to provide an estimate of the moment capacity of the slab.

Three further assumptions now need to be added to allow completion of the analysis:

- Compatibility of deformation need only be sought for the centre and the edge of the slab and not for the entire slab-soil interface.
- Shear stresses between the slab and soil can be ignored.
- The vertical distribution of applied stresses in the soil mass can be approximated by elastic analysis of a homogeneous material. The principle of superposition is used to sum the effects of the rectangular soil reaction stress blocks.

It should be reiterated that each of these assumptions can be refined, by using more sophisticated measurements of soil properties and finite element analyses of the soil-slab interaction to more accurately establish soil and slab deflections and slab moments. Such improvements do not impair the logic of the design process, the steps of which are outlined:

1. A slab design is chosen for analysis.
2. The soil beneath the foundation is divided into a number of layers. Each layer is considered to be homogeneous and isotropic.
3. Any soil pressure distribution is selected that is in equilibrium with the structural loads.
4. The central deformation of the slab and the central bending moment are computed.
5. The deformations of the soil surface beneath the centre and edge of the slab are calculated and the difference compared with the slab deformation.
6. If the deformations are incompatible the soil pressure distribution is modified to reduce the misfit and a second trial is commenced.
7. Modification is continued until compatibility is satisfied, or until the designer is satisfied that further changes to soil pressures would produce an unrealistic distribution.
8. If the indicated central bending moment in the slab is excessive the analysis for that slab design is terminated.
9. If the bending moment is satisfactory the slab deformation is compared with that tolerable for the superstructure.
10. If the slab proves to be adequate in all respects a lighter slab may be analysed to determine if this too would be adequate.

6 Conclusions

Following consideration of the behavior of expansive clays and slab foundations, a method of designing stiffened slabs has been described. The method uses soil characteristics obtained from direct measurements of deformations under extreme conditions and design soil suction profiles to study the interaction between the slab and the foundation soils, and to compute the deformations of each.

The greater understanding of the development of deformations and stresses in a slab that the use of this method provides represents an improvement on current approaches and facilitates the use of sound engineering judgment throughout in making design decisions.

As all the assumptions and simplifications are explicit, the design procedure reveals if more accurate procedures are warranted; such as more detailed soil testing to account for variations in soil characteristics, evaluation of local soil suction profiles likely to be attained under operational conditions, or more sophisticated modeling of the soil-structure interaction possibly with a finite element analysis.

It should also be recognized that as experience with the method is accumulated, empirical correlations between certain terrains, soil types and applicable foundations will develop. Consequently the need to perform specific calculations for each and every foundation will diminish and it will be sufficient merely to carry out the laboratory testing to characterize the soil.

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Improving the Mechanical Properties of Cold Rolled Asphalt Containing Cement Utilising by Product Material

A. Al-Hdabi, H. Al Nageim, F. Ruddock and L. Seton

Abstract Reduction of hot asphalt mixtures for the usage and development of sustainable supplementary Cold Asphalt Mixtures (CAM) for the construction of road and highway surface layers is a hot subject for researchers around the world. This will cover many advantages in terms of: environment impact, cost effectiveness and energy saving.

The aim of this study is to enhance the properties of a gap graded Cold Rolled Asphalt (CRA) containing cement as filler by addition of a by-product material as an activator. Ordinary Portland cement was added to the cold rolled asphalt as a replacement for the conventional mineral filler (0–100 %), while a by-product material represents Liverpool John Moores University Additive (LJMUA) was added to the whole mix in the range from 0 to 3 % by total mass of aggregate. Laboratory tests included stiffness modulus and uniaxial creep test as indicators to the mechanical properties.

The study concluded that there is a considerable improvement in the mechanical properties from the addition of LJMUA to the CRA containing cement especially for the early life stiffness modulus that is the main disadvantage of the cold mixtures.

Keywords Creep stiffness • Stiffness modulus • By product material • Cold asphalt mixture

1 Introduction

Hot Rolled Asphalt (HRA) surface course is a continuous gap graded mixture of mineral filler, sand and bitumen coarse aggregate is added to it. The mechanical properties of the mixture are controlled by the strength properties of the mortar i.e. mineral filler, sand and bitumen. The material is widely used for surfacing major roads in the UK because it provides a dense, impervious layer resulting in a weather resistant and durable surface able to withstand the demands of today's traffic loads,

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providing good resistance to fatigue cracking. Nevertheless it might experience some weakness to deformation resistance [1].

Additionally, issues like safety and energy saving at work have encouraged efforts to introduce alternative method of using 'cold mixture technology', in which the production of bituminous mixtures are at ambient temperatures by utilising liquid asphalts (bitumen). Liquid bitumen is achieved by decreasing the straight run bitumen viscosity in several different ways. The 'bitumen emulsification' is one of these methods and the decreasing of viscosity takes place by emulsifying the bitumen in water [2].

Chevron Research Company in California after many research studies reported that full curing of cold bituminous mixtures on site depending on the weather conditions and curing times may extend from 2 to 24 months. Unfortunately, UK weather conditions are not assistant to decrease the curing time; humid, cold, and rainy most time of the year [3].

There are many studies to improve mechanical properties of the cold mixes in terms of cement addition. Initial study conducted by Head in (1974) [4] and concentrated on the improvement on the Marshall Stability of the modified cold asphalt mix. He concluded that Marshall Stability of modified cold asphalt mix increases by about three times with the addition of 1 % Portland cement compared with un-treated mix.

Li et al. [5] conducted experiments to assess the mechanical properties of a three-phase cement-asphalt emulsion composite (CAEC). Through experimental study, they stated that CAEC possessed most of the characteristics of both cement and asphalt, namely the longer fatigue life and lower temperature susceptibility of cement concrete, and higher toughness and flexibility of asphalt concrete.

Another study by Wang and Sha [6] indicated that the rise of cement and mineral filler fineness has a positive impact on micro hardness of the interface of aggregate and cement emulsion mortar. Moreover, they presented that the limestone and limestone filler impact hardness value are highly when compared with granite and granite filler.

The main aim of this research is to enhance the mechanical properties of Cold Rolled Asphalt (CRA) containing cement as a replacement for conventional filler by addition of by product material. To achieve this aim, Liverpool John Moores University Additive (LJMUA) was used as additive in the range from 0 to 3 % by total mass of the aggregate to the CRA containing different amounts of cement. Stiffness modulus and uniaxial compressive cyclic creep tests were used as an indicator to the mechanical properties in this investigation.

2 Experimental Program

2.1 Materials Properties

The coarse and fine aggregate used in this investigation were crushed granite and their physical properties are shown in Table 1. Two types of filler were used in this study, traditional mineral filler (limestone dust) and cement. The aggregate was dried, riffled and bagged with sieve analysis achieved in accordance with BS EN 933-1[7].

Table 1 Physical Properties of Aggregate

Material	Bulk specific gravity, g/cm³	Apparent specific gravity, g/cm³	Water absorption, %
Coarse aggregate	2.79	2.83	0.6
Fine aggregate	2.68	2.72	1.6
Mineral filler	2.71	–	–

Table 2 Bituminous Binder and Bitumen Emulsion Properties

Bitumen emulsion (K3-60)		Bituminous binder (40–60)		Bituminous binder (100–150)	
Property	Value	Property	Value	Property	Value
Appearance	Black to dark brown liquid	Appearance	Black	Appearance	Black
Boiling Point, ºC	100 ºC	Penetration at 25 ºC	43	Penetration at 25 ºC	122
Relative Density at 15 ºC, g/ml	1.05	Softening point, ºC	54	Softening point, ºC	43.6
Residue by distillation, %	64	Density at 25 ºC	1.02	Density at 25 ºC	1.05

Table 3 Aggregate gradation for 55/14C Gap Graded Surface Course (BS EN 13108-4)

Sieve size, mm	20	14	10	2	0.5	0.25	0.063
% passing (specification range)	100	98–100	42–63	40	19–31	9–31	6
% by mass (passing mid)	100	99	52	40	25	20	6

The cationic slow setting bituminous emulsion (K3-60) was used to produce the new CRA to develop high adhesion between aggregate particles. In contrast, the 125-pen and 50-pen bitumen grades were used to produce the traditional Hot Rolled Asphalt (HRA). Table 2 shows the properties of the selected bituminous emulsion and bituminous binder.

2.2 *Selected Gradation*

The aggregate gradation of wholly mixtures (CRA and HRA mixtures) used in this study was based on BS EN 13108-4 [8] for HRA; 55/14C gap graded surface course mixture gradation has been used in this work. Table 3 shows the selected gradation.

2.3 *Preparation of CRA and HRA Mixtures*

The design procedure for the new CRA mixtures used in this investigation was based on the method adopted by the Asphalt Institute (Marshall Method for Emulsified Asphalt Aggregate Cold Mixture Design (MS-14)) [9]. According to this procedure pre-wetting water content, optimum total liquid content at compaction and optimum residual bitumen content were 5, 15.16 and 7 % respectively.

Different percentages of cement (0, 1.5, 3, 4.5 and 6 % by total mass of aggregate) as a replacement for the conventional mineral filler were used in preparation of the specimens of CRA mixtures. On the other hand, a by-product material (LJMUA) was used as an additive to the CRA mixtures containing cement with a range of (0–3 %) by total mass of aggregate. In contrast, HRA mixture samples were prepared with the same aggregate type and gradation, 5.5 % optimum binder content was used according to the BS 594987 Annex H [10] for the 55/14C HRA surface course design mixture. Both cold and hot mixes were prepared to produce three specimens for each specific mix. The cold mix specimens were mixed and compacted at lab temperature (20 °C), while hot mix specimens were mixed at (150–160 °C) and compacted at (135–140 °C).

2.4 Curing of the CRA Samples

The conditioning of the CRA specimens is depending on the procedure adopted by the Asphalt Institute MS-14 [9]. The curing process consists of two stages; the first stage was achieved with 24 h @ 20 °C as the sample needs to be left in the mould before being extruded to prevent specimen disintegration, whereas stage two was achieved with 24 h @ 40 °C (the samples have been left in the ventilated oven). After these stages, the samples have been left in the lab (20 °C) and tested at different ages i.e. 2, 7, 14 and 28 days to indicate the indirect tensile stiffness modulus. Jerkins [11] reported that 24 h @ 20 °C plus 24 h @ 40 °C represents 7-14 days in the field.

3 Testing

3.1 Indirect Tensile Stiffness Modulus

The test is conducted in accordance with BS EN 12697-26:2004 [12], the Cooper Research Technology HYD 25 testing apparatus is used (Figs. 1 and 2), and the test conditions are shown in Table 4.

3.2 Uniaxial Compressive Cyclic Test

The Uniaxial Compressive Cyclic Test (UCCT) is a destructive test used mainly to evaluate the permanent deformation characteristics of hot mixes. UCCT at 40 °C was used to assess the effect of addition of LJMUA to the CRA containing cement on creep performance. The test was conducted in accordance with BS EN 12697-25 [13], also the Cooper Research Technology HYD 25 testing apparatus was used. The test conditions as in Table 5.

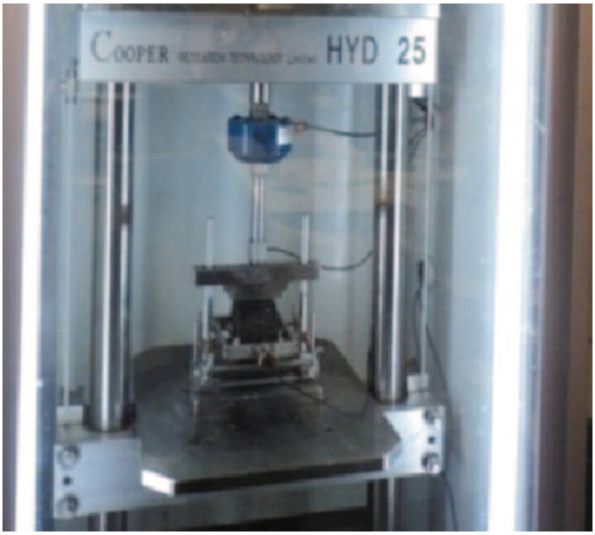

Fig. 1 HYD 25 Indirect Tensile Apparatus

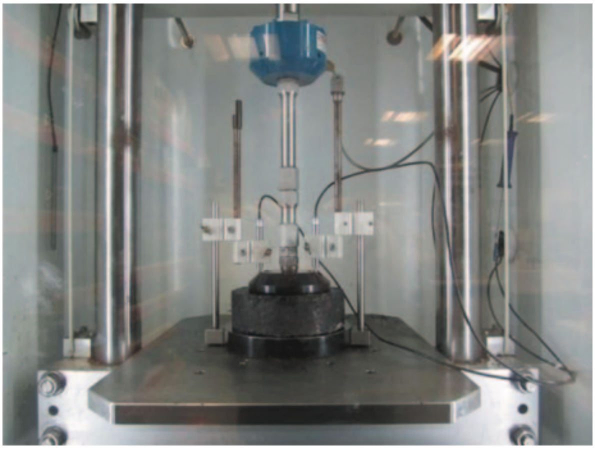

Fig. 2 Creep test configuration

Table 4 ITSM Test Conditions

Item	Range
Specimen diameter mm	100 ± 3
Width of loading strip, mm	12 ± 1
Rise time, micro strain	124 ± 4
Transient peak horizontal deformation, µm	5 ± 2
Load repetition, s	3 ± 0.1
Poisson's ratio	0.35
No. of conditioning pulse	5
No. of test pulse	5
Test temperature°C	20 ± 0.5
Specimen thickness mm	63 ± 3
Specimen temp. conditioning	4 h before testing

Table 5 UCCT Conditions

Item	Range
Frequency	0.5 Hz
Loads	100 ± 2 KPa
Loading pulse	1 ± 0.05 s
Rest period	1 ± 0.05 s
preloading	10 KPa for 10 min
Poisson's ratio	0.35 for 20 °C test tem.
No.of test puls	3600
Test temperature°C	40 ± 0.5
Specimen diameter	148 ± 5
Specimen thickness	60 ± 2 mm

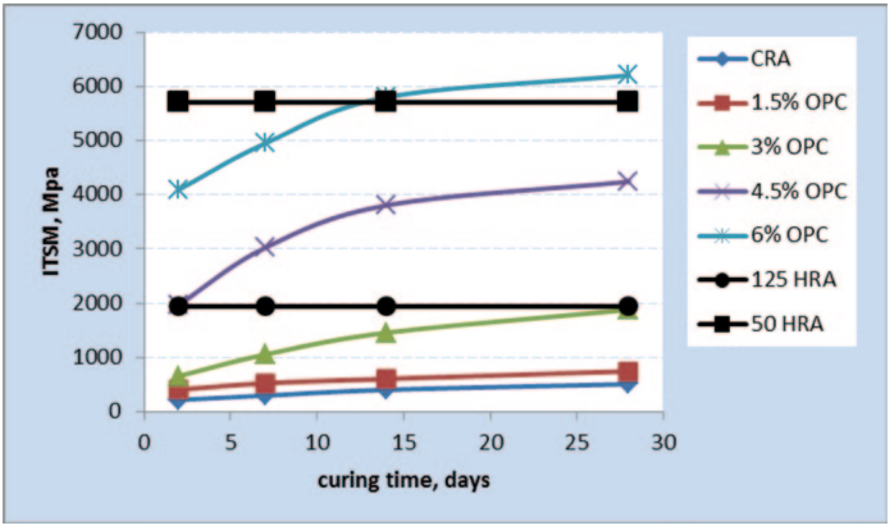

Fig. 3 Effect of curing time and cement percentage on ITSM results

4 Results and Discussion

4.1 ITSM Results

The specimens were tested according to BS EN 12697-26:2004 [12] at ages 2, 7, 14, and 28 days to identify the effect of replacement of cement for the conventional mineral filler as well as addition of LJMUA to these mixtures, see Figs. 3, 4 and 5. It is clearly shown that the addition of cement instead of filler in the CRA increased the stiffness modulus considerably. Also there is incredible enhancement to the stiffness modulus from the addition of LJMUA to the CRA containing cement within the early life of mixtures. Additionally added of 2% LJMUA to the CRA containing 3% cement increased stiffness modulus more than three times and its value is more than the target value for the 125-pen HRA.

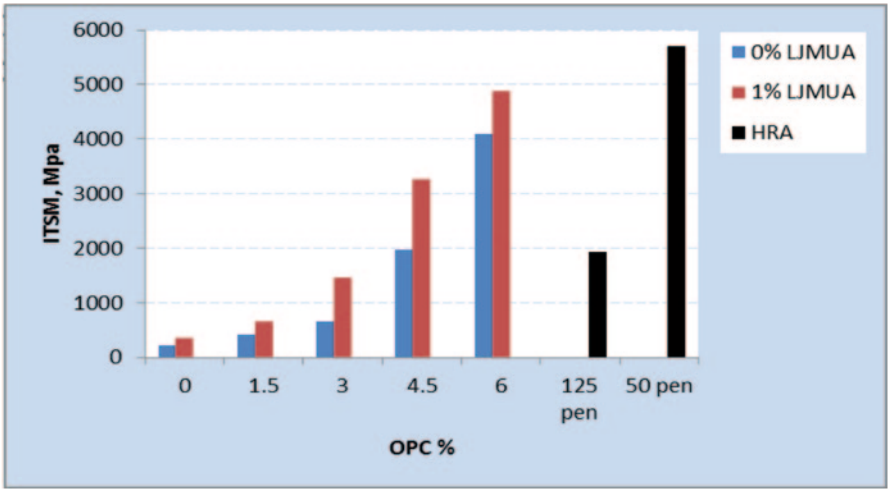

Fig. 4 Effect of addition of 1 % LJMUA to CRA containing cement after 2 days

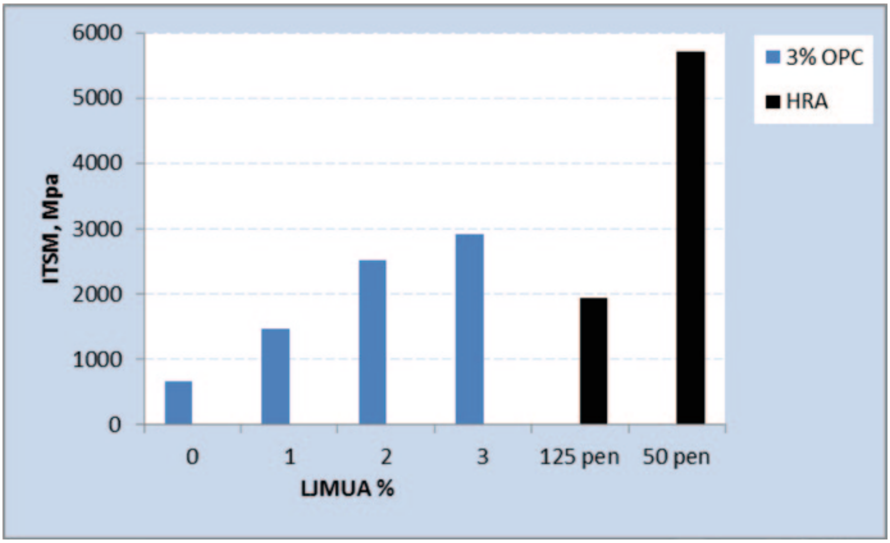

Fig. 5 Effect of addition of LJMUA to CRA containing 3 % cement after 2 days

4.2 Uniaxial Compressive Cyclic Test Results

The results of the UCCT tests for CRA containing cement with and without LJMUA are given in Figs. 6 and 7. The creep strain versus number of pulse applications for CRA containing cement is shown in Fig. 6, while Fig. 7 shows the effect of addition of 1% LJMUA to the CRA containing 1.5 and 3% cement on creep stiffness. These

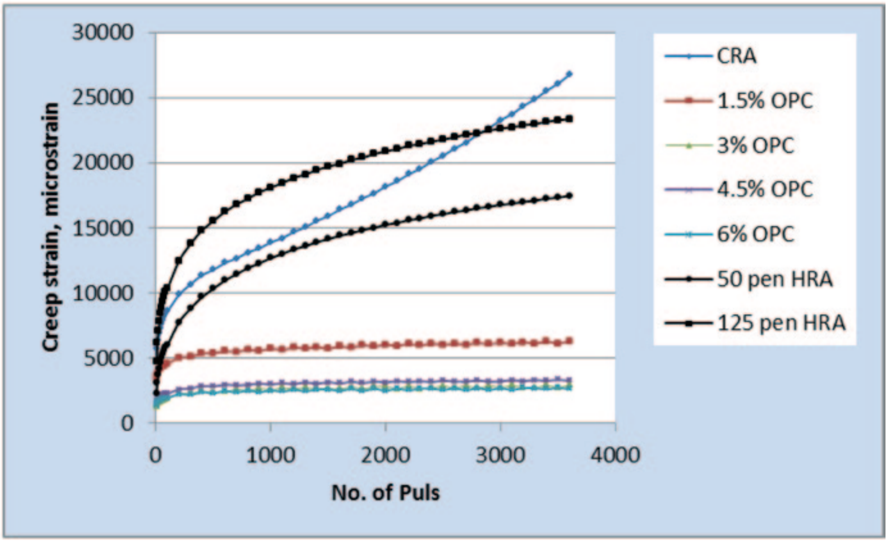

Fig. 6 Creep strain versus number of pulse applications of specimens with different of % cement

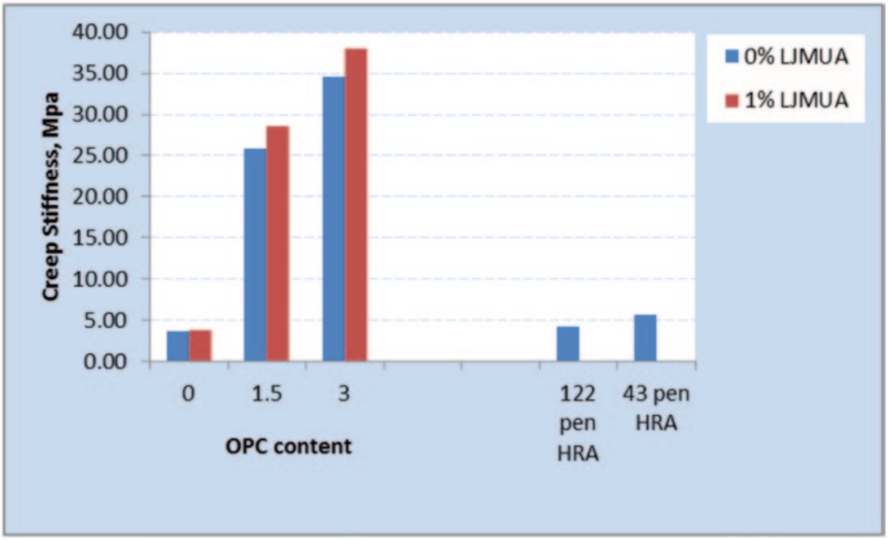

Fig. 7 Influence of % LJMUA on ultimate creep stiffness of CRA containing cement

Figures reveal the positive effect of cement on the creep properties of CRA; specimens with 1.5% cement decrease the creep strain incredibly compared to the control specimens as well as HRA Mixtures. On the other hand, there is no further outstanding from the addition of LJMUA to the CRA mixtures containing cement on the creep performance of these mixtures.

5 Conclusions

Addition of the by-product material LJMUA to the CRA containing cement as mineral filler provides a promising enhancement to the mechanical properties of the new CRA mixtures (especially stiffness modulus) to a level that they are comparable with those of HRA mixtures.

The main conclusions drawn from this investigation are as follows:

1. The replacement for the conventional mineral filler by cement into CRA mixtures improves significantly the stiffness modulus results especially with higher percentages of filler replacement (4.5 and 6 %).
2. The addition of LJMUA improves considerably the stiffness modulus of the CRA containing cement. Addition of 1 % of LJMUA to the CRA containing 3 % cement increases the stiffness modules more than twice and addition of 2 % LJMUA increases it to more than three times and its value is more than the target point for the conventional 125-pen HRA.
3. The replacement of cement for the conventional mineral filler can also improve the permanent deformation resistance when compared to both control CRA and traditional HRA. The creep stiffness of CRA containing just 1.5 % cement improves more than 6 times compared to control CRA.
4. Addition of LJMUA to the CRA containing cement keep the creep performance better than control CRA as well as HRA prepared with 50-pen and 125-pen bitumen.

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Analysis of the Acoustic Performance of Slabs Regarding Airborne Sound and Impact, at the University City of Madrid

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Abstract The existence of a general model of acoustic prediction in the Spanish legislation is widely known. It has been based on the simplified models previously defined in the EN 12354 standard. In this work, different types of slabs in overlapping enclosures, built between 1927 and 2003 in the Ciudad Universitaria of Madrid, and with volumes larger than 250 m^3 are compared. After testing them, the accuracy of the predictions were checked obtaining differences in weighted standardized levels and evidencing a bias in the predictions when standardized impact noise pressure levels were obtained.

Keywords Acoustics • Airborne sound • Impact noise • slabs

1 Introduction

The difficulty of an accurate estimation of a building acoustic characteristic is a well-known problem.

The Spanish regulation incorporates models based on prediction experience in dwellings and theoretically, they could also be applied to other types of buildings. However, research in this area is scarce, and the effect in the prediction of notably different construction systems and dimensions of structural elements from those usually found in residential buildings is unknown. Most of the faculties and schools of the Universidad Complutense de Madrid and Universidad Politécnica de Madrid are located in Ciudad Universitaria, as well as over thirty students' residences and facilities of the Universidad Nacional de Educación a Distancia (Spanish Open University). All together there are colleges, schools, administration buildings, lab buildings, lecture halls, annexes, student residences, colleges, facility buildings, sports centres and the botanical garden.

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Due to the abundance of buildings of various kinds, a selection of them was made trying to gather different buildings, used in the university campus, and which included a representative sample of the construction history throughout the University City.

At the University City of Madrid the construction date of the building greatly conditioned the constructive systems used. Indeed, it was possible to carry out a general constructive classification of the slabs based on the decade in which the building was constructed.

Some types of floor slabs found had already been studied previously by several authors [1, 2].

In addition to the constructive chronology, key in the selection of buildings, in order to reach comparable results, independent variables were decreased as much as possible leaving the horizontal compression element (slab) as the primary variable for the study. Overlapping enclosures, with volumes greater than 250 m^3 and slabs with the greatest possible homogeneity were chosen.

2 Methodology

2.1 Tests

After the selection of building spaces subject of analysis were chosen, they were tested.

The procedure followed in all tests is specified in the relevant parts of the international ISO 140 standard, which was approved by CEN (European Committee for Standardization) as European standard EN ISO 140: 2004. Acoustic. Measurement of sound insulation of buildings and of building elements.

The sections of the EN ISO 140: 2004 standard used defining the procedure followed are:

- Part 4: Field measurements of airborne sound insulation between rooms.
- Part 7: Field measurements of impact sound insulation of floors.
- Part 14: Guidelines for special situations in the field. [3]

The guidelines marked by the UNE EN ISO 140–14 for special in situ cases were taken into account at all times, which considerably increased the number of measuring points. The use of these guidelines in volumes greater than 250 m^3 contributes to improving the reproducibility of measurements in situ.

All the tests were performed in the laboratory of acoustics and vibration of the School of Architecture of the Polytechnic University of Madrid, featuring the ENAC accreditation n ° 688/LE1477 for carrying them out.

Equipment used in the tests has been:

- Power amplifier. Brüel & Kjaer 2716
- Revolving dodecaedric sound source. Brüel & Kjaer 4292

- Sound spectrum analyzer. Brüel & Kjaer 2260
- Acoustic calibrator. Brüel & Kjaer 4231
- Pink noise generator. Internal sound level meter.
- Impact machine. Brüel & Kjaer 3207

Measurements were performed in bands of third octave in a range of frequencies from 100 to 3,150 Hz.

Because measurements are performed between vertical enclosures, the bottom enclosure has been used as air noise emission enclosure, and as noise impact receiver enclosure.

In all tests performed, it was proven that the influence of the airborne noise emitted by the machine of impacts could be considered negligible.

Values of the standardized level difference [D_{nT}], the global value and the spectral correction terms [D_{nTW} ($C;C_{tr}$)] were obtained with the on site airborne sound insulation measurements between the rooms, calculating the total weighted level value difference [D_{nTA}] for each case.

The in situ measures of the airborne sound insulation between rooms, allowed to obtain the standardized level difference values, the global value and the spectral correction terms by calculating, for each case, the global value of the A weighted level difference.

The values of the sound levels of standardized impacts [L'_{nT}], the global value and the term of spectral correction [L'_{nTW} (Cl)] were obtained with the measurements of the in situ impacts sound insulation between rooms. Table 1

2.2 Predictive Calculation

The existing prediction models are based on the statistical methods of energy analysis (S.E.A), which are applied to the transmission of vibrations between constructive elements. However, many walls and light floors do not act as simple reverberation subsystems, and therefore predictions of models are limited to items with a minimum surface density.

With so many ways of transmission, it is possible to predict what may seem like a proper in situ sound insulation, using a model that is not able to adequately describe the actual process of sound transmission. It would also be possible that, without realizing, the mistakes of a portion of the model compensate with the invalid assumptions in another part of the model. For this reason, special emphasis on many assumptions and limitations must be taken into account to predict transmission by flanks [4] in all models.

It should be highlighted that the Gerretsen model [5], on which the current UNE EN 12354 parts 1 and 2 standard is based [6], has served, in turn, as inspiration to the general method of our existing technical code DB-HR [7].

The main assumptions of these predictive methods are that the described transmission paths can be independent and that the acoustic and vibratory fields behave statistically. With these restrictions, several types of structural elements can be con-

Table 1 Results of the tests

Premises tests	$D_{nT,W}$ (C; C_{tr}) [dB]	$L'_{nT,W}$ (Cl) [dB]
School of Agricultural Engineering UPM	54 (−1; −5)	54 (−3)
School of Philosophy and Letters UCM. (Builiding of Philology)	50 (0; −3)	59 (7)
School of Architecture UPM	56 (−2; −5)	55 (−5)
	56 (−1; −5)	56 (−5)
School of Forestry Engineering UPM	52 (−1; −6)	53 (0)
School of Naval Engineering UPM	54 (−1; −6)	50 (0)
School of Building Engineering UPM	50 (0; −3)	68 (−10)
School of Physycal Education UPM	56 (−1; −4)	55 (−6)
School of Journalism UCM	56 (−1; −5)	40 (0)
Lecture Building at the School of Agricultural Engineering UPM	54 (−1; −4)	46 (−2)
School of Forestry Engineering (Enlargement) UPM	58 (−2; −5)	51 (−4)
Lecture building School of Chemistry UCM	56 (−1; −4)	47 (−4)

sidered. However, restrictions are imposed by the possibilities available to describe the transmission in each direction. As a result, the predictive model is restricted to adjacent enclosures, while the type of elements is mainly restricted by the available information on vibrational reduction rate.

Using the predictive calculation tool of the HR basic document,—protection against noise—the weighted difference of levels [D_{nTA}] and global values of the standardized impacts noise levels [L'_{nTW}] are obtained in the enclosures and slabs stated above. Table 2.

3 Contrasting Hypotheses

Contrasting the data, the existence of an unequal behavior between the predictions of global values of the standardized level difference and the impact noise level in all exposed cases is evident.

This claim can be based on the following evidence:

the differences between the tested values and the predicted values are random variables (errors) and hence, it can be assumed that, under the central limit theorem, these variables behave as a normal distribution would do.

The following normal probability graph (Fig. 1), with its adaptation to a straight line, underscores the coherence of this assumption in the case of the variable obtained as a difference between tests and predictions of global values of the standardized level difference.

Once the hypothesis of normality was accepted, t test was carried out in order to contrast the hypothesis that the mean of prediction-test variable difference of the

Table 2 Results of the calculations

Premises calculated in	$D_{nt, A}$ [dBA]	$L'_{nt, w}$ [dB]
School of Agricultural Engineering UPM	56	57
School of Philosophy and Letters UCM. (Builiding of Philology)	55	61
School of Architecture UPM	56	61
	56	60
School of Forestry Engineering UPM	50	63
School of Naval Engineering UPM	57	61
School of Building Engineering UPM	52	65
School of Physycal Education UPM	56	60
School of Journalism UCM	58	55
Lecture Building at the School of Agricultural Engineering UPM	57	58
School of Forestry Engineering (Enlargement) UPM	58	59
Lecture building School of Chemistry UCM	57	59

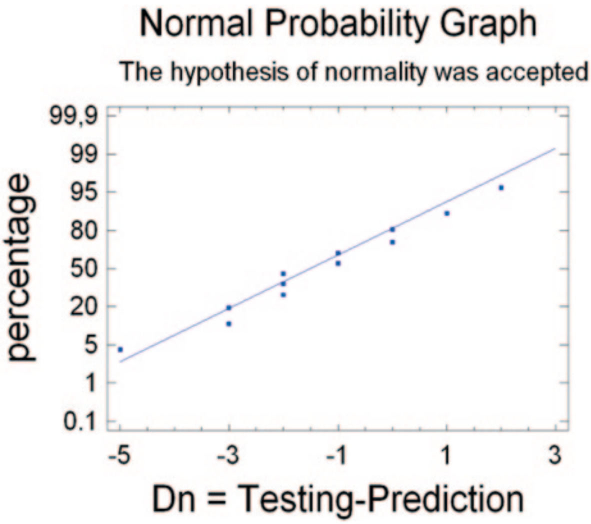

Fig. 1 Normal probability graph

global values of the standardized level difference equals 0. With a 95 % confidence the hypothesis could not be accepted, but with a 99.0 % this hypothesis is acceptable (p-value = 0.035).

If the variable behaves like a normal of mean equal to zero, the percentage of positive and negative values of the variable should be 50 %. To verify whether the proportion of values is in fact 0.5 (50 %), a contrast of proportions was performed.

The contrast performed allows accepting this hypothesis to 90, 95 and 99 % (p-value = 0.38), which permits not to reject that the mean of the variable equals zero.

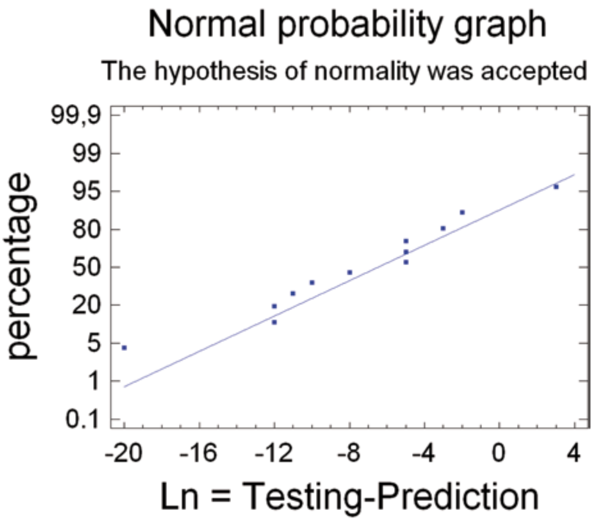

Fig. 2 Normal probability graph

Therefore, it can be considered that in the case of the variable obtained as the difference between the tests and the predictions of global values of the standardized level difference, there is no evidence of the model making biased predictions.

Regarding the differences found between tests and predictions of global values of standardized impact noise, again with the normal probabilistic graphic and its adaptation to a straight line, the assumption that such random variables (errors) behave as a normal is accepted (Fig. 2).

However, very different results are obtained with the same analysis when making the t test and the contrast of hypotheses concerning the proportion of positive and negative values. When performing the t test, the hypothesis that the mean of the prediction-test variable difference of the global values of the standardized level difference is equal to zero is rejected with a 99, 95 and 90 % confidence (p-value = 0.0012)

In addition, contrast is performed to check whether the proportion of prediction-test difference values of the global values of standardized impact noise level greater than zero is 50 %, which allows not to accept the hypothesis with a confidence of 90, 95 and 99 % (p-value = 0.0063). It can be therefore assumed that the mean of the variable is not equal to zero.

Therefore it can be assumed that, in the case of the variable obtained as a difference between the tests and the predictions of global values of the standardized impact noise level, the contrasts performed seem to prove that the model is making predictions with a bias. Since the errors obtained are in 11 of the cases negative, we can affirm that the predictive model seems to be getting excessive global values of standardized impacts noise.

4 Conclusions

It has been confirmed that in superimposed classrooms and lecture rooms, of large volumes (more than 350 m^3) built in different decades in the University City of Madrid, the results of the tests have provided differences in weighted standardized levels that almost always match the expected values and the analysis of the results by frequency have not achieved any unusual results.

Predictions about differences of standardized levels weighted with the calculation of the existing CTE DB-HR tool and based on the formulation of the UNE EN 12354 standard can be considered accurate (±3 dB) and without the presence of significant bias.

On the contrary, the results of the tests have provided surprisingly low standardized levels of impact sound pressure and do not match the expected ones.

Notable differences (+2∼−15 dB), are obtained with the predictions based on the formulation of the EN 12354 standard when compared to the values obtained in the tests.

The bias has to be in the predictive model, just to find justification in the favorable influence of the floor, which may not be well considered in the model, for purposes of such large rooms (more than 250 m^3).

Results obtained contradict the low contribution of the upper floors and the general consideration that sand beds behave like (rigid) compacted material that do not provide any appreciable gain in terms of the transmission of noise impacts.

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Influence of the Type of Binder on the Properties of Lime-Hemp Concrete

R. Walker and S. Pavia

Abstract This paper compares the properties of hemp concrete made with hydrated lime and pozzolan with those of composites made with commercial binders containing hydraulic additions, in an effort to make hemp concrete more sustainable. The binder type affects the properties and microstructure of hemp concrete. The results indicate that increasing the binder's hydraulicity enhances compressive strength and lowers capillary action. As in lime and cement-lime mortars, this is probably due to the presence of hydrates.

Despite the high hydraulic content of the commercial binder evidenced with Scanning Electron Microscopy, the ultimate strength of the commercial concrete is similar to that of the lime-pozzolan concrete. The commercial composite did not reach its full potential strength due to the strong hydraulic nature of its binder and the competition for water with the hemp. The paper also concludes that, initially, composites including highly hydraulic binders dry faster however, at later ages, composites with hydrated lime binders dry faster. The slow early drying of the lime is likely due to its high water retention while drying becomes faster at later ages due to its higher permeability.

Keywords Lime-hemp concrete • Lime-pozzolan • Hydraulic binder • Strength • Drying

1 Introduction

Due to environmental problems, there is a need to develop low-energy, carbon-negative, sustainable construction materials to partially replace products responsible for high CO_2 emissions, consumption of non-renewable materials and waste generation. Lime-hemp concrete is an alternative, appropriate for certain applications. This is a carbon-negative, sustainable building material made of lime, hemp and water. Developed in France in the 1990s, it has since been used in hundreds of houses in Europe. Although an innovative material, organic matter has been added to building materials since antiquity: straw was added to clay bricks and animal

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hair used in lime renders while, in wattle and daub construction, a lattice of wooden strips called wattle was daubed with a mixture of wet soil, clay, sand, animal dung and straw.

The aggregate (shiv) is the woody interior of the hemp stalk cut into small chips. The shiv is an excellent sustainable resource however, the binder also needs to have a low environmental impact for the composite to be sustainable. Commercial and site-made hemp binders usually contain hydraulic binders (hydraulic lime/Portland cement-PC) to enhance setting and strength development and facilitate building. However, these lower the material sustainability.

This paper investigates hemp concrete bound with calcium lime and pozzolans. Pozzolans have been used to enhance the properties of composites since antiquity. They contain amorphous silica or silica/alumina which react with portlandite ($Ca(OH)_2$) to form cementitious hydrates similar to those formed on PC hydration, therefore, they can eliminate the need for hydraulic lime and PC lowering environmental impact.

Lime-hemp concrete is light-weight (average wall density 275–400 kg/m^3) and non-structural, typically used in combination with load-bearing frames. There are a number of construction techniques including: casting around a timber frame using temporary shuttering, spraying against permanent shuttering or prefabricated panels. The material properties depend on several factors including: binder type, binder:hemp ratio (usually 2:1—by weight—for wall construction), mixing water, density, shiv properties, manufacturing method, curing conditions and age. It typically exhibits low strength and a ductile compressive failure between 0.2–0.9 MPa [1–4]. It has an open pore structures (70.6 % porosity) including macro, meso and micropores [5] which results in high water vapour permeability (water vapour diffusion resistance factor 4.85 ± 0.24 [6]) and high water absorption coefficient by capillary action (0.0736 ± 0.0045 $kg/m^2s^{1/2}$ [6] and 0.15 $kg/m^2s^{1/2}$ [7]). Lime hemp concretes exhibit excellent thermal performance. A high thermal capacity (between 1,000 J/kgK [8] and 1560 ± 30 J/kgK [6]) coupled with a medium density and a low thermal conductivity (0.05–0.12 W/m K [9]) providing the material with excellent insulation capabilities.

This paper compares the properties of lime-pozzolan hemp concrete with those of composites made with proprietary binders containing hydraulic lime/cement. It is known that the type of binder affects the properties of lime-hemp concrete. For example, hydraulic additions introduce pores in the sorption size range whereas hemp particle and lime binder pores are in the capillary size range, efficient for moisture transport. De Bruijn [2] found no significant sorption difference amongst mixes with different proportions of hydrated, hydraulic lime and cement however, Evrard [10] states that composites with hydraulic lime had a lower capillarity. Lime binders have a high capillarity (0.3 $kg/m^2s^{1/2}$) and cement and a lower capillarity (0.1 $kg/m^2s^{1/2}$) [7 referring 11] In a cement-lime paste, the capillary coefficient decreases with the percentage of cement and this is due the wider pore size distribution with a greater quantity of small pores in cement [12]. In relation to drying, composites with proprietary binders containing cement appeared to dry faster than those with hydraulic lime [13, 14]. The effect of binder on strength has yielded varying

Table 1 Composition of the hemp concrete

Name		Binder (% by weight)	B	H	W
Commercial mix	CM	100 % commercial binder	2	1	2.9
GGBS	G	70 % hydrated lime (CL90s), 30 % GGBS	2	1	3.1
Metakaolin	M	80 % hydrated lime(CL90s), 20 % Metakaolin	2	1	3.3

B binder ratio by weight, *H* hemp, *W* water

opinions. Hirst [15] found that the composite strength does not increase with the strength of the binder. However, generally, compressive strength grows with increasing binder hydraulicity (provided hydration is not compromised by the absorption of water by the hemp). Higher compressive strengths are usually obtained for cement-rich binders [3, 7, 16]. However, at 90 days, Nguyen [16] found that lime binders reached higher compressive strengths than commercial hydraulic binders.

2 Materials and Methods

2.1 Materials

Three mixes were investigated: a commercial binder (CM) and two lime:pozzolan mixes GGBS(G) and metakaolin (M) including a hydrated lime (CL90s) complying with EN 459-1 ([17]; Table 1). The composition of the commercial binder is not known but has been formulated specially for use with hemp and contains hydraulic additions. The M and G pozzolans are amorphous and mostly siliceous/aluminous with surface areas of 18.33 and 2.65 m^2/g respectively [18, 19]. The binder:hemp:water ratio was 2:1:3.1 (by weight). The recommended ratio for the commercial binder was not adhered to in order to maintain an equal binder:hemp ratio of 2:1 for all mixes. The water content cannot be kept constant because the different binders have varying water demands in order to ensure an appropriate workability therefore, the water content was slightly lowered for the commercial mix and slightly raised in the metakaolin specimens on account of the high water demand of this pozzolan [18].

2.2 Mixing

Mixing was carried out on site in a large pan mixer at 2 batches per mix. The dry binder was premixed by hand. The binder and ¾ of the water were then mixed for 2.5 min to form a slurry. The hemp was then gradually added as well as the remaining water. The total mixing time was 7 min. After mixing, the composite was put into cling-film lined, 100 mm cubic moulds in a single layer. The mould was removed and the samples transferred to a curing room at temperature of 20 ± 3 °C and 65 ± 10 % RH. The samples had a dry density of c.360 kg/m^3.

2.3 Analysis of Microstructure

The microstructure of the binder and the surface of the hemp were investigated using a Tescan MIRA Field Emission Scanning Electron Microscope. The samples were freshly fractured and covered with a gold coating in an 'Emscope SC500' plasma coating unit. Individual hemp particles were extracted from fractured surfaces and mounted on pin stubs prior to coating.

2.4 Drying

The evolution of the mass over time was recorded. The samples were stored in a curing room at 20 °C and 50 % RH and weighted at regular intervals. Mass equilibrium is considered to be reached when the mass measurement vary by less than 1 % over 24 h.

$$Drying\ rate = \frac{Weight\,@\,T_1 - Wesight\,@\,T_2}{T_1 - T_2} \tag{1}$$

T1−T2 Time interval over which rate is measured

2.5 Capillary Action

The water absorption coefficient by capillarity was measured according to EN 1925:1999 [20]. The standard was altered in order to adapt it to the lime-hemp composite. On account of the highly porous nature of the composite, the duration of the test was extended to 10,000 min. The samples were placed on a wire grill, in a container of water so that the water covered the lower 10 mm of the samples, and weighted at intervals over time. The coefficient is a measure of the water sorption as a function of the surface area of the specimen and time.

2.6 Compressive Strength

Compressive strength was measured on 100 mm cubes using a Zwick Testing apparatus. No standards currently apply to lime-hemp concrete thus lime standard (EN 459-2-[21]) was used. The samples did not break but continuously deformed in a plastic manner (Fig. 4) at 20 N/s (loading rate). Failure strength was considered as the point at which the stress/strain curve departs from linear behaviour (Fig. 4).

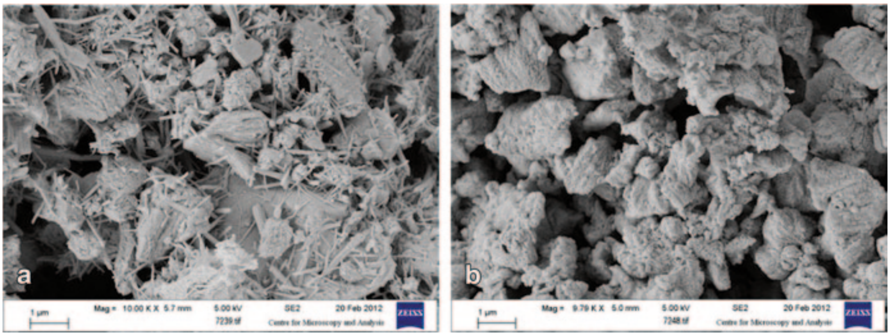

Fig 1 SEM images at the hemp interface. **a** Commercial binder including abundant needle-like hydrates. **b** lime-pozzolan binder consisting mainly of carbonated lime

3 Results and Discussion

3.1 Microstructure of the Lime-Hemp Concrete

At 6 months, there is a significant difference between the microstructure of the commercial binder (Fig. 1a) and that of the lime:pozzolan binder (Fig. 1b). The abundant needle-like hydrates in the commercial binder indicate that it includes a significant quantity of hydraulic additions. In contrast, the lime:pozzolan binders are largely carbonated and show few hydration products. The results agree with previous research that investigated pozzolanic reaction in lime-hemp concrete and concluded that, even though hydrates form early in the lime-pozzolan binder (after 1 day), they do not appear on the lime-hemp interface probably due to the high water suction of the hemp particles [22].

3.2 Drying

The composite dried in a similar manner to that observed by other authors [23] in which the drying rate is initially relatively constant and then follows a curve in which the rate of drying decreases as the moisture content of the sample decreases over time (Fig. 2). The initial drying rate is determined by liquid evaporation from the composite surface and capillary forces. However, following a critical moisture content, diffusion prevails over capillary forces and moisture content reduces until equilibrium with the ambient environment is achieved [24]. The results show that, at early ages (between 5–12 days), the commercial samples dry the fastest, followed by the GGBS and the Metakaolin samples (19.1, 17.4 and 13.9 g/hm^2 respectively—Fig. 2). Drying is proportional to the moisture content and, as aforementioned, CM has a slightly lower water content due to workability requirements. However,

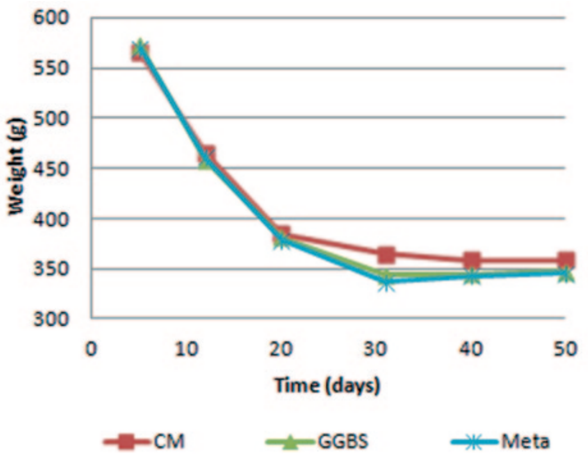

Fig 2 Rate of drying (weight loss over time) of the initial mixing water

unexpectedly, CM dries the fastest and M the slowest. As time progresses, the drying rate of CM slows down compared to that of the lime-pozzolan composites G and M. The results indicate that the drying rate is clearly influenced by the binder type and increasing binder hydraulicity increases the initial drying rate. This agrees with previous authors [13, 14]. In order to confirm this, pastes and hemp composites with the same water content were made either with lime or cement. In all cases, at early ages, the cement specimens dry faster than the lime ones whereas, at later ages, those made with lime dry faster. The slow drying of the lime at early ages is likely due to its higher water retention compared to that of hydraulic binders. As time progresses, the drying rate of lime becomes greater than that of the cement, likely on account of the lime's higher permeability.

3.3 Capillary Action

The capillary behaviour of all the samples is similar (Fig. 3). Initially, the composite absorbs water at the fastest rate decreasing over time. The water sorption coefficients are 3.014, 3.159 and 3.370 kg/m^{2}h$^{1/2}$ for the commercial, GGBS and metakaolin composites respectively—as aforementioned, dry density c.360 kg/m^3.

The commercial binder concrete shows the lowest capillary suction and the metakaolin concrete the highest. This result was expected as, on one hand, the commercial binder includes hydraulic additions, and these introduce pores in the sorption pore size range, unable for capillary transport. On the other hand, the lime-pozzolan concretes contain hydrated lime which has a higher capillarity than cement. This trend is similar to that of cement-lime pastes whereby the capillary coefficient decreases as the percentage of cement rises.

All the results are lower than those reported by previous authors for commercial (4.42 ± 0.27 kg/m^{2}h$^{1/2}$ [6]) and cement/lime binders (9 kg/m^{2}h$^{1/2}$ [7]).

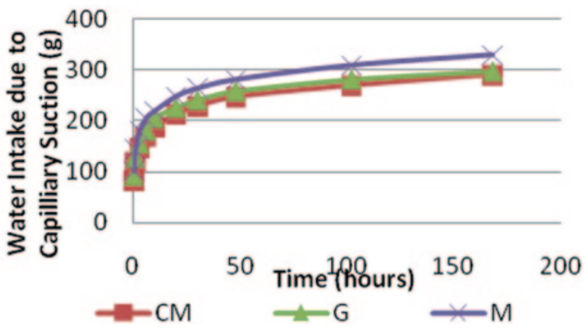

Fig 3 Water absorption by capillary suction over time

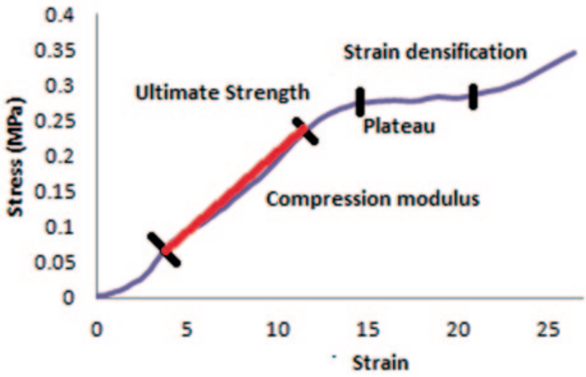

Fig 4 Behaviour of composite under axial load

3.4 Compressive Strength

The composite deformed in a similar manner to Elfordy [25] (Fig. 4) and also similarly to timber [26 referring to 27] and other porous materials [28]. The material behaviour in compression depends on the geometry of the specimens. Glouannec [29] observed a clear fracture with a peak compressive strength followed by a stress decrease for tall specimens, and continuous crushing in stout specimens (height < width) however, both geometries exhibited similar strengths. According to the results, the stress-strain behaviour of a cubic specimen can be typically divided into 3 stages: a linear region, a plateau (region of rising strain for small stress increase) and densification (large increase in stress for small strain gain). The specimen geometry alters this behaviour: authors using cylinders observed the linear and plateau stages followed by a decrease in stress rather than strain densification.

The results show that most of the strength gain takes place between 5 and 28 days. This early strength is due to drying and hydration. The strength continues to increase up to 1 year except for the metakaolin hemp concrete. At early ages, the commercial binder shows a higher compressive strength due to the early formation of hydrates. However, at later ages, its strength gain is relatively slow, likely due to the low water content available for hydration. Similarly, Hirst [15] and Nguyen [16]

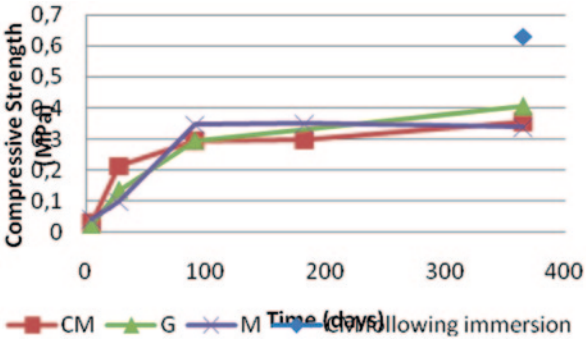

Fig 5 Compressive strength over time

found that mechanical strength in commercial binders did not increase significantly after 28 days. The GGBS-lime concrete achieves the highest compressive strength at 1 year. Similarly, Nguyen [16] observed that at 90 days, hydraulic lime binders (NHL2/3.5) had reached a higher compressive strength than concretes made with a more hydraulic commercial binder. Similarly to Eires [30], the metakaolin-lime concrete achieved the highest strength at 3 months but then showed a strength reduction. A similar trend in lime:metakaolin pastes which was attributed to morphology changes in the hydrates [31, 32]. Hydration was reactivated in the commercial concrete by immersion in water for 2 weeks at 9 months and subsequent drying. SEM revealed that the resulting composite has a very high quantity of hydrates and exhibits the greatest compressive strength (0.63 MPa—Fig. 5). This illustrates that the hydrates strongly contribute to strength, and that hydration was prematurely terminated due to the lack of available water in the composite.

4 Conclusion

The binder type affects the properties and microstructure of hemp concrete. The concrete made with commercial binder displays a great amount of hydrates, both in the matrix and at the hemp interface, after 6 months of curing. In contrast, the lime-pozzolan composites mainly show carbonated lime at the hemp interface. Increasing the binder's hydraulic content enhances compressive strength and lowers capillary action of hemp-lime concrete. As in lime and cement-lime mortars, this is probably due to the presence of hydrates.

The abundant hydrates determined by SEM indicate that the commercial binder contains a great amount of hydraulic additions, therefore, faster strength development and a greater ultimate strength were expected due to the formation of early hydrates. However, the ultimate strength of the commercial concrete is similar to that of the lime-pozzolan mix. At 28 days, the hydraulic material provides the commercial composite with a superior strength, however, at 1 year, the lime:pozzolan concrete displays a similar strength to that of the commercial concrete.

The commercial hemp concrete did not reach its full potential strength due to the strong hydraulic nature of its binder and the competition for water with the hemp. This paper also concludes that, early ages, composites including highly hydraulic binders dry faster however, at later ages, lime hemp concrete dries faster. The slow early drying of the lime (up to 2 weeks depending on drying conditions) is likely due to its high water retention. Drying speeds up for lime binders at later ages becoming faster than that of hydraulic binders likely due to the higher permeability of the lime.

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Durability Analysis of PVC-P Membrane in Inverted Flat Roof

Antonio Pedrosa González, Mercedes del Río Merino and Carmen Fonseca Valero

Abstract Nowadays, the inverted roof is certainly, the most used solution in flat roofs, in this study this constructive system will be analyzed, it places the insulation above waterproofing material as a "protection", limiting the thermal variations that the waterproofing material bears, up to the end of its life cycle. This configuration is believed to provide a longer life cycle, and greater protection for the roof elements. There are well known incompatibilities between construction materials, these are originated by interactions between some of them, which produce modifications in their internal structure, degenerating, and even discomposing them totally or partially. In the case of this paper, the inverted flat roof will be analyzed from different points of view, on the one hand from the perspective of the "incompatibilities" that occur between the extruded polystyrene board (EXPS) and the PVC-P (plasticized polyvinyl chloride) waterproofing sheets, on the other hand the barrier effect that the separating geo-textiles normally used; i.e. polypropylene, polyester, etc, provides for the solution.

Keywords Inverted flat roof • Upside down flat roof • Extruded polystyrene • Plastic interaction • Plasticizer • Durability of PVC-P membrane

1 Introduction

The interactions between Polystyrene and the PVC-P (plasticized polyvinyl chloride) have been studied; in fact, Polystyrene is commonly used as a vehicle, for accelerating the speed of the plasticizer loss in a PVC-P sheet [1]. The incompatibility between these polymer materials might be summarized as a transference process of plasticizers between them, known by the term "plasticizers migration"; this process has been widely studied in other industries, such as sanitation and food [2].

Plasticizers are additives that increase the plasticity of a material. The dominant applications of plasticizers are additives for plastics, especially polyvinyl chloride (PVC). Using PVC as polymer base material, a plastisol can be prepared, which is a dispersion of PVC in plasticizing liquids that contain additives and plasticizers.

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With this PVC formulation a PVC-P plastic polymer can be made, the mechanical properties of the final plastisol material will depend on the proportion of the different components in the formulation.

Plastic plasticizers are additives that work by intercalating themselves between the polymer chains, spacing them apart (increasing their "free volume"), and thus significantly lowering the glass transition temperature of the plastic and making it softer at room temperature. Polyvinyl chloride PVC-P sheet used as waterproofing membrane contains significant concentrations of plasticizers, along with other additives. Plasticizers of plastic materials can migrate to another substance or material, such as food, liquids [3], or even to another plastic [4].

2 Objective

The main factors in this study are: to extend the knowledge of these interactions and incompatibilities that can occur in an inverted flat roof, to evaluate the effectiveness of the geo-textiles commonly used as a barrier to cut down the risk of plasticizer loss, and to analyze the effect on the PVC-P sheet that some factors, such as the ultraviolet radiation, or the direct contact with XPS produce on the amount of plasticizers contained in a PVC-P sample.

3 State of the Art

The loss of plasticizers and other additives from the PVC-P can be speeded up by the introduction of different determinants, such as ultraviolet radiation, or contact with incompatible materials. This loss implies a loss of volume, and as a consequence in the case of PVC-P membrane sheet, a variation of the dimension of the membrane, in other words shrinkage of the sheet [5]. Incompatibilities between materials involved in the upside down flat roof are mentioned in current Standards [6] however most of them are not mandatory; somehow, there is a loophole in the compulsory Standards on this issue. There are some studies about plastic interactions (chemical field works). The plasticizers contained in synthetic membranes have been studied, identifying additives and plasticizers and analyzing their behavior through time; nevertheless these studies are focused in the civil engineering branch [7], the determinants that a synthetic waterproofing sheet has to bear in the construction field, are usually more complicated, and involving more inconvenient factors.

4 Methodology

The methodology of the present study is going to follow two different Standards. By using the UNE-EN ISO 177:2001 Standard, it is possible to determine the tendency of the plasticizers to migrate from plastic materials (into which they have been incorporated), towards other materials or plastics, placed in touch with them [8], this is possible by analyzing the loss of mass of the samples after several days in the drafty oven.

On the other hand, three samples of a PVC-P lamina have been extracted from an inverted flat roof in use for twelve years. The amount of plasticizers of a collected sample of PVC-P, can be analyzed with Differential Scanning Calorimetry (DSC), which is a thermoanalytical technique widely used for analyzing polymers, to study their composition, and thermal transitions. By virtue of this procedure, it is possible to compare different samples of the same PVC-P waterproof membrane installed on an inverted flat roof; in order to study the different anchoring level of plasticizers in the samples taken from different positions of the membrane. The UNE-EN_ISO_11358 = 1997 Standard [9] will be used as a reference in order to carry out the analysis of the samples. The factors that will be analyzed in this part of the study will be; the effect that the exposure to climatic elements (aging), have had on the amount of plasticizers contained in the membrane (for samples from out in the open air); and the effect that XPS has had on the lamina.

5 Results and Discussion

This study is partially in the experimental process; however some aspects and results for the two different parts of the study can be shown:

Part 1 Experiment for the study of plasticizer migration in impermeable commercial sheets of PVC-P according to UNE-EN ISO 177:2001 Standard(*test in drafty oven*).

Three different commercial PVC-P waterproof membranes have been studied; PVC-P Sikaplan®-SGMA 1.2 (Trocal SGMA 1.2 mm); Danopol FV 1.2-DANOSA; Novanol 1.5 mm PF BASF. Every lamina has been tested three times with the same configuration (following the current Standard). Polyester geo-textile 300 gr/m^2; Polypropylene geo-textile 300 gr/m^2; 0.013 mm thick aluminum foil; were analyzed as auxiliary separating laminas, finally another sample was formed with direct contact between XPS and PVC-P lamina.

The results of the experiment show a similar behavior of the different brands of PVC-P laminas tested, the graphs in Fig. 1 present a reliable manner of comparison the effectiveness of the auxiliary separating laminas as a plasticizer barrier, independently of the brand of the PVC-P membrane.

Part 2 Experiment for the quantitative analysis of the plasticizers in impermeable sheets of PVC-P installed on inverted flat roofs following UNE-EN_ISO_11358 = 1997 Standard. Three samples of PVC-P impermeable sheet have been taken from an inverted flat roof (12 years in use). One of the samples was taken in the north section of the roof, extracting material from the vertical part of the waterproof membrane (exposed to elements) and from the horizontal part of the lamina under the XPS board. Another sample was extracted from the south area of the roof, taking material likewise from the horizontal and vertical part. Finally, the

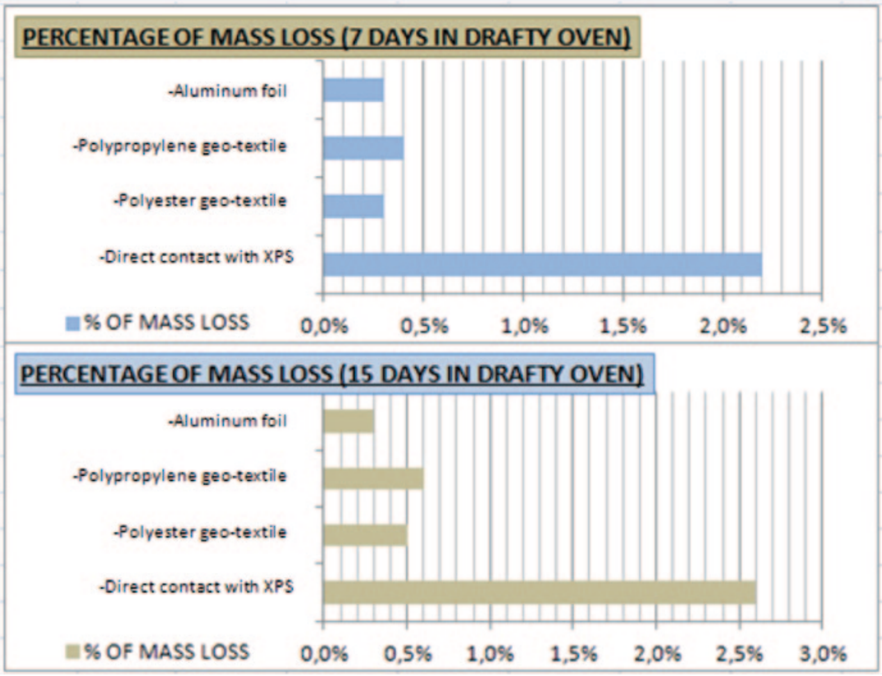

Fig. 1 Average of the results of mass loss percentage; test in drafty oven at 7 and 15 days

last sample was extracted from an area with no protection, totally exposed to elements in horizontal position, in the south area of the roof.

The roof from which the samples were extracted did not have any geo-textile or auxiliary separating layer between XPS and PVC-P. In the zone exposed to the south of the roof, there were evident symptoms of tension (produced by loss of dimension) on the vertical and exposed zone of the lamina. The red arrows in Fig. 2, show the waves that produce this movement of the horizontal part of the waterproofing membrane.

The waterproofing membrane extracted for the thermal analysis was RHENOFOL CG (Intemper Española S.A.), the roof is completely formed by this lamina.

Once the XPS board has been removed from the south extraction area of the roof (same area of Fig. 2), a clear effect of interaction can be appreciated between XPS and PVC-P. The XPS board has evident marks on its surface of the effect that PVC-P contact, temperature, and pressure have had on the material; furthermore this effect has consequences on the dimension and mass of the PVC-P lamina, and as a matter of fact in the amount of plasticizers contained in it.

In Fig. 3 the marks of these interactions can be seen, there are Polystyrene loss in the XPS board (visible in the inferior part of the figure), this material is not gone, it is adhered on the surface of the PVC-P, however, this form of Polystyrene in not plastic foam of polystyrene anymore.

Fig. 2 South extraction area; *red arrows* show waves on the waterproofing, produced by loss of dimension in the lamina

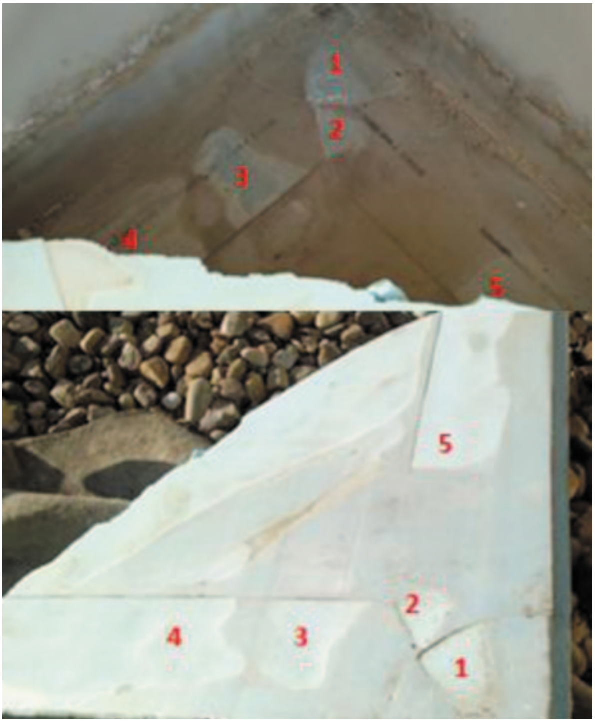

Fig. 3 South extraction area, in the superior part the PVC-P lamina, in the inferior part the XPS board, *red numbers* identify interactions

The thermal analysis with DSC is going to complete this research, by the comparasion between thermograms of the different samples. Four areas of the PVC-P lamina are going to be analized:

- Horizontal area with direct contact with XPS.
- Horizontal area totally exposed to elements.
- Vertical area (with no protection) in the south part of the roof.
- Vertical area (with no protection) in the north part of the roof.

Fig. 4 Loss of plasticizers in a PVC-P waterproof membrane, showing consequently a considerable shrinkage of the sheet. (Source: GEORA Aplicaciones Técnicas)

Three thermograms of every area previusly described are going to be analized, the comparasion between the amount of plasticizers in these different positions of the upside down roof, will offer results about the incidence of some factors, such as, the effect of the ultraviolet radiation, temperature, and interactions have had on the quality and integrity of the PVC-P lamina taken.

6 Conclusions

There are incompatibilities between XPS and PVC-P, these interactions affect the integrity of both. It is important for the durability of the constructive solution, to place a proper barrier to minimize this effect.

The direct contact between both materials (tested in the drafty oven) produces eight to nine times more mass loss that those configurations, with a proper barrier placed in. This mass loss produces a loss of dimension in the membrane, which brings internal tension, pressure on the perimeters of the sheet (which worsen it), and finally the end of the life cycle of the constructive system.

The geo-textile tested with the best behavior as an auxiliary separating layer has been the Polyester geo-textile of 300 gr/m^2 (Fig. 4).

The polypropylene geo-textile of 300 gr/m^2 can offer a good response to reduce the transference of plasticizers in a PVC-P waterproof membrane.

The pressure is a main factor in the plasticizer migration of a PVC-P waterproofing membrane; it has to be properly considered in roofs with an extraordinary load on it. The pressure practiced on the samples in the drafty oven test is approximately of 125 gr/cm^2, the pressure that a protection with gravel (5 cm) practices on the waterproofing is around 14 gr/cm^2. However, the load on flat roofs in the building industry sometimes can exert much more pressure on a waterproofing membrane.

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Porosity and Pore Size Distribution of the Dimension Stone in the Historic City of Cuenca

E. Torrero, D. Sanz and V. Navarro

Abstract The historic city of Cuenca is a first-rate architectural complex in terms of its architectural and cultural landscape. The conservation of the existing stone requires comprehensive studies that take into account the petrological and petrophysical source materials (historical quarries) and condition (study of pathologies) of the material used. Porosity and pore-size distribution are important properties as they partially determine weathering. This paper studies the pore system of the historic building stones of Cuenca. These stones have a total porosity of 10–20 % with pore-size intervals of 0.1–10 μm. These characteristics make them sensitive to processes such as salt and ice crystallization pressures. New introduced stones (e.g., Vara del Rey stone) with a different porosity and pore-size intervals may cause incompatibility problems in the short and middle term.

Keywords Limestone-Dolostone • Porosity • Cuenca • Durability

1 Introduction

Any study on the behaviour of natural stone buildings in the architectural heritage must determine the causes of its deterioration [1]. At present, most of the stone built heritage is in serious danger due to damage by weather, exposure to changing environmental conditions (e.g., air pollution), and alterations caused by biodeterioration [2].

This is part of a larger study whose goal is to accurately diagnose the stone materials in Cuenca and to formulate, test, and propose technically and economically viable conservation solutions compatible with the existing heritage.

The architectural and cultural landscape of Cuenca makes it a leading architectural complex. In fact, it is listed on UNESCO's 1996 World Heritage Sites list. However, this important heritage is currently suffering a threat to its conservation

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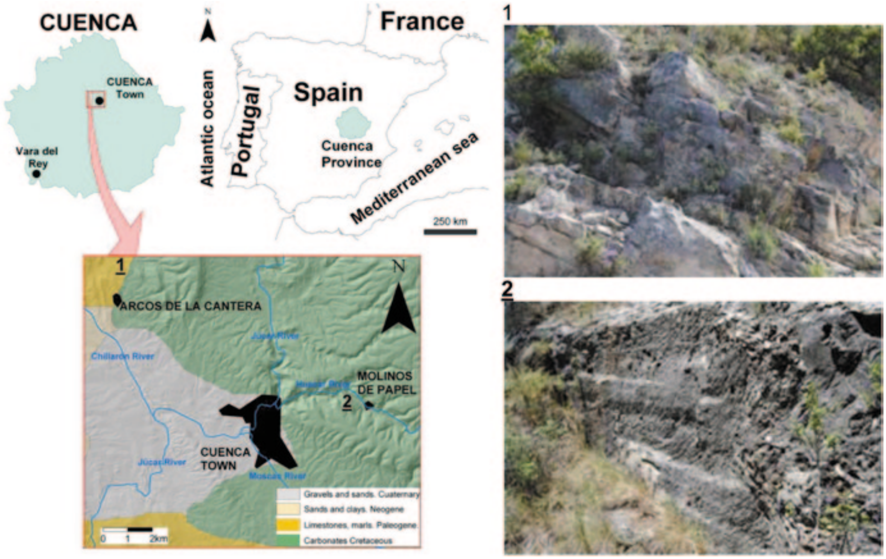

Fig. 1 Location and simplified geological map of the study area (Cuenca, Spain). 1. Lacustrine white limestone in historical quarries of Arcos de la Cantera. 2. Dolostone and limestone of Molinos de papel, historical quarries in Huécar river. The vertical scale of the photos is about 3 m

due to deterioration of the stone. In recent years, the government has undertaken a number of conservation measures that must meet certain characteristics and conditions. Conservation requires comprehensive studies that take into account the petrological and petrophysical characteristics of the source material (historical quarries) and the conservation status in the different buildings (study of pathologies).

The city of Cuenca is located in the central part of Spain and belongs to the autonomous community of Castilla – La Mancha (Fig. 1). In the words of Pio Baroja, “Cuenca is built on a hill overlooking the plain and is defended by two ravines, in the bottom of which flow the Júcar and Huécar rivers”. Cuenca is 946 m about sea level, with a Mediterranean continental climate (cold temperatures in winter and mild temperatures in summer). Rainfall is over 500 mm/year. The mean minimum daily temperature in January is −0.7 °C and the maximum daily average in July is 30.7 °C.

Geologically, the city of Cuenca is located on Cretaceous (Mesozoic), Tertiary, and Quaternary deposits (Fig. 1). Tertiary and Quaternary terrigenous formations appear at the bottom of the valleys and rivers. Most of the stone used in the construction of various historic buildings in the Cuenca come from the quarries near the Júcar and Huecar rivers and close to Arcos de la Cantera town (historical quarries) (Fig. 1). Historical buildings such as the Cathedral of Cuenca, the Castle gate, the City Hall, St. Peter’s Church, the Convent of “Las Petras” (Fig. 2), and bridges such as San Pablo and the Descalzos, as well as historic walls were constructed with these types of stone.

Fig. 2 Images of historic buildings in the city of Cuenca. A) Cathedral of Cuenca; lantern, cross, and flying buttresses of Arcos de la Cantera stone. B) City Hall of Cuenca; limestone pilaster, Júcar River quarries. C) Monastery of "Las Petras"; limestone quarries of the Júcar and Huécar rivers. D) St. Peter's Church; limestone from Ciudad Encantada. E) Gateway to the castle; the arches are made of stone from Ciudad Encantada and the badge is made with stone from Arcos de la Cantera. F) Replacing part of the top of the wall (Ciudad Encantada limestone—right) with Vara del rey limestone (left in photo)

In general, the rough stone come from quarries near the Júcar and Huécar rivers (e.g., Molinos de Papel), ashlar reinforcing the corners is obtained in situ or from quarries in the Ciudad Encantada (CE) formation, and the materials used in cornices and decorative elements are from the limestone quarry of Arcos de la Cantera (AC) (Fig. 2). A special case is the Cathedral of Cuenca, whose original material comes from predominantly historical quarries in the town of Arcos de la Cantera (see Fig. 1 and 2). Currently, the façade of the cathedral is made of Novelda stone and the base with Torrubia stone (not studied in this work). The reader may consult studies by [3] on the selection of stone materials for the replacement of the stone from the ledge of the Cathedral's cloister.

One of the most important physical and mechanical properties of rocks is their porous system. This determines the mobility of fluids such as water and aggressive agents such as salt solutions, which affect durability. In addition, it has an effect on the mechanical properties. As a result, natural stone used in construction must be classified as a function of the pore system [4].

Various methods of measuring stone porosity have been commonly used, such as direct measurements by quantitative image analysis (stereology), X-ray and gamma ray attenuation, deductions from the bulk density, helium pycnometry, and liquid saturation methods (see [5] and references therein). In the fluid saturation technique, mercury intrusion porosimetry (MIP) has the advantage of not only quan-

Table 1 Basic information of rocks. Fm: Formation is a lithostratigraphic unit. See examples of buildings in which the rock has been used in Fig. 2

Rock notation	Rock name	Quarry (source)
AC	Lacustrine limestone (Neogene)	Arcos de la Cantera town
VR	White Limestone (Upper Cretaceous)	Vara del Rey town
CE	Dolostones of the Ciudad Encantada Fm. (Upper Cretaceous)	Júcar and Huecar rivers
MP	Stratified Limestone of Villa de Ves Fm	Molinos de Papel town

tifying the total open porosity but its pore-size spectrum. This information is very important because the pore-size intervals can reveal different processes involved in heritage stone deterioration. In fact, [6] relates pore-size intervals with processes involved in stone deterioration: a) water adsorption and capillarity condensation (1 nm–0.1 μm radius pore), b) capillary imbibitions (1–100 μm radius pore), c) salt and ice crystallization pressure (0.1–10 μm radius pore).

2 Materials and Method

In the work presented here, we have analysed original stone used in the city of Cuenca. The following materials were studied (Table 1).

The pore system of these materials was analysed using mercury porosimetry, with a Micrometrics Autopore porosimeter model 9500 at a presure of 228 Mpa and a pore diameter covering the range of 6 to 0.005 μm. All the testing was carried out in the Escuela Politécnica de Cuenca. Two samples were evaluated for each stone type studied. The size of the samples did not exceed 0.2 cm^3 dry weight, and ranged from 2.1 to 4.3 g. All samples were dried in a ventilated oven at 105 °C for 24 h prior to measurement. Open porosity, density, permeability, and pore-size distribution were measured.

3 Results

The most compact stones studied are the Ciudad Encantada (EC) Fm. and the Vara del Rey (VR) limestones with apparent densities above 2.6 g/cm^3. In the case of Molinos de Papel limestone (MP), the apparent density does not exceed 2.4 g/cm^3. The stones studied have a porosity ranging from 22 % for the AC samples, 10–13 % for the Mesozoic limestones (EC and MP, respectively), and only 2 % for the replacement stone VR (Table 2). Open porosity is directly related to the rock's accessibility to fluid (water). In fact, there are empirical relationships, such as the Kozeny expression, where permeability depends on porosity and pore size. Higher porosity

Table 2 Data obtained by mercury intrusion porosimetry. Da: apparent density (g/cm^3), Dr: relative density (g/cm^3), Kd: permeability (mdarcy), Po: open porosity (%). Sample notation is as follows: Ciudad Encantada (CE) Fm., dolostone/limestone from the Molinos de Papel (MP) Fm., Arcos de la Cantera (AC), and Vara del Rey (VR)

Stone	D_a	D_r	K_d	P_o
CE	2.66	2.81	25.03	10.7
MP	2.36	2.67	34.30	13.6
AC	2.51	2.65	48.35	22.4
VR	2.60	2.64	17.70	1.88

and greater pore size lead to greater permeability. This fact is confirmed in Table 1, where porous materials are more permeable. Therefore, the most permeable stones allow water to pass through them most easily, and consequently they are more susceptible to weathering. However, as pointed out [7], it is necessary to support these statements with a knowledge of the spectrum of pores for each stone. In fact, stones with a higher percentage of small pores are more susceptible to degradation (e.g., salt decay) than others with the same porosity but a larger pore size.

The pore-size distribution of the different stones is shown in Fig. 3. All samples correspond to macroporous materials according to the IUPAC classification [8]. The EC stone has a unimodal pore distribution with a maximum access radius between 0.1 and 1 μm. The Cretaceous material from Molinos de Papel (MP) has a bimodal distribution with two porosity peaks. One peak lies between 0.01 and 0.1 μm, and the other one between 0.1 and 1 μm. AC is a more porous stone than the others and has three peaks as a percentage between 0.01 and 10 μm. Vara del Rey stone (VR) has a peak of over 10 μm.

This suggests that the Mesozoic stones (EC and MP) have similar porosities and pore-size distributions, although the EC stone is more compact and less permeable. AC is more porous and (having a higher percentage of pores below 0.1 μm) is therefore more susceptible to decay. The VR stone has a lower porosity and its pore size is greater than 10 μm; therefore, it has greater durability.

4 Conclusions

Porosimetry analysis of the original stones of the city of Cuenca indicates that the Molinos de Papel (MP) and Arcos de la Cantera (AC) stones present a greater capillarity and hygroscopicity, which means lower durability. Both stones may be affected by salt and ice crystallization pressure because of their pore size ranges (0.1–10 μm). This can be evidenced in the Cathedral and the pillars of the city hall, where there is significant decay.

Moreover, the Ciudad Encantada stone (CE), having a porosity of nearly 10 %, is more resistant to weathering because this pore size does not seem to be affected by water adsorption, capillary condensation, and imbibition.

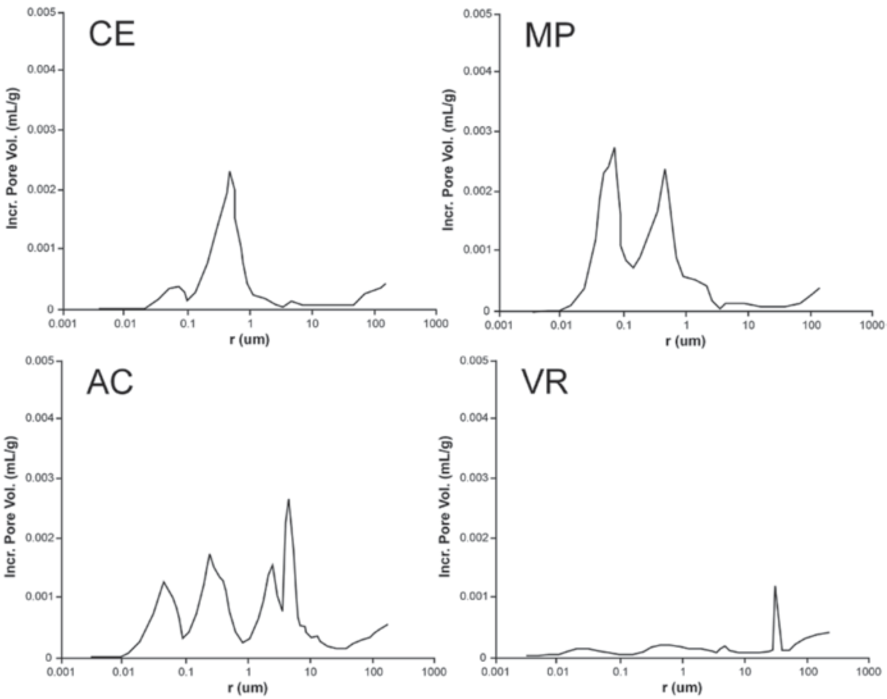

Fig. 3 Pore-size distribution curves of different stones obtained by mercury intrusion porosimetry (MIP). Stone abbreviations are indicated in Table 1. Incremental pore volume (Incr. Pore. Vol.) in mL/g. Log mean radius pore in μm

The Vara de Rey stone (VR) has low porosity values (<2%) and a pore radius of over 10 μm. With these features, the (VR) stone will suffer less degradation processes such as salt and ice crystallization pressure, water adsorption, and capillarity condensation.

The notable differences in density, porosity, and pore size ranges between the studied stones can cause compatibility issues when used in the same buildings. A future project is to expand the petrological knowledge of these stones. A final assessment of the stone to be used in possible replacements of damaged parts in the heritage city of Cuenca will be made based on criteria of suitability, compatibility, and durability.

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Thin Solar Film Application for Improving Thermal Comfort in Classrooms

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Abstract This paper presents the results of a thermal survey that has been carried out in 3 representative classrooms of a college in Bolzano, Italy. Users complain about the discomfort in the classrooms due to excessive temperatures on the premises exposed to solar radiation. Thus thermal probes have measured the temperature during about 2 months in 5 different locations in order to assess the thermal behavior of the enclosures. The windows of one of them have been fully treated with a special thin solar film in order to gather information about the final thermal behavior of this special enclosure. Data will be also collected from the closest official meteorological station in order to compare and better asses the ground situation and the possible intervention on the whole facade.

Keywords Thermal comfort • Classroom • Thin solar film

1 Introduction

Environmental comfort is a very important issue and is strongly related with the build environment, its constructive characteristics, the used materials, the climate conditions and the energy efficiency. Regarding classrooms, thermal, acoustical and luminous comfort has a direct effect on the teaching and learning process. Overheated or too cold classrooms can produce physical stress and affect the performance of students and teachers [1].

Users of the investigated building complain about the discomfort in the classrooms due to excessive temperatures on the premises exposed to solar radiation. Moreover the specific spectral content of the radiation shows no direct effect on thermal sensation [2].

There are two main international standards about thermal comfort: the ASHRAE Standard “Thermal environment conditions for human occupancy” (2003) and UNI EN ISO 7730 ”Ergonomics of the thermal environment—Analytical determination

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and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria" (2006). The environmental conditions required for comfort show large variations from person to person but the EN ISO 7730 presents methods for predicting the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments [3]. However, laboratory and field researches provide the necessary statistical data to define six primary factors for defining conditions for thermal comfort [4, 5]:

1. metabolic rate
2. clothing insulation
3. air temperature
4. radiant temperature
5. air speed
6. humidity.

The goal of this paper is to present the results of a two-month long thermal survey realised in 3 classrooms of a college in Bolzano, Italy.

2 Methodology

Due to the excessive temperatures on the premises exposed to solar radiation, we carried out a 12 weeks long thermal survey to have a first check of the global situation. At the same time we decided to experimentally verify the possibility of improving the thermal performance on the existing enclosures. This has to be achieved without affecting the aesthetics of the building, since the glass wall constitutes an architectural identifier between the building materials. Furthermore we cannot reduce drastically the brightness of the premises and its luminous comfort by using the already existing shading devices, as shown on Fig. 1.

It is therefore proposed to optimize the performance of windows by the application of a film. The filtering of the solar radiation should allow increasing the comfort in the premises and ultimately, also reducing the use of shading elements in order to maintain practically unchanged the availability of natural lighting. Furthermore we also expect significant energy savings.

For our experimental purposes 3 similar and representative classrooms have been chosen. Table 1 summarizes the main characteristics of the 3 enclosures.

In one of the top floor classrooms (309) the experiment of application of solar thin solar protection film will be carried out. We expect to reduce the local effects of excessive heating due to sun exposure and test directly whether this solution can contribute solving the problem.

The thin solar film, made by polyester with pressure sensitive acrylic adhesive, has a solar factor G-value = 0,49 with 51 % of total solar energy rejected and a thickness of 0,050 mm/ 50 μm. The film covers all the windows surfaces of the sample classroom and shows a neutral colour.

Fig. 1 Interior of classroom 309 and 310 with use of shading devices

Table 1 Characteristics of the selected enclosures

Classroom	210	309	310
Floor	2nd	3rd	3rd
Surface [m^2]	66.70	65.71	66.70
Exterior windows	yes	yes	yes
Exposure	South	South	South
Thin film application	no	yes	no

The second enclosure (310) is located just next to the first. The third classroom (210) is located in the second floor, just below the second one. The exposure for all classrooms is south and there are no possible external shading from other building.

The location of the classroom is not random. Comparison between classroom 210 and 310 could give us some information about the influence of the floor of the top floor facing the exterior with an open air gap.

The comparison of classroom 309 with the other two classrooms will permit a (double) check about the adequacy of the chosen solution (application of thin solar film) in different parts/levels of the building, where other aspects can be important.

The measurement survey began the 28.03.2012 and ended the 25.05.2012.

In all premises five measure points have been chosen:

- close to the glass wall (_01)
- close to the wall opposite the window (_02A)
- interior surface of the interior layer of window/glass wall (_02B)
- exterior surface of the interior layer of the window/glass wall (_03A)
- air gap inside the glass wall (_03B).

Furthermore, we also performed a measurement of the roof and the outside temperatures in order to considerate the external climatic conditions [6]. The measurement device was a Testo Temperature datalogger with the NTC internal sensor and a resolution of 0.1 °C, capable of storing up to 1 million data. The connected probe for measuring surface temperature has a measure range from −50 up +80 °C.

Fig. 2 Probe on the interior windows (*left*) and the air gap (*right*)

As the chosen sampling frequency was 4 for hour considering so far the thermal inertia, we could get a quite exhaustive database with 86400 inputs (4 [sampling/h] 24 [h/day] 60 [d] 5 [probes] 3 [classrooms] = 86400).

Due to the possible subjectivity of the responses, the use of a specific questionnaire for users has not been integrated in the survey.

3 Results

All collected data will be evaluated in graphical form. We will have a visual development of nine items: the roof temperature, the five measured temperature values in the location of the enclosure, the outdoor "official" temperature, the sun radiation and the sunshine. We present next the graphic for classroom 210 without solar film (Fig. 3) and classroom 309 with thin solar film (Fig. 4).

In both figures we can observe how the roof temperature (kaki line) starts growing fast every day in direct relationship with the sunshine (yellow line). Its development shows a kind of saw with a quite important temperature gap between the roof and the outside temperature. The indoor temperature close to door (_01) and the temperature close to the wall opposite the window (_02A) always show as well small differences but with a quite similar and more relaxed (plane) development. The values of temperature for the interior glass layer of the window (_02B) are also quite similar depending on the moment of the day but show larger fluctuations.

Finally the air gap (_03B) and the exterior surface of the interior windows layer (_03A) always show the highest value of temperature that have reached 51.4 ºC with a roof temperature of 24.7 ºC and an outdoor temperature of 25.5 ºC on 31/03/2012 in classroom 209.

The thermal inertia plays a very important role in the complex thermal behaviour of a building where windows and walls/roof show different transmittance U. A time gap is always described by the towards rights shifted development of some temperature measure.

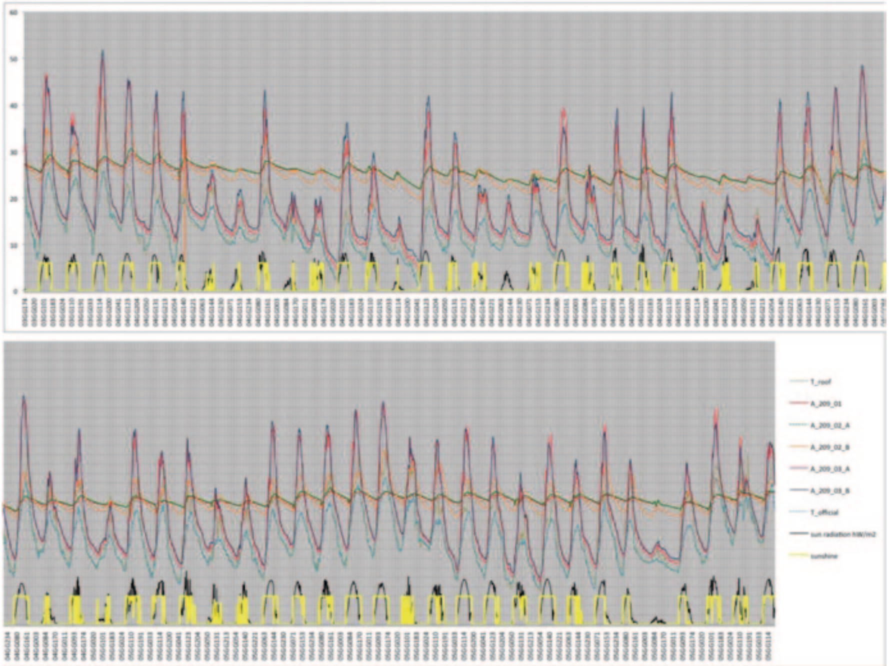

Fig. 3 Temperatures evolution in Classroom 210

In Fig. 4 we observe slightly lower general values for interior temperatures (_01 and _02A).

4 Conclusions

This paper reports the results of a thermal survey carried out during about two months in three classrooms of a college, where we observe a quite similar thermal behaviour. As a general remark, we observe also lower final indoor temperature values in classroom 309 compared with classroom 209 and 310.

In Fig. 5 we describe the difference between the temperature of the interior surface of the interior windows layer and the room temperature close to the windows during approximately a whole week. We realize how the thin solar film application in classroom 309 is increasing this difference during the day. This is for sure an advantage as this surface is directly related with the temperature growth in the classroom and the final thermal comfort.

Furthermore we observe an interesting difference between both classrooms without film application. The location on the 2nd floor seems to affect directly the thermal behaviour of the classroom 209 that shows smaller fluctuations compared with classroom 310.

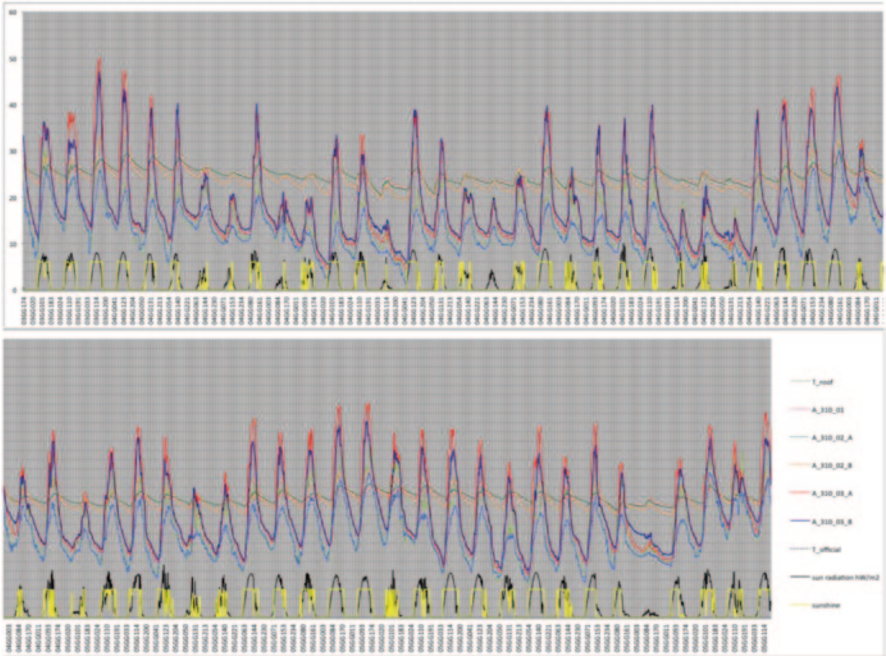

Fig. 4 Temperatures evolution in Classroom 310

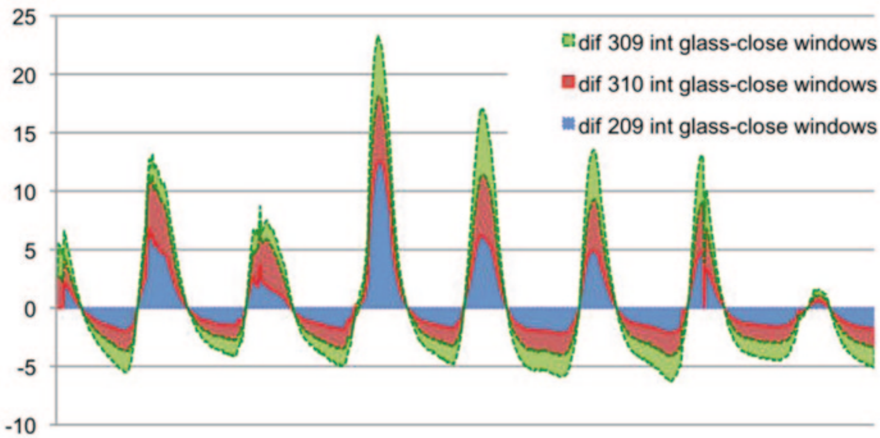

Fig. 5 Difference of temperature between area close to windows and windows glass

Figure 6 shows the difference of the absolute temperature close to the windows in classroom 209 (red line) and 310 (blue line) always compared with classroom 309, the one with the solar film. This location was chosen as it could be the hottest

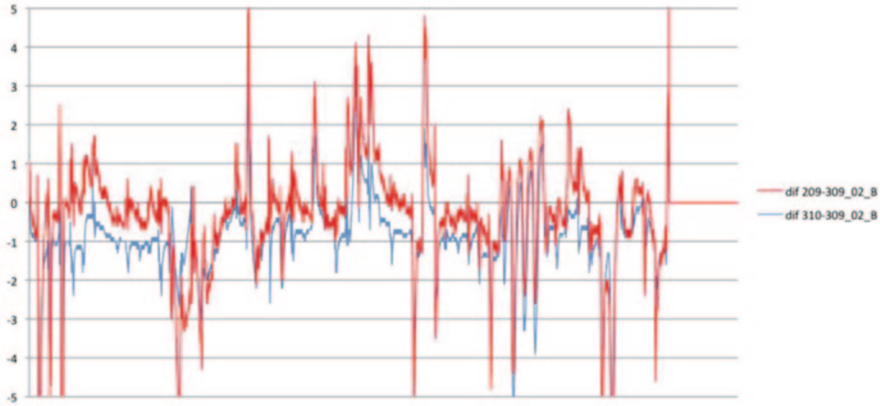

Fig. 6 Temperature difference close to windows in classroom 310 and 209 vs 309

and at the same time should depend less on the users presence. We observe how this temperature difference for classroom 209, as well as for classroom 310, vs 309 during the whole survey is greater, indicating a better general thermal performance of this enclosure. The solar film has produced some improvement of the thermal conditions in classroom 309.

Furthermore the results of our survey suggest that this simple treatment of the windows will not solve completely the related discomfort by users. Forced ventilation or improvement of the natural ventilation will for sure also help removing the excess of heat and humidity. A better heating regulation system (automatic or manual) would also improve the general comfort of students.

The changing of the building materials was not a viable option due to the aesthetics of the building and the presence of a glass facade as architectural identifier. A more invasive solution could add some external architectonical shading elements (horizontal or vertical), in order to protect the interior of the classrooms with south exposure.

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Analysis of the Reflected Wave Arrival Position in Timber Specimens Emitted by GPR with an Antenna of 1.6 ghz

R. Martínez-Sala, I. Rodríguez-Abad and J. Tapia

Abstract This work was focused on the establishment of the best criterion to perform the readings of the amplitudes of the waves emitted by ground-penetrating radar, when timber specimens were inspected with an antenna of 1.6 GHz. This is a critical parameter when we are dealing with near-field readings, since no unique definition of this point has reached an agreement in the literature.

To be able to perform amplitude readings in timber beams, two problems might be taken into account. Firstly, the standard timber dimensions (7.5 × 20 cm) used in building structures leaded to an overlap of signals that increased the difficulty of identifying the reflected wave arrival. Secondly, due to the low dielectric contrast between timber and air, the reflected wave had little energy. In addition, when assessing a physical parameter such as moisture content, the higher the moisture content the bigger the attenuation was.

This paper describes the best procedure to identify the wave arrival positions. In addition, different amplitude reading criteria were adopted, depending on the antenna position on the timber specimen. Finally, the criteria were compared to establish which one provided best information of the analysed parameter: moisture content.

Keywords Timber • Nondestructive technique • Ground-penetrating radar

1 Introduction

Radar techniques were originally developed for the detection of targets in the sky or on the surface of land or sea, but over the last twenty years have been adapted and used in a wide range of applications. At present, ground-penetrating radar (GPR) is a real-time, non-destructive testing technique with two additional major advantages: it is feasible to scan areas of interest extremely quickly and can produce data with very high spatial resolution (on the order of centimetres). These characteristics make GPR a very useful technique to investigate no conducting materials and structures. Indeed, GPR has been increasingly used to inspect building structures and many works dealing with this application [1] and the effects of building materials

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properties on electromagnetic (*EM*) wave parameters have been published [2–3]. In particular, recently our team has performed some investigations to explore the ability of GPR, with a 1.6 GHz antenna, to analyse timber properties: density, moisture content [4–5] and dielectric anisotropy [6].

The aim of this paper was to present the survey we carried out at the beginning of these investigations to establish the best criterion to make the readings of the amplitudes of the waves in the radargrams, when timber specimens are inspected. This is a critical parameter when near-field readings are performed, since no unique definition of this point has reached an agreement in the literature as [7] described.

When the antenna is placed on the timber surface there is an interaction that alters the transmitted waveform and that affects the direct (*D*) and reflected ® waves. The true time zero position of the radar wave radiated from a ground-couple antenna, as [7] affirmed, is not necessarily a fixed value since it depends on the antenna, the height of the antenna above the surface and the electrical properties of the medium beneath the antenna. In fact, GPR users proposed different positions for the time zero in a survey conducted by Georadar Research. Some of these positions are labelled with a letter in Fig. 1. When analysing the *R* waves, to set the positions as the ones marked in Fig. 1 is more difficult. The *R* is less identifiable than the *D,* since its signal is weaker and, in addition, usually interferes with other signals.

In concrete, in this paper we present the experiments implemented to search the best criterion to set the position of the *R* and to probe its validity, when an antenna of 1.6 GHz is used to prospect timber. For that purpose, amplitudes of the *R* of timber specimens, which were put under drying process, were analysed. In order to be sure that the position of the *R* identified in the radargrams was the one reflected from the backside of the timber, we compared traces registered when both a metal plate was placed or not beneath the timber specimens. In these cases the waves reflected from the interfaces, timber-air and timber-metal reflector had opposite polarities and that shift helped to identify the signals [8].

2 Background Theory

The theory that explains when a shift in polarity of a reflected wave occurs is the following. *EM* wave propagation is controlled by the physical properties of the host material in which wave propagates and it is reflected at interfaces where there is a difference in dielectric properties of the materials on each side of the interface. The reflection coefficient (*Rf*) is a parameter that describes the amplitude and polarity of the reflected *EM* wave with respect to the amplitude and polarity of the incident *EM* wave. The reflection coefficient of a plane wave normally incident is governed by:

$$Rf = \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}} \tag{1}$$

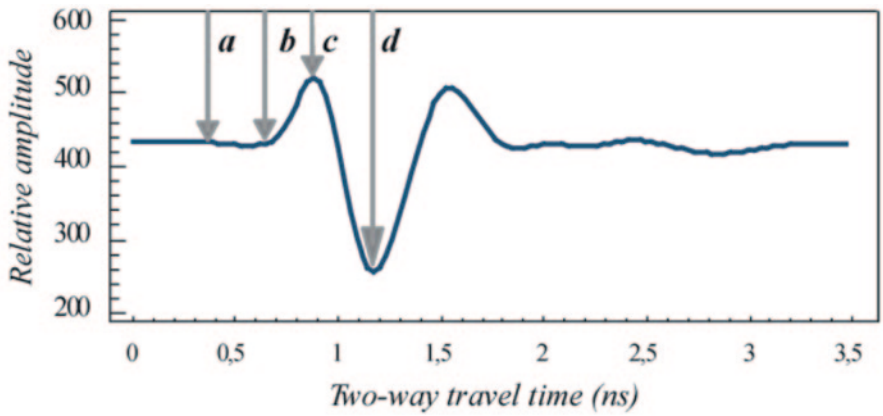

Fig. 1 Locations of zero time positions on direct wave: a (Zero point), b (First break), c (First positive maximum), d (First negative maximum). When the amplitude measured is from c to d is named peak to peak reading (PtP)

Where ε_i is the dielectric permittivity and $i = 1$ refers to the material where the incident wave is propagated and 2 for the material where the wave is transmitted. When the material 1 is wood and 2 is air, $\varepsilon_1 > \varepsilon_2$ and $Rf > 0$ that means that the reflected and incident wave have the same phase (Fig. 2a). However, when 1 is wood and 2 is a metallic medium, $\varepsilon_1 << \varepsilon_2$ and in this case the percentage of energy that is reflected is greater and the incident and reflected signals have opposite polarities because $Rf < 0$ (Fig. 2b).

3 Material and Method

Radar measurements were carried out using a SIR-10H system and a 1.6 GHz ground coupled antenna, both developed by GSSI. The test was conducted on 20 timber specimens of maritime pine (Fig. 3a), with an average density of 0.49 g/cm^3 when the moisture content (*MC*) was equal to that of the hygroscopic equilibrium (*MC* = 10 %).

Initially, the specimens had an *MC* ≅ 100 % of their anhydrous mass and were then subjected to a drying process which was interrupted at various times for GPR measurements. The measurements consisted of recording approximately 400 scans by placing the antenna on the centre of the sample surface (Fig. 3b, c), when the bottom of the beams was in contact with air and with a metallic reflector plate. The humidity of the specimens in every session was determined following the standard UNE-EN 13183-1:2002. GPR signals were processed and analysed using RADAN NT software (GSSI) and no gain function was applied so as to leave the amplitude values unaltered.

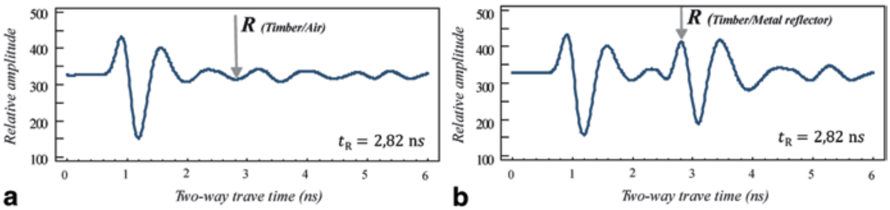

Fig. 2 Polarity of the reflected wave in a timber-air interface (a) and shift when a metal reflector is placed beneath timber (b)

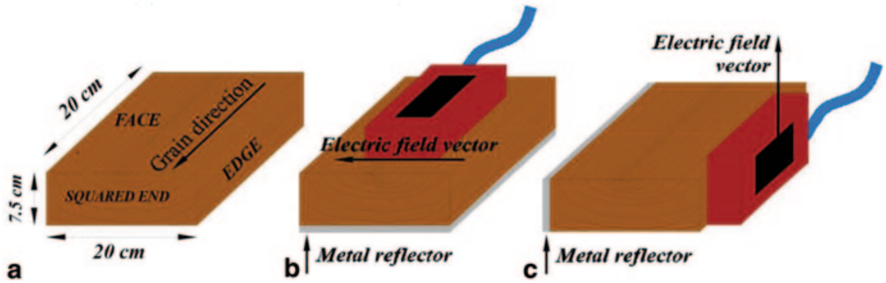

Fig. 3 Principal surfaces and dimensions of timber specimens with respect to grain direction; Positions of the antenna with respect to the grain, antenna placed on the: face (b) and edge (c)

4 Results and Discussion

In this survey the time zero was set on the first positive peak of the *D*. This election was due to the fact that this point, which matches *c* position in Fig. 1, was always the largest amplitude of the *D* and therefore the easiest to identify throughout all the sessions. But, when analysing the *R*, we need to divide the recorded traces into two groups depending on which surface of the beam the antenna was placed on: the face (Fig. 3b) and the edge of the beam (Fig. 3c).

4.1 Antenna Placed on the Edge

In this case the beam is 20 cm thick and using a 1.6 GHz antenna the *D* and *R* arrived separately in time. However, due to the long path, the *R* experienced a large attenuation to be clearly distinguished, overall when the *MC* of the beam was high. In this case the reading of the *R* can be taken in two positions: *R1*, first positive peak and *R2*, second positive peak. As it is shown in Fig. 4, when the *MC* is close to 10 % both peaks are clearly depicted (Fig. 4a). Nevertheless, as the *MC* increases the wave attenuation become higher, up to a point that *R1* was not visible (Fig. 4b). In particular, when the *MC* was higher than 34 %, no *R1* arrival was identified.

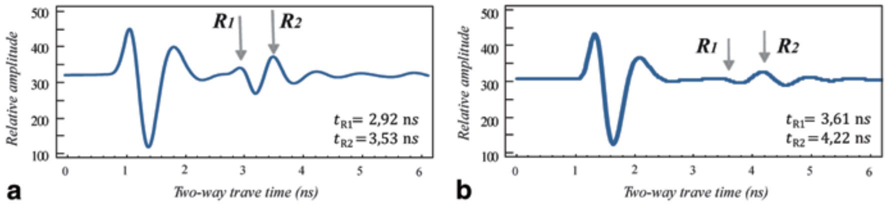

Fig. 4 Typical traces from edge acquisitions when timer had a MC=11 % (a) and a MC=21 % (b)

Table 1 Effect of MC variation on the R amplitude when the antenna is placed on edge and face with different reading criterion

Antenna placed on	Normalized amplitude *R*	MC range	Equation	R^2
Edge	Peak to peak	11 %-34 %	$nA = 0.65\text{-}0.046MC + 0.00086MC^2$	92 %
Edge	2nd positive peak	11 %-44 %	$nA = 0.60–0.031MC + 0.00043MC^2$	93 %
Face	1st positive peak	11 %-120 %	$nA = 0.94–0.014MC + 0.00086MC^2$	95 %

Therefore, the election of the second positive peak as the reading position, which amplitude was higher, allowed us to broaden the range of *MC* readings.

Following, we chose other criteria (*PtP*), in order to corroborate that with both we obtain the same accuracy in the *MC* assessment, since that was the final goal of the measurements. We calculated the best adjustments between the *PtP* amplitude and the *MC*, when the signals were recorded with the metal reflector and their amplitudes were normalized dividing by the amplitude of the first positive peak of the *D* when emitting in air. The best adjustment between the *R2* normalized amplitude and the *MC* was also calculated, following the same normalizing procedure. The functions found in the two adjustments and the correlations are given in Table 1. Both functions, second degree polynomial, were quite similar and the correlation values very high, $R^2 > 90\,\%$. Therefore, similar information was to be found with both reading positions. But it is important to highlight that with the *R2* information, to perform the reading was much easier and the range of *MC* analysed broaden.

4.2 *Antenna Placed on the Face*

Although in this case the beam is 7.5 cm thick and using a 1.6 GHz antenna the *D* and *R* interfered, we assessed the reflection point and therefore located the first positive peak of the *R* by making a comparison between traces recorded with and without the metal reflector. In this case, the amplitude of the first positive peak of the *R* was high enough to be identified up to 120 % *MC* (Fig. 5).

Therefore we considered this position the best one and the adjustment of these normalized amplitudes with the *MC* was calculated. When calculating the adjustments between the normalized amplitude of first positive peak of the *R* and the *MC*,

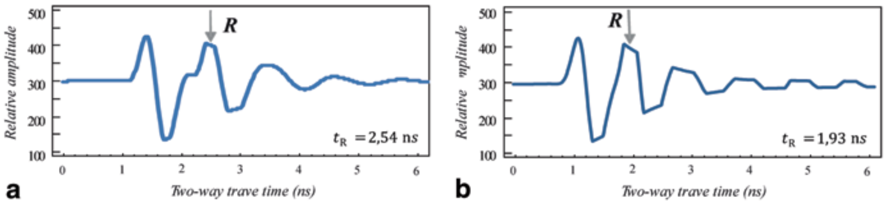

Fig. 5 Typical traces from face acquisitions when timer had a MC=11 % (a) and MC=21 % (b)

the best fitting was again a second degree polynomial and the correlation value was $R^2=95\,\%$ (Table 1). Again, we corroborated that no lost of information was done by choosing this criterion.

5 Conclusions

The election of the best criterion to perform the readings of the amplitudes of the *D* and *R* waves, when we work with near-field acquisitions is critical. To be able to perform amplitude readings in timber beams, two problems must be taken into account. The first one is that standard timber dimensions (7.5 × 20 cm) used in building structures leads to an overlap of signals that increases the difficulty of identifying the *R* wave arrival. The second one is that, due to the low dielectric contrast between timber and air, most of the energy is transmitted and only a little part is reflected. In addition, the higher the *MC* the bigger the attenuation is.

This paper demonstrates that following a precise procedure all these conflicts might be overcome and high accuracy adjustments between wave amplitudes and *MC* are to be found. To be sure, when the reflection occurs acquisitions, with or without metal reflector beneath the beam, must be performed. Following, when *MC* was the studied parameter, the best amplitude reading position was *R1* for face acquisitions and *R2* for edge acquisitions.

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Mechanical Performance of Traditional Lightweight Concretes from the Canary Islands

P. Yanes González and M. del Río Merino

Abstract In the Canary Islands, due to their volcanic origin, clay cannot be found, and therefore, in building construction, vibrated concrete blocks are used, which include Picón (pyroclastics, tephra)—whose scientific name is LAPILLI–among their components.

To improve the qualities of these blocks, as required in the Technical Building Code (CTE in Spanish acronym)different percentages of treated expanded polystyrene (EPS)were added to the concrete mixture from which the blocks are made.

In the study regarding mechanical behavior and water vapor transmission properties, the following results were obtained:

- Weight decrease of the test pieces: they turned out to be 32.82 % lighter.
- Flexural strength decreased to 78.79 %.
- Compressive strength diminished up to 85.85 %.
- Regarding water vapor resistance, test pieces resulted 63.57 % more resistant.

Keywords Tephra • Lightweight concretes • Vibrated concrete blocks

1 Introduction

Once the Technical Building Code, establishing among other things, the basic requirements against noise, and the needed energy demand to achieve thermal and acoustic well-being, was set into force, in the Canary Islands studies were conducted concerning airborne noise and thermal resistance in the interior wall partitions and façades, built with blocks of vibrated concrete lightened with Picón. These blocks offered constructive solutions which almost always needed inner linings of blocks or plasterboard, so that they would conform to the existing legislation, as can be seen in [1] y [2]

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This research work aims to study the mechanical behavior and the water vapor transmission, when treated expanded polystyrene (EPS_t) is added to traditional concrete. It needs to be noted that the Canary Islands present a lithology characterized mostly by materials and volcanic structures, due to their volcanic origin; therefore, it lacks clay suitable for the manufacture of bricks. Indeed vibrated concrete blocks are used as enclosure elements, which have the peculiarity of including Picón (pyroclastic), whose scientific name is LAPILLI among its component materials.

The aim of this research work is to analyze the characteristics of the Lapilli mortar with the addition of EPS_t to determine:

1. The weight variation.
2. Bending or flexural strength and compressive strength.
3. Water vapor transmission properties.

2 Methodological Procedure

The methodological proposal in order to reach the stated objectives of the present study was based on two research methods:

- *Descriptive study*.- seven test pieces of 60 x 60 x 5 cm in thickness were performed using concrete lightened with lapilli, equal to the one used for the building blocks.
- *Comparative study*. So as to compare the results obtained with the previously mentioned specimens, two series of seven specimens each were carried out with different proportions of the added percentage of treated expanded polystyrene(EPS_T).

After 28 days, the following tests were performed:

a. Study of the weight variation, to calculate the average weight of each series and draw up the percentages.
b. Mechanical bending strength and compression strength carried out according to the UNE-EN 1015-11: 200 standard. Three test pieces of each series were carried out, 160 mm long x 40 mm wide x 40 mm high. Once the bending test was made, with each half of the broken specimens, a compression test was run.
c. Determination of water vapor transmission properties. The test was carried out according to UNE—EN ISO 12572: 2001 standard, using specimens of 11 cm x 11 cm x 5 cm thick.

3 Materials

Materials studied in this study are the traditional components of the lapilli concrete, with addition of treated expanded polystyrene (EPS_t).

a. Potable water.
b. Cement: CEM II/A-P 42.5R.
c. Coarse and fine aggregate: Lapilli.
d. Treated expanded polystyrene (EPS_t).

The two most characteristic materials are analyzed here:

A.- LAPILLI.

General information.

One of the characteristics of the Canarian archipelago, which differentiates it from the Iberian Peninsula, is the presence of a lithology characterized mostly by materials and volcanic structures, setting up a landscape dominated mostly by different nature lavas and pyroclastic deposits, of very varied compositions. This presence can be traced back almost since the beginning of the subaerial volcanic activity in the archipelago. Excluding the prior history of submarine growth of the Islands, te volcanic activity can be dated in the Middle Miocene, i.e. approximately 20 million years ago [3].

This peculiar characteristic has substantially conditioned the constructive activity of the inhabitants of the Islands, in terms of the use of more immediate and within reach resources. In this sense, volcanic materials have always been, not just raw materials for local buildings, but the only settlement possible for all the buildings in the Canary Islands.

Within the construction materials, the most important characteristics of the aggregates use din different proportions for the blocks are anlyzed:

Porosity.

Aggregates have been classified in four different types: [4]

A.-“Waffle” porous slab .

B.- “Vacuolar” porous structure.

C.-“Mixed” porous structure.

D.-Non-macroscopic (*matrix*) porous structure.

Specific weight (unit weight) and simple compressive strength.

Strength increases as the specific weight of lapilli increases, in the same way as what happens with other stones. It can be said that, strength increases with the increasing amount of dense ferromagnesian minerals.

B.- Treated Expanded Polystyrene.

General information.

They are perfectly spherical EPS pearls, varying in between 2 to 8 mm in size (granulometry), of light grey color, and treated with additives, so that these spheres neither float nor segregate. The resulting concrete has uniform physical and mechanical properties and can be used for large surfaces without having to perform expansion joints.

The additive has a pH= 13+-1 and is alcaline, non-corrosive and stable in normal conditions. Reaction of EPS_t to the effect of organic solvents should be taken into account. Checking the material reaction when in contact with substances of unknown composition is recommended

Table 1 Concrete proportion used in the manufacture of vibrated concrete blocks P(I)

Proportion				
Materials	Type	Quantity	Consistency	Mixing
Cement	CEM II/A-P 42.5R	230 kg	Dry	45–50 seg
Water	Potable	130.00 L		
Fine aggregate	Lapilli sand(Ø0/2)	200 kg		
Coarse aggregate	Lapilli (Ø 4/16)	1000 kg		

4 Tests Performed

1. Manufacture of test pieces.
2. Study of the weight variation of the specimens.
3. Determining bending and compressive mechanical strengths.
4. Determining water vapor transmission properties.

4.1 Manufacture of Test Pieces

A MF 3000 A (Manufacturer: Poyatos) mixer was used.

Lapilli mortar was used in the following proportions in the test pieces:

Test pieces, series II, (P 2). Developed with the same mortar than the previous ones but once the mortar came out of the masonry mixer, EPS_t was added to 36.85 % of the mass volume, and 300 cm^3 of water were added to a total of 0.126 cm^3 of mortar used to fill the seven specimens.

Test pieces series III, (P 3) were prepared using the same mortar as the one in P(I), but adding: 73.70 % of the mass volume of EPSt and 500 cm^3 of water to a total of 0.126 cm^3 of mortar used to fill the seven specimens.

4.2 Study of the Test Pieces Weight Variation

After 28 days, specimens were removed from the dryer and taken to the Laboratory of Quality in Construction of the Canarian Government studying variations in weight.

To calculate the average weight of each series, the two extreme weight measurements were dismissed.

4.3 Determining Bending Mechanical Strength

The test pieces were performed in accordance with the **UNE-EN 1015-11:2001** standard. Specimens of 160 x 40 x 40 mm were made, and 3 units from each series were extracted of 60 x 60 x 5 cm.

Table 2 Study of the test pieces change in weight

	Weight in kg	Percentage %	
P(I)	28.83	x	x
P(II)	21.979	23.79 %	x
P(III)	16.772	41.84 %	23.99 %

4.4 Procedure to Determine Compressive Strength

Compressive strength was determined for each of the two halves (semi prisms) resulting from the bending strength test.

4.5 Determining Water Vapor Transmission Properties

The test was carried out in accordance with **UNE-EN ISO 12572:2001** standard.

For this test, specimens of 11 cm x 11 cm x 5 cm were used. The shape of them are squared prisms, because the lab molds had this shape.

5 Results and Conclusions

5.1 Study of the Test Pieces Change in Weight

With the addition of traditional lapilli concrete, a decrease in the weight of the specimens was reached based on the percentage added to the original proportion. So, we can see how P(I) specimens made with traditional mortar proved to be 23.79 % heavier than the P(II), and 41.84 % heavier than P(III). And the P(II) with a 36.85 % of the volume of EPS_t were 23.69 % heavier than the P(III) containing 73.70 % of EPS_t.

5.2 Determining Bending and Compressive Mechanical Strengths

The strength of specimens with EPSt addition diminished in proportion to the water content and to the EPS_t content, being the loss of mechanical strength greater in compression than in bending.

Table 3 Determining bending and compressive mechanical strengths

Test pieces	Bending mechanical strength (N/mm^2)	Compressive strength (N/mm^2)
P(I)	3.30	10.60
P(II)	−24.24%	−35.85%
P(III)	−78.79%	−85.85%

Table 4 Determining water vapor transmission properties

Tests	P(I)	P(II)	P(III)
Density of water vapor flow.(g), kg(m^2.s)	$3.49.10^{-7}$	−38.68%	+27.79%
Permeance to water vapor. (W), kg(m^2.s.Pa)	$3.19.10^{-10}$	-38.56%	+27.90%
Permeability to water vapor. (δ), kg(m.s.Pa)	$1,67.10^{-11}$	−38.92%	+25.75%
Resistance to water vapor. (Z), m^2.s.Pa/Kg	$3,15.10^{9}$	+62.54%	−21.27%
Water vapor resistance factor. (μ) at 23°C and 53/925HR	11.75	+63.57%	−20.08%

5.3 Determining Water Vapor Transmission Properties

As can be seen from the results on water vapor resistance factor, the P(II) proportion obtains a better resistance to the original proportion P (I), therefore, by adding a certain EPS_t concentration, the material resistance to water vapor improves. It can be concluded that this EPS_t addition diminishes the water absorption of the material.

With the P (III) proportion, it can be seen that the optimum proportion for this property is exceeded, since it reduces the water vapor resistance factor and therefore increases the permeability to water vapor. Nevertheless, it all depends on where the material is going to be placed and on the demands that are required in each case.

6 Final Conclusion

Once the results of the tests on the addition of EPS_t to traditional lapilli mortar, used for the construction of prefabricated elements—such as blocks, hollow bricks etc—have been analyzed, the conclusions from this study can be drawn and be classified into two types:

1. Mortar characteristics.
   a. Resulting mass was homogeneous.
   b. Mortar was bonded to the EPS_t pearls.
2. Physical properties.
   a. From the mean between the two used proportions, the decrease in weight of the specimens turned out to be of 32.82%.
   b. Regarding bending strength, it decreased 78.79%, and compression decreased 85.85%.

c. Regarding water vapor barriers, specimens with addition of EPS_t proved a 63.57 % stronger and as water increased within the proportion, it reached 90.13 %, while that if the amount of EPS_t is increased, the resistance to water vapor decreases.

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