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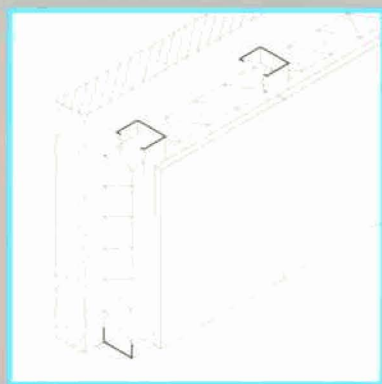
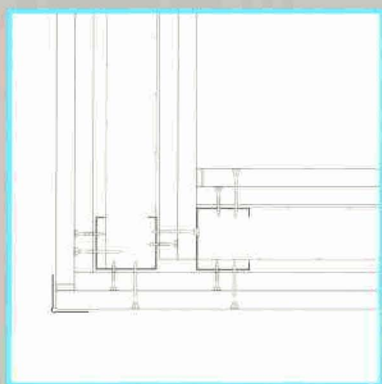
DETAIL Practice

Dry Construction

Principles
Details
Examples





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An Edition DETAIL book

ISBN: 978-3-7643-8808-9
Printed on acid-free paper made from cellulose bleached without the use of chlorine.

Typesetting & production:
Peter Gensmantel, Cornelia Kohn, Andrea Linke, Roswitha Siegler, Simone Soesters

Printed by:
Aumüller Druck, Regensburg

1st edition, 2008

This book is also available in a German language edition (ISBN 978-3-920034-21-8).

A CIP catalogue record for this book is available from the Library of Congress, Washington D.C., USA.

Bibliographic information published by
Die Deutsche Bibliothek
Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliographie; detailed bibliographic data is available on the internet at http://dnb.ddb.de.

Institut für internationale
Architektur-Dokumentation GmbH & Co. KG
Sonnenstraße 17, D-80331 München
Telefon: +49/89/38 16 20-0
Telefax: +49/89/39 86 70
www.detail.de

Distribution Partner:
Birkhäuser – Publishers for Architecture
PO Box 133, 4010 Basel, Switzerland
Tel.: +41 61 2050707
Fax: +41 61 2050792
e-mail: sales@birkhauser.ch
www.birkhauser.ch

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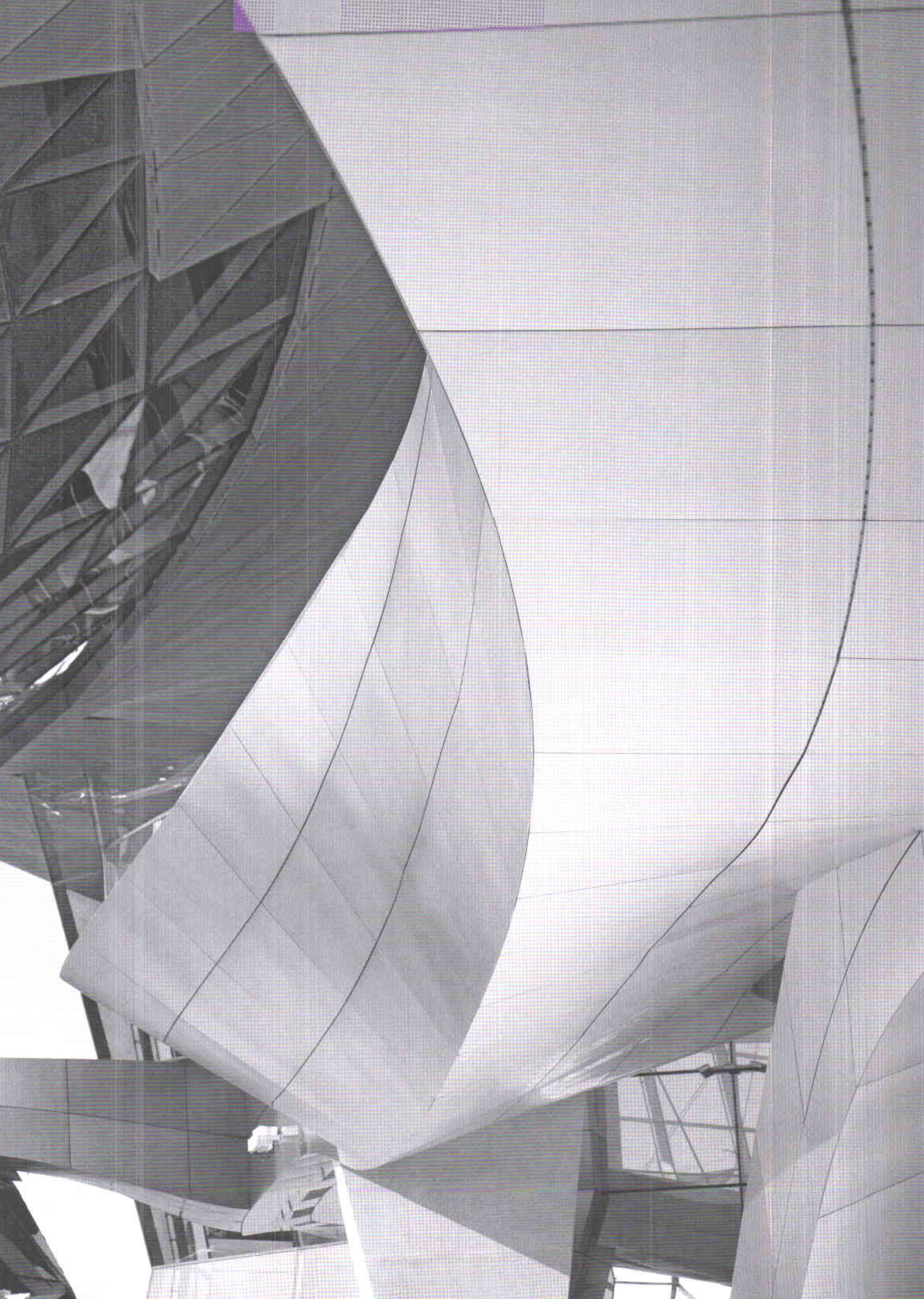
Contents



Introduction

"There is no inevitable rejection of dry and lightweight forms of construction. But there are huge gaps on the map of the constructional mind-set – among the public, but also among planners and architects. It is not the 'lightweight' that is causing the problem, but rather the lack of knowledge about the advantages of lightweight." Karsten Tichelmann

Aspects of dry construction

The growing use of dry construction systems in the building sector is due to the many advantages of these systems, primarily their short construction times, good economics, superiority in terms of building physics and, first and foremost, their sound insulation and fire protection benefits compared to masonry and concrete with the same overall component thickness. Other advantages include the ease of installation and the ease of integrating fitting-out elements such as lighting units, loudspeakers, detectors and sensors flush with the finished surfaces, plus the almost limitless design freedoms of these systems. At the same time, shapes and surface characteristics can be adapted to suit individual architectural requirements.

The approach to minimising the masses to be moved, whether in the automotive industry, in shipbuilding or in aircraft construction, has led to highly developed lightweight construction technologies which in the construction industry, however, have remained insignificant, apart from a few mobile or temporary structures. Here, comparing natural forms of construction with high-performance technical configurations reveals the following similarities: the economic use of materials to achieve a high functional efficiency, and the care taken in the execution. If we grasp the quality of these principles, we adopt an attitude that is particularly relevant in the current architectural debate.

Economic, ecological, technological and social developments are resulting in the need to plan lightness and flexibility into the fitting-out of our buildings if we want them to remain useful in the future. Such an approach means that the demand for good architectural design is linked with economic forms of construction and a reduction in the use of materials. This demand is also mainly aimed at the internal enclosing elements in buildings of all kinds, regardless of whether newly built or part of the existing building stock.
It is here that dry construction plays a significant role today – a role that will grow in the coming years.

Dry and lightweight forms of construction are set to make major contributions. Their development is only just beginning, but is already proceeding at such a pace that very soon we shall be able to solve hitherto untypical tasks with an increasing number of composite and material optimisations (e.g. adaptive systems, "self-healing" systems, fitting-out forms that regulate the interior climate and cut the amounts of dangerous substances). Dry construction systems are lightweight hollow assemblies that adhere to the technological principles of lightweight construction. In dry construction we therefore speak less of components and more of systems, less of building materials and more of semi-finished and finished products, less of building or building processes and more of assembly and erection.

The use of systems in dry and lightweight construction, optimised for their particular functions, is generally associated with a gain in floor space and greater flexibility of usage – the so-called soft skills of this form of construction which were underestimated in the past. For example, the vast majority of buildings erected between 1950 and 1995 will become unusable in the long-term and will become increasingly difficult to let or sell. The small-format interior layouts acceptable in those days are no longer popular with users and buyers. Changing the room sizes means an expensive intervention in the solid building fabric. However, as infill development increases, there is also a rise in the demands for individuality and freedom of expression in housing and office cultures. We are witnessing more and more individualisation in the way buildings are used; buzzwords like "living work" and "work@living" reflect this trend. Buildings must react to the demands associated with such changes.

Owing to their building physics properties and their different building physics behaviour, dry construction systems differ fundamentally from the technology and construction of heavyweight, solid building components. The lightweight properties of dry construction must be understood if the high efficiency of this form of construction is to be fully exploited. The result is a highly economic, high-quality building with superior technical and building physics characteristics. Other important criteria for evaluating a form of construction are, for example, the thickness of components, the weight, the construction times and the subsequent adaptation to suit changing requirements. These characteristics are not covered directly by any statutory requirements. Nevertheless, they are critical when choosing a form of construction because there is a direct relationship between these and the cost, efficiency and economic factors of a building – all criteria where dry construction in fitting-out is far superior to heavyweight forms of construction.

Dry construction systems are especially suitable when a combination of building physics requirements – such as sound insulation and fire protection, moisture control and thermal performance – have to be fulfilled simultaneously. Depending on the choice of system, the supporting construction, the insulating materials and the boarding materials, the building physics properties required can be achieved by a number of different types of construction. Owing to the assembly-type construction, changing or adding an element, e.g. another layer of boarding or a different board material, can achieve better building physics properties.

Furthermore, dry construction systems can be added to existing constructions in order to improve specific properties, an aspect that is especially important for infill development tasks (extra storeys, expansion, extensions) and alterations to existing buildings. The low weight of dry construction systems means that loadbearing components can be sized more economically than would be the case with a fitting-out scheme involving masonry and concrete. A clear reduction in mass and at the same time better sound and thermal insulation properties is readily achievable, primarily with wall systems (partitions, external walls, facades).

The design of lightweight fitting-out constructions also always implies the design of multifunctional constructions. Reducing the demands placed on a construction to just one factor is, in principle, no longer up to date. Even apparently purely functional components such as non-loadbearing partitions, suspended ceilings, access floor systems or fire-resistant casing systems have to satisfy additional tasks other than those suggested by their names: they are always constituents in a building concept and always interact with the interior spaces, engage in a dialogue – both architectural and technological – with all other enclosing constructions. They therefore represent not only the fulfilment of a (mono-functional) purpose, but also a change in the environment, an architectural symbol, a visual mass, light, colour and shadow. There is therefore no subdivision into mono- and multi-functional, into important and less important constructions, only the need to come to terms with new developments and their influence on our own actions. Defining dry construction as the combination of lightweight construction and building with dry materials is not new, but its influence on the housing market – with its apparently unrecognised advantages and opportunities – is.

The design principles of dry construction

Dry construction systems are based on three fundamental principles, which may be combined in different ways:

- Lightweight materials
- Lightweight structures
- Lightweight systems

Lightweight materials

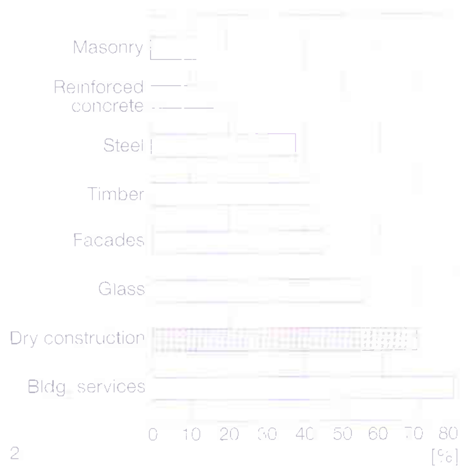
This is the use of building materials with a low density. In this form of construction, the density must be placed in relation to the stresses and strains to which the material is subjected. For the typical dry construction materials such as thin sheet metals, boards and wood-based products, this assessment concerns not only the maximum stresses and strains possible, but primarily the permanent loads plus creep effects and loss of stiffness. It is mainly through the combination of various materials that dry forms of construction are made considerably more efficient than a consideration of the individual materials alone leads us to suspect (see "Lightweight systems" below).

Lightweight structures
Moving on from the building materials level to the constructions and systems made up of those materials, we find that it is the lightweight structure that is faced with the task of resisting a given load with a minimum of self-weight. These are primarily mechanical loads that have to be transferred via suitable loading paths within a design framework that is usually restricted in some way. But this idea can be extended to cover all types of loads that act on dry construction systems (fire, sound, heat, radiation, electromagnetic fields, etc.). A lightweight structure therefore represents the solution to a minimisation, i.e. optimisation, problem for a series of given boundary conditions (loads, two- and three-dimensional functional requirements, lighting demands, etc.).

The choice of the load governing the system, structure and form is therefore of fundamental importance. In masonry and concrete constructions, it is primarily the loadbearing capacity and static loads due to the self-weight that represent the dominant effects determining the geometry. From our modern viewpoint, it is worthwhile relating the precision of a structural optimisation to the architectural and constructional aspects and their mutual dependency.

Lightweight systems
A lightweight system is one in which an element combines the loadbearing function with other functions, e.g. enclosing, sound insulation, fire protection, etc. Such a principle has always been assumed to apply to a whole series of building elements. Dry construction systems for walls and ceilings are just such multi-functional elements.
Developments in dry and lightweight construction have led to complex building elements in which, for functional and technical reasons, it is necessary to combine layers of materials which often exhibit fundamentally different mechanical and building physics parameters. In many cases the combination of disparate materials or components can also be exploited for structural purposes. The combination of thin-wall metal sections and board materials with optimised functions (e.g. gypsum- or wood-based board products) enables the creation of very simple, extensive, self-supporting, enclosing composite constructions.

Conscious design and planning means arranging the building materials – representing the optimum in many respects – at the appropriate places (a combination of lightweight materials and lightweight systems), which inevitably leads to dry construction systems.



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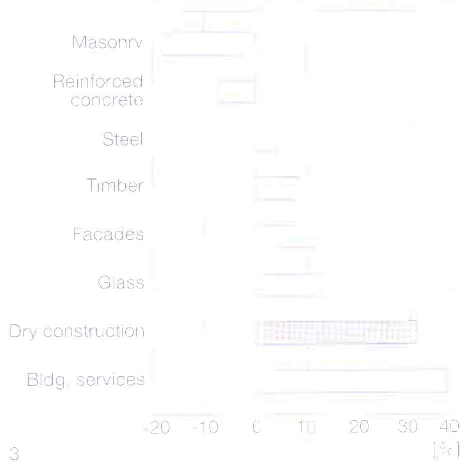

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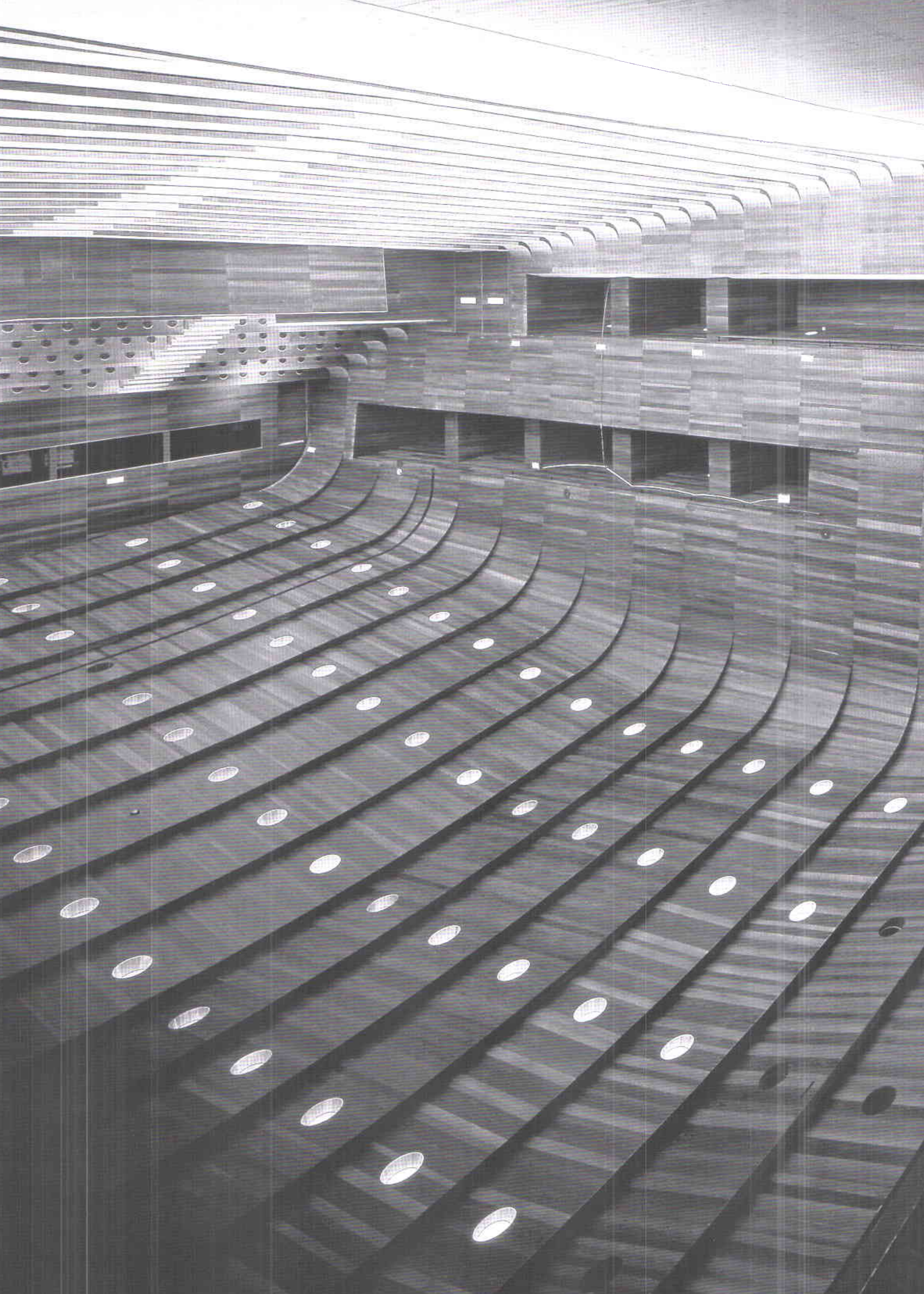
1 "Pinakothek der Moderne" art gallery, Munich, 2002, Stephan Braunfels
2 The innovation potential of various forms of construction, expressed as percentages related to the current status of development
Source: VHT Study "FutureTrend", 2007
3 Prognosis: market changes for various types and forms of construction up to 2015, expressed as percentages
Source: VHT Study "FutureTrend", 2007



Dry construction systems for walls, ceilings and floors are, in principle, all based on the same concept of supporting framework (framing), boarding and usually some form of insulation in the intervening voids. The other materials involved are mechanical fasteners, special connectors and jointing elements, jointing compounds and adhesives plus films, foils and accessories specific to certain products. The physical properties of dry construction result from the combined action of the individual components.

Materials for the supporting framework

For reasons of stability (limiting the deformations), elements made from thin sheets or boards require a stiffening supporting framework if they are not glued or stapled to a substrate over their entire area. The sizes, type and spacing of the framing members determine the interaction with the boarding. Their fixings determine the structural properties of the elements (e.g. deflection) and also have an influence on the sound insulation and fire protection characteristics of the elements.

Metal sections

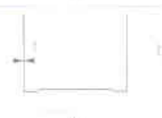
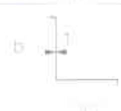
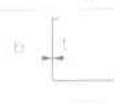
The majority of dry construction systems, e.g. independent wall linings, stud walls, ceilings and suspended ceilings, use metal sections for their supporting framework. Such metal sections provide the supporting construction to gypsum-based boards, wood-based board products and other board materials. Channel-type (U-shaped) sections are generally preferred.

Metal sections for ceilings or walls according to DIN 18182-1 (in future EN 14195) are made from corrosion-resistant (galvanised), cold-formed, thin-wall steel. DIN 18182-1 specifies a zinc coating of at least 100 g/m², which corresponds to a coating thickness of 7 µm each side and thus ensures adequate protection to any cut edges. A thicker coating is prescribed for sections used externally and those permanently exposed to the outside air (e.g. open sheds). Additional protective measures are required for applications in particularly corrosive conditions (e.g. chlorine gas in swimming pools), which usually means the addition of some form of organic coating.

The standard thicknesses of these thin-wall sections are 0.6 mm, 0.75 mm and 1.0 mm. Stiffer sections for the framing around wall openings, door frames, etc. are customarily 2 mm thick. Please refer to DIN 18182-1 for details of other section dimensions and metal thicknesses (see table T1).

- CW sections (= C studs for walls), i.e. inwardly lipped channels, are bent over at the ends of the flanges to improve their stiffness. Holes are usually punched in the web so that pipes and cables can be passed through. Openings are possible in the top and bottom thirds of wall studs ≤ 3 m high; the maximum side length of such an opening (length and width) may not exceed the

T1: Standard metal sections – dimensions and forms to DIN 18182-1

Type of section		Section abbreviation [nom. web depth × nom. metal thickness]	Web depth h [mm] (± 0.2 mm)	Flange width b [mm]
Example of a C stud with 2 different lip forms Designation CW		CW 50 × 0.6 (0.7, 1.0)	48.8	
		CW 75 × 0.6 (0.7, 1.0)	73.8	50 ± 3.0
		CW 100 × 0.6 (0.7, 1.0)	98.8	
Example of a wall channel Designation UW		UW 30 × 0.6	30	40 ± 0.2
		UW 50 × 0.6	50	40 ± 0.2
		UW 75 × 0.6	75	40 ± 0.2
		UW 100 × 0.6	100	40 ± 0.2
Example of a stiffening channel Designation UA		UA 50 × 2.0	48.8	40 ± 1.0
		UA 75 × 2.0	73.8	40 ± 1.0
		UA 100 × 2.0	98.8	40 ± 1.0
Example of a wall internal corner angle Designation LWi		LWi 60 × 0.6	60	60 ± 0.2
Example of a wall external corner angle Designation LWa		LWa 60 × 0.6	60	60 ± 0.2
Example of a suspended ceiling channel Designation CD		CD 48 × 0.6	48	27 ± 0.2
		CD 60 × 0.6	60	


1

1 Internal lining of plasterboard, Frieder Burda Collection, Baden-Baden, 2004, Richard Meier
2 Longitudinal edge forms of plasterboards to DIN 18180
a Tapered edge (AK)
For filled joints; the taper accommodates the jointing compound.
b Square edge (VK)
Primarily for dry lining without filled joints.
c Round edge (RK)
Primarily when used as a background for plaster.
d Half-round edge (HRK)
For filled joints without jointing tape.
e Half-round tapered edge (HRAK)
For filled joints with or without jointing tape.
3 Perforated acoustic ceiling of plasterboard, combined police and fire station, Berlin, 2004, Sauerbruch Hutton

depth of the web. The flanges of CW sections provide the bearing surfaces for the boarding materials and therefore must be at least 48 mm wide so that there is enough material to fix two boards butted together over the flange. The depth of the web of a CW section is such that it fits into a UW section.

- UW sections (= wall channels) have no inward-facing lips, which means they can accommodate CW sections.
- UA sections (= stiffening channels) have no inward-facing lips and are made from 2 mm thick material; they are used for strengthening the framing around wall openings, door frames, etc.
- CD sections (suspended ceiling channels) are bent or folded inwards at the ends of the flanges to accommodate the hangers of a ceiling system. The bearing width for the ceiling materials (web width) must be at least 48 mm. Curved suspended ceiling channels are used for curved ceiling forms.
- UD sections (ceiling channels) are not bent/folded inwards at the ends of the channels, which means they can accommodate CD sections.
- Wall internal corner angles LWi or wall external corner angles LWa are used to construct wall junctions.

Many other sections are produced for various applications in dry construction. For ceilings, there are various clamping rails, resilient channels, T and Z sections plus inlay, supporting, long-span, modular grid and perimeter sections.

Solid timber
The softwood for timber framing must comply with the requirements of DIN 4074-1 grade S10, cutting class S (square-edged). Upon installation, the timber should have a moisture content appropriate to the conditions; however, in order to avoid drying-related deformations, the moisture content should not exceed 20%. Common timber sections are listed in table T2.

According to DIN 68800-2, constructions without chemical wood preservatives are always to be preferred if the constructional measures taken mean they can be allocated to risk class 0. This is generally possible with wall, roof and floor constructions. On the other hand, in interiors where the type of use can lead to a timber moisture content > 20% (swimming pools, abattoirs, etc.), a chemical wood preservative should be used in compliance with DIN 68800.

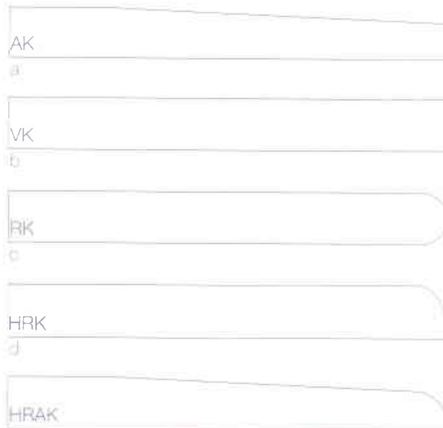
Materials for the boarding
The surfacing materials have a direct effect on the adjoining interior space (comfort, interior climate), but on the other hand are also directly influenced by the conditions in the room (moisture, mechanical loads, exposure to fire, etc.). Element properties important to biological living conditions, e.g. moisture balance, thermal mass, etc., are, first and foremost, properties of the element surfaces. From the structural viewpoint, the boarding materials brace the underlying supporting framework and reduce the buckling lengths of the individual members. Connecting the boarding to the framing with mechanical fasteners creates a composite construction with a loadbearing capacity much higher than the sum of the individual components.

Gypsum-bonded board materials
Gypsum-bonded board materials (plasterboard and gypsum fibreboard) are the most popular board types for fitting-out work. This is due to their favourable building physics and building biology characteristics, their adequate strength, their easy workability and the wide range of applications, which include sound insulation, fire protection, moisture control and thermal insulation, plus bracing the construction. Their physical properties can be influenced through the use of additives and fillers. In addition, the easy mouldability and short setting times of gypsum building materials represent good conditions for the industrial production of building boards.

Gypsum building boards contain chemically bound water. In the event of a fire, this water of crystallisation is released as water vapour, which means that the temperature on the rear of the board (not directly exposed to fire) remains in the region of 100°C, thus delaying the spread of the fire.

The porosity of gypsum building boards is the reason behind their good building biology characteristics. The high proportion of macropores enables a very fast absorption and release of water in both liquid and vapour form. It is this porosity that is responsible for the favourable moisture-regulating properties of gypsum building boards. Providing any given coating is diffusion-permeable, gypsum can absorb large quantities of moisture during periods of high humidity and release it again once the air is drier.

Gypsum-bonded boards are "warm-to-the-touch" building materials and therefore are comparable with timber. Thermal comfort is achieved because the low thermal effusivity of gypsum building boards



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means that less heat is lost from the human body. Despite identical surface temperatures, a wall clad with gypsum building boards feels warmer than, for example, a solid concrete wall or calcium silicate masonry, or one finished with traditional interior materials (e.g. lime plaster or lime-cement plaster).

Gypsum building boards undergo only very minor dimensional changes, which means they are ideal for relatively large areas without movement joints, i.e. with filled or adhesive joints only.

However, moisture has a detrimental effect on the mechanical properties and deformation behaviour of the boards, and the long-term presence of water destroys their microstructure. Such boards are therefore used mostly for interior fitting-out works. Temporary contact with moisture presents no problems, provided the gypsum elements have the opportunity to dry out again. However, they should not be exposed to interior atmospheres where moisture is constantly present (e.g. laundry, sauna, etc.). Do not install damp boards – let them dry out first.

Gypsum building boards are normally fixed with screws (without pre-drilling) or dabs of mortar, adhesive or plaster, but nails, staples and adhesives can also be used, depending on the substrate. Suitable paints, wallpaper, plaster, film and ceramic finishes may be applied to gypsum building boards in accordance with the manufacturer's instructions.

Gypsum plasterboard

In future, gypsum plasterboards will be covered by European standard EN 520. The old German standard DIN 18180 will, however, remain in force, which is why the customary abbreviations and designations of the boards are still used.

Board types and uses

Plasterboards are manufactured as a continuous sheet. The gypsum core and the longitudinal edges are covered with paper (so-called lining paper), whereas the gypsum core remains visible at the cut transverse edges. The nominal board thicknesses available are 9.5 mm, 12.5 mm, 15 mm, 18 mm, 20 mm and 25 mm. The board width is limited by the manufacturing process. The standard width is 1250 mm, but the 20 mm and 25 mm boards are 600 mm wide as standard (Fig. 2).

According to EN 520/DIN 18180, there are different board types for different applications, which are distinguished by the paper covering and additives in the gypsum core. The EN 520 board designations, which correspond approximately to those of DIN 18180, are given in brackets below. The board types are compared in table T4.

- Gypsum plasterboard GKB (type A) – the standard board for cladding walls, soffits and other components (light grey paper, blue printing).
- Plasterboard with reduced water absorption rate GKBI (type H) – for the same applications as the standard board but where a higher moisture content is expected, i.e. wet areas (kitchens, bathrooms, etc.) and as a background to ceramic tiles (green paper, blue printing).
- Gypsum plasterboard with controlled density and improved core adhesion at high temperatures GKF (type DF) – for the same applications as the standard board but where the fire resistance of the elements is relevant, too (light grey paper, red printing).
- Gypsum plasterboard with controlled density, improved core adhesion at high temperatures and reduced water absorption rate GKFI (type DFH) – for the same applications as the type DF board but where a higher moisture content is expected as well (green paper, red printing).
- Gypsum baseboard GKP (type P) – with a face intended to receive gypsum plaster, 9.5 mm thick.
- Gypsum plasterboard with enhanced strength/enhanced surface hardness (type R/type I) – for applications where better strength and surface hardness are required, mostly achieved through a higher board density, additives in the gypsum core and a paper with a higher tearing strength.
- Gypsum acoustic boards – depending on their composition, these boards correspond to one of the above board types, but owing to their design they have further properties (e.g. good resilience) that make them ideal for sound insulation tasks. The composition of these boards is specific to each manufacturer and they should be used according to the test certificates and instructions of the manufacturers.
- Gypsum perforated boards – these boards help to reduce the reverberation time in a room; owing to the different perforation patterns available, they are often employed as a form of soffit decoration, irrespective of their acoustic properties. If used in conjunction with fibrous insulating materials to enhance the sound insulation, the rear face of such boards must be factory-laminated with a fleece to retain the fibres. There are also boards available with an acoustic fleece bonded to the rear of the board.

T2: Common timber sections

Studs	60 × 60 mm	60 × 80 mm	60 × 120 mm
Battens	24 × 48 mm	30 × 50 mm	40 × 60 mm

T3: Bending radii for various types of plasterboard

Board type	Bend. rad. dry [mm]	Bend. rad. wet [mm]
Plasterboard for curves, 6.5 mm	≥ 1000	≥ 300
Plasterboard, 9.5 mm	≥ 2000	≥ 500
Plasterboard/gypsum fibreboard, 12.5 mm	≥ 2750	≥ 1000
Plasterboard for structural applications, 12.5 mm	≥ 3200	≥ 2000

T4: Comparison of plasterboard type designations according to DIN EN 520 and DIN 18180

DIN EN 520	DIN 18180	
Plasterboard type A	Gypsum plasterboard GKB	
Plasterboard type H (1/2/3) with reduced water absorption rate, type H2 in Germany	Impregnated gypsum plasterboard GKBI	Impregnated gypsum fire-resistant board GKFI
Plasterboard type F with improved core adhesion at high temperatures	Gypsum fire-resistant board GKF	
Plasterboard type D with controlled density		
Plasterboard type R with enhanced strength	Corresponds roughly with "structural boards" (Diamant, Duraline, LaDura), including types F, D (H)	
Plasterboard type I with enhanced surface hardness		
Baseboard for plaster type P	Gypsum plaster background GKP	
Gypsum building board type E (reduced water absorption rate, minimised water vapour permeability)	No corresponding national products	

- Gypsum composite boards to DIN 18184 – these consist of 9.5 or 12.5 mm plasterboard bonded to insulating boards (rigid polystyrene or polyurethane foam). They are used for thermal insulation applications. Although not covered by DIN 18184, composite boards with mineral-fibre insulating materials are also suitable for sound and thermal insulation applications.
- Faced plasterboard – plasterboard provided with a special finish for certain purposes, e.g. plastic film or aluminium foil as a vapour barrier, wood veneers or sheet metal for decorative purposes, lead foil for radiation screening.
- Flexible gypsum board – thin, pliable boards for cladding curved constructions.

Gypsum plasterboards are easy to work: simply score the paper to snap the board at that point; they are also easily sawn, chased and drilled. Cutting a notch as far as the outer paper enables the board to be bent and glued. Owing to the covering of paper, the edges are precise and hardwearing; time-consuming filling and costly protective corner beads are unnecessary. This "folding" technique is widely used these days to help rationalise work on site and also to form elaborate (stepped) geometries for architectural reasons.

The boards are flexible (see table T3). Once wetted, they can be placed in special jigs to create curved shapes with small radii. To create very small radii, the boards are slit through on one side as far as the paper and subsequently filled.

Properties of gypsum plasterboards
The mechanical properties are based on the composite action between the gypsum core and the paper covering. The paper acts as tension reinforcement and, firmly bonded to the gypsum core, lends the board the necessary stiffness. The strength and elasticity properties are greater in the direction of the fibres of the lining paper, i.e. in the longitudinal direction of the board, than in the transverse direction. This anisotropy should be taken into account in practical applications. The density depends on the type of board and lies between 680 and 1050 kg/m³.

Gypsum plasterboard types to EN 520 meet the requirements of Euroclass A2–s1, d0 to EN 13501-1. According to DIN 4102-4, they comply with the requirements of building materials class A2, incombustible; perforated boards are class B1, composite boards (with rigid foam) class B2.

Gypsum fibreboard
Gypsum fibreboards consist of a mixture of gypsum, cellulose fibres (which act as reinforcement) and possibly further additives.

Gypsum fibreboards are currently not covered by a standard. Different manufacturers use different production methods. The final products and the constructions made with them exhibit different properties (e.g. sound insulation, fire resistance, mechanical strength), which must be verified by way of tests and approvals.

As a rule, gypsum fibreboards exhibit higher strengths and surface hardness values than gypsum plasterboards, but because of the cellulose fibres, shrinkage and swelling caused by moisture fluctuations are greater than with plasterboard. Both types of board can be used for the same purposes, but they should not be mixed in practice. Gypsum fibreboards can also be used for bracing and stiffening functions in timber-frame construction. Types with a particularly high density (> 1350 kg/m³) are used primarily for floors.

The customary nominal thicknesses of the boards are 10 mm, 12.5 mm, 15 mm and 18 mm, and the standard width is 1250 mm. Small-format boards up to 40 mm thick can be produced for flooring systems.

Boards are normally cut to size by sawing, but a special tool is available that enables boards up to 15 mm thick to be scored and snapped like plasterboard. The boards can also be drilled and worked with abrasive tools. It is also possible to cut profiled edges (e.g. rebates) in homogeneous board types. Gypsum fibreboards can be fixed with screws, staples and nails. Joints between boards can be filled but also glued with appropriate adhesives.

The density lies between 950 and 1500 kg/m³, depending on intended application and manufacturer.
Gypsum fibreboards generally comply with the requirements of Euroclass A2–s1, d0 to EN 13501-1, or building materials class A2 to DIN 4102-4.

Wood-based board products
Wood-based board products are produced by pressing together pieces of wood of different sizes, e.g. planks, laths, veneers, chippings, fibres, with adhesives or mineral binders.
We distinguish between the following main products:
- Particleboard
- Wood fibreboard
- Plywood
- Oriented strand board (OSB)
- Medium density fibreboard (MDF)
- 3- and 5-ply core plywood (softwood)
- Wood cement particleboard

Wood-based board products are less common in dry construction. The reasons for this are their higher price compared to gypsum building boards, their more involved working with woodworking tools, their combustibility and their less favourable behaviour when exposed to moisture. Moisture fluctuations cause wood-based board products to shrink and swell to a greater extent than gypsum building boards. Added to this is the fact that saturated boards are at risk of rotting and mould growth. Demands for incombustible forms of construction or at least incombustible surfaces cannot be satisfied by wood-based board products. Their higher strengths are generally unnecessary for the typical non-loadbearing applications in interiors, apart from applications with higher mechanical loads, e.g. dry subfloors, or as strengthening to accommodate local loads.

Depending on the binder used, some wood-based board products release formaldehyde into the interior air. However, all modern boards lie well below the statutory limit (0.1 ml/m³ [ppm], class E1). The requirements placed on standard wood-based board products and the classes, applications and designations are all covered by EN 13986. The specifications and minimum properties of each type of board can be found in the respective product standards, the characteristic strength and stiffness values in DIN 1052:2004. In the case of non-standard boards, these properties can be found in the corresponding approval documents.

Fire-resistant boards
Such boards are primarily used to clad wall and suspended floor constructions, also beams, columns, cable ducts and ventilation ducts where high requirements are placed on the fire resistance.

Special fire-resistant boards based on gypsum are, like plasterboard, made from hemihydrate gypsum, water and additives. But instead of a covering of paper, a glass-fibre fabric is used which is bonded permanently to the gypsum core and may also have a surface finish of gypsum, depending on the particular product. These boards exhibit a high tensile bending strength and a good reaction to fire because their fire resistance is higher than conventional DF/DFH plasterboards, and they are somewhat lighter, too. Special fire-resistant boards comply with DIN 4102 building materials class A1. The use of such boards enables fire resistances up to class F180 A to be achieved. The boards are available in standard thicknesses of 15 mm, 20 mm, 25 mm and 30 mm. They can be sawn, drilled and chased, and are fixed with screws or staples (follow manufacturer's instructions).

Calcium silicate boards are basically calcium silicate to which further mineral fillers and various reinforcing fibres (e.g. cellulose) have been added. Boards with various densities, and hence different properties, are available. Different binders are used, e.g. cement for heavyweight boards, lime for lighter varieties. These boards are unaffected by moisture, are incombustible (class A1 to DIN 4102) and available in standard thicknesses from 10 to 50 mm. They can be sawn, drilled and chased, and are fixed with screws or staples. Prime them first before applying any adhesives, paints, coatings etc. (follow manufacturer's instructions).

Moisture-resistant boards
Special moisture-resistant boards are suitable as a background for ceramic tiles in damp areas and interiors with extreme water loads (e.g. swimming pools).

Cement-bonded building boards are produced from mineral components and hydraulic binders. The core consists of cement-bonded lightweight aggregates. This is reinforced both sides with a glass-fibre fabric and coated with cement mortar. Such boards are 12.5 mm thick, but the formats can vary depending on the manufacturer.
These boards are resistant to water, frost and the effects of the weather, and are also rotproof. They are suitable, without additional impregnation, as boarding to lightweight walls and independent wall linings, and as dry subfloors in wet rooms and interiors with extreme water loads (e.g. swimming pools). Certain products can also be used externally as facade cladding and as a substrate for render. These boards can be scored with an HSS knife and snapped. Accurate cutting is best carried out with a hand-held circular saw fitted with a carbide-tipped blade. They are fixed with special system screws. Cement-bonded building boards are incombustible (Euroclass A1 to EN 13501).

1 Internal lining using curved plywood, Nord LB Bank, Magdeburg 2003, Bolles & Wilson

1 Concert Hall, Copenhagen, 2005, Kant Architekten

Cement-faced polystyrene building boards consist of an extruded polystyrene rigid foam core reinforced both sides with a glass-fibre fabric and coated with a cement mortar that has been improved with a synthetic additive. Nominal thicknesses between 6 and 50 mm can be produced. These boards are water-resistant and rotproof, and remain dimensionally stable when subjected to thermal and moisture loads. They can be cut with a panel saw, jig-saw or knife, and can be glued or screwed to any substrate. Apart from wet areas, finish joints and corners with a suitable jointing tape, and in wet areas cover them with a sealing tape. Slitting on one side enables curves to be formed; fill the slits afterwards with tile adhesive. Thicker boards can be used as self-supporting elements, e.g. for vanity units, tank linings or shower cabins, without any additional loadbearing framework.

Mineral-fibre boards
Mineral-fibre boards are available in varieties complying with DIN 4102 building materials classes B1 or A2.
They are used primarily for the panels in suspended ceilings and as soffit claddings below loadbearing suspended floor or roof constructions.
The surfaces of the boards can be finished differently to suit appearance and room acoustics requirements – smooth or perforated, embossed or textured in different ways. In the standard version, the surface is given a white paint finish, but when a certain strength is required or hygiene requirements have to be satisfied, special coatings can be applied.
The edge profiles of mineral-fibre ceiling panels depend on the hanger system selected and the respective technical and architectural specifications. The standard thicknesses are 15 mm, 19 mm and 20 mm.
As mineral-fibre boards are supplied with ready-finished surfaces and edges, the work on site is limited to cutting the boards to size with a suitable knife.

Mineral-fibre boards have a low mechanical strength. Ceiling panels therefore require support on all sides and the span may not exceed 625 mm; larger formats require stiffening ribs on the back of the panels.
The elements should not be allowed to become wet, and they react poorly to high humidity levels; they then tend to sag and do not return to their original shape upon drying out. During installation, the room temperature should be > 15°C and the relative humidity < 70%. These boards are frequently used for acoustic purposes because the majority of types exhibit a high sound absorption coefficient of approx. 0.7 (= 70%).

Sheet metal
The main applications for sheet metal are in ceilings. Such panels consist of galvanised sheet steel or aluminium 0.4–1.25 mm thick, and can be supplied with various finishes. Anodised aluminium or stainless steel materials can be used without any surface coatings, other materials can be powder- or coil-coated. In addition, sheet metal can be used for demountable partitions or as a wall finish in clean rooms. It can serve as a decorative wall finish, and perforated panels in combination with sound-attenuating materials can improve the room acoustics.

The surfaces of the panels are finished smooth or with perforations for appearance or acoustics reasons. Various arrangements of perforations are available – from microperforations to 3 mm diameter holes, which means that the panels have a proportion of holes of 8–25% per unit area. The rear of the panel can be finished with a sound-absorbing acoustic fleece or a plastic sheet to retain loose fill.
The panels can be supplied as square trays, rectangular plates (300 x 300 mm to 625 x 2500 mm) and as metal elements.

Metal ceiling panels are supplied with ready-finished surfaces and edges so that work on site is limited to cutting the panels to suit around obstacles. What all panels have in common is that their edges are bent up or over in order to improve the stability of the thin sheet metal. Use hacksaws or snips to cut the panels where necessary. If the bent-up edges are cut through, the panel loses its stability in this area and will require some form of support (e.g. perimeter angle).

Used internally, metal panels never corrode, even in wet areas and swimming pools. They can be washed without causing any damage and are not hygroscopic.

Metallic materials meet the requirements of DIN 4102 class A (incombustible). The building materials class of the final product, however, depends on its finish (see table T5).

Insulating materials

Insulating materials are used in dry construction mainly for sound insulation and fire protection purposes. Many forms of construction achieve their intended building physics properties only in conjunction with a suitable insulating material. The thermal insulation properties of the insulating materials are relevant in the case of internal insulation to external walls and when converting roof spaces into habitable rooms. As insulating materials are almost always concealed within building elements, provided the design has been properly implemented, their building biology effects are less important and have only a minor effect on the interior climate and comfort. But what is important are their physical properties.

Insulating materials are covered by the standards DIN EN 13162 to DIN EN 13171, or have been awarded national technical approvals (see also table T6, p. 18). The standards contain classifications for the properties of the insulating materials arranged in product groups (e.g. tolerance classes, various mechanical properties, dynamic stiffness, water absorption, sound impedance, etc.). With the help of

T5: Board materials in dry construction, overview of properties and applications

Board material	Product standard	Properties				Applications						
		Density	Fire classification[4]	λ [W/mK]	μ joints	No	FP	SI	RA areas	Wet	DSF	Structural
Gypsum-bonded boards												
Gypsum plaster boards												
Gypsum plasterboard GKB	DIN 18800 EN 520	680–750	A2 s1, d0 (A2)	25	4/10	++	o	+	-	o	o	o
Gypsum fire-resistant board GKF		800–950				++	+	+	-	o	o	o
Impregnated gypsum plasterbd. GKBI		680–800				++	o	+	--	+	o	o
Impregnated gypsum fire-resistant board GKFI		800–950				+-	+	-	-	+	o	o
Gypsum sound insulation board		800–900				-+	+	+-	--	o	o	o
Gypsum struct. bd./hard-surface bd.		800–1050				++	+	++	--	o	+	-
Gypsum perforated board	EN 14090	–	(B1)	–	–	++	-	-	+	-	--	-
Gypsum fibre boards												
Gypsum fibreboard	approval	950–1250	A2 s1, d0 (A2)	0.2–0.38[3]	13–19	++	+	++	--	o	-	++
Highly compressed gypsum fibreboard	approval	1350–1500	A2 s1, d0 (A2)	0.44	30/50	+	+	+-	--	o	++	++
Gypsum special fire-resistant board	–	800–900	(A1)	–	–	++	++	+	--	o	o	-
Mineral-bonded boards												
Calcium silicate board	–	450–900	(A1)	0.01–0.3	3–20	+	++	-	--	+	o	-
Cement-bonded mineral board	–	1000–1150	A1	0.17–0.4	19–56[3]	+	o	o	--	++	++	-
Cement-faced polystyrene building board	–	30	B-s1, do, (B1)	0.037	100	o	--	-	--	+-	-	--
Wood-based board products												
Synthetic resin bonded wood-based board	EN 13986	600–700	D-s2, d0, (B2)	0.13	50/100[1] 200/300[2]	--	-	o	+-	--	++	++
Mineral-bonded wood-based board		1000–1200	B-s1, d0 (B1, A2)	0.23	30/50	--	o	o	--	-	++	++
Mineral-fibre board	–	300–500	(B1, A2)	0.05–0.07	5	--	-	-	++	+-	--	--
Metal trays	–	–	(A2, A1)	–	–	--	-	-	-	+	--	--
Glass granulate board	–	320–350	(B1, A2)	0.095	–	++	-	-	++	++	--	--

Assessment:
- ++ ideal, specific application
- \+ very suitable, typical application
- o suitable, untypical application
- \- generally unsuitable
- -- absolutely unsuitable

Applications:
- FP: fire protection
- SI: sound insulation
- RA: room acoustics
- DSF: dry subfloor

Footnotes:
[1] Particleboard
[2] OSB
[3] Depends on product, manufacturer, density
[4] Euroclasses to DIN EN 13501-1 (DIN 4102-2 national classes in brackets)

the standard, the respective properties (classes) can be ascertained from the designation code of a product.
In addition to the standard products, national technical approvals have been granted for a whole series of non-standard insulating materials, made from

- cellulose fibres,
- cotton,
- sheep's wool,
- flax.

In Germany, DIN V 4108-10 covers applications for thermal insulating materials, irrespective of the particular products.

Insulating materials for fire protection
The primary characteristics of insulating materials that are to be used for fire protection purposes are building materials class, melting point, specific heat capacity, reaction to fire (flaming droplets, smoke development), specific surface,

T6: Insulating materials for dry construction, overview of properties and applications

Insulating material	Product standard	Properties			Applications				
		Fire classification[2]	λ [W/m²K]	μ	FP	SI	RA	ISI	TI
Fibrous insulating materials									
Organic									
Wood fibres (WF)	EN 13171 (DIN 68755)	B2	0.04–0.055	5/10	o	++	+	++	+
Coconut fibres	(DIN 18165)	B2	0.04–0.055	1	o	++	+	++	+
Cellulose fibres	approval	B2	0.04–0.045	1/2	o	++	+	o	+
Cotton, sheep's wool, flax, hemp	approval	B2	0.04	1/2	o	++	+	o	+
Polyester fibres	approval	B2			-	+	+	o	
Mineral									
Mineral wool (MW) – glass wool	EN 13162 (DIN 18165)	A1, A2, B1	0.035–0.04	1	+	++	++	++	+
Mineral wool (MW) – rock wool					++	++	++	++	+
Foam materials									
Organic									
Polystyrene, expanded (EPS)	EN 13163 (DIN 18164)	B1	0.035–0.04	20/50–40/100	--	--	–	+[1]	++
Polystyrene foam, extruded (XPS)	EN 13164 (DIN 18164)	B1	0.03–0.04	80/250	--	--	--	--	++
Polyurethane rigid foam (PUR)	EN 13165 (DIN 18164)	B1, B2	0.025–0.035	30/100	--	--	--	--	++
Phenolic foam (PF)	EN 13166 (DIN 18164)	B1, B2	0.03–0.045		--	--	–	–	+
Melamine foam (MF)	–	B2	0.034		--	o	++	–	+
Mineral									
Cellular glass (CG)	EN 13167 (DIN 18174)	A1	0.045–0.06		+	-	--	--	+
Miscellaneous									
Organic									
Wood-wool board (WW)	EN 13168 (DIN 1101, DIN 1102)	B1, B2	0.09–0.15	2/5	+	-	+	--	o
Wood-wool composite board (WW-C)			0.035–0.045	1, 20/50	o	-	+	--	+
Insulation cork board (ICB)	EN 13170 (DIN 18161)	B2	0.045–0.055	5/10	o	--	--	o	o
Loose fill									
Mineral									
Expanded perlite (EPB)	EN 13169	A1	0.05–0.06		++	o	--	+	-
Perlite, vermiculite, expanded clay/shale	–	A1	0.05–0.09		++	o	--	+	-

Assessment:
++ ideal, specific application
+ very suitable, typical application
o suitable, untypical application
- generally unsuitable
-- absolutely unsuitable

Applications:
FP: fire protection
SI: sound insulation/insulation to voids
RA: room acoustics/sound attenuation
ISI: impact sound insulation
TI: thermal insulation

Footnotes:
[1] Plasticised EPS
[2] DIN 4102-2 national classes

stability and their bond with other materials. According to these criteria, unprotected rigid foams are unsuitable for fire protection. But mineral and even certain organic fibre insulating materials have proved suitable.

Insulating materials complying with the requirements of DIN 4102 class A consist of inorganic materials, e.g. silicate glass, igneous rocks or clay. Class B insulating materials are products made from organic foams or organic fibres. The behaviour of the insulating materials in fire can be improved – e.g. achieving class B2 (flammable) instead of B3 (highly flammable) – by adding flame retardants (e.g. boron salts).
For constructions where it is necessary to satisfy the fire resistance according to DIN 4102-4, class A mineral wool insulating materials with a melting point ≥ 1000°C must be specified.

Insulating materials for sound insulation
Open-cell insulating materials (e.g. fibrous insulating materials) are suitable for sound insulation tasks such as sound attenuation or reducing the resonance in voids. Such materials have a high sound absorption coefficient α_s and a sound impedance per unit length r of at least 5 kPa·s/m². These requirements are satisfied by all customary fibrous insulating materials.

Materials for impact sound insulation function by absorbing the impact energy transferred into the layer of insulation from the trafficable floor finishes (screed, floor covering, etc.) and not passing it on to the supporting construction. The measure of this resilience of insulating materials is the dynamic stiffness s' [MN/m³]. The lower this value, the "softer" is the insulating material.

Thermal insulation materials
Products are classed as thermal insulation materials when their thermal conductivity λ in the dry state at an average temperature of 10°C is less than 0.1 W/mK.

Loose fill
Loose fill is understood to be an unbonded granulate material with particle sizes normally between 0 and 7 mm. Different raw materials are used to produce the various products. The most important loose fill materials are those based on

- perlite,
- vermiculite,
- expanded clay,
- expanded shale,
- lightweight aerated concrete granulate,
- cork,
- organic raw materials.

Loose fill can be used to compensate for uneven floors or an undesirable slope in the floor. They have a thermal insulation effect and improve the impact sound insulation of a suspended floor construction. Loose fills with finer particle sizes are ideal for levelling purposes, especially in conjunction with dry subfloor elements (impact sound insulation); loose fills with coarser particles are best suited to filling voids and at the same time providing thermal insulation.

When using a loose fill in conjunction with a dry subfloor, only use materials that are suitable for the respective flooring system (follow manufacturer's instructions). It is the elastic properties (elastic bedding) and the low subsequent compaction that are primarily important here.
The raw materials of mineral loose fills make them inherently resistant to rodents and rotting. Products made from organic materials require additional measures (see table T6).

Sundries

Fixings
Board materials and their supporting frameworks plus elements in the supporting construction must be joined together by means of suitable fasteners.

Self-drilling/tapping screws
Attach board materials to thin-wall metal sections with self-drilling/tapping screws. DIN 18182-2 applies here to gypsum plasterboards. Use the self-drilling/tapping screws forming part of the system as supplied by the manufacturer for fixing other board materials (e.g. gypsum fibreboards, cement-bonded boards).
The screws are coordinated with the metal thickness of the sections. Accordingly, we distinguish between screw types TN (sharp point, sheet metal thicknesses ≤ 0.7 mm) and TB (drill point, sheet metal thicknesses ≥ 0.7 mm, e.g. for UA sections).
When connecting timber members (e.g. main batten and cross-batten), fixing (anchoring) battens directly to joists and connecting hangers to timber members, use screw types TN and TB as well, provided the national technical approval for each product also covers this type of application. Otherwise, use screws to DIN 1052 (wood screws).

Nails and staples
Nails to DIN 18182-4 and staples to DIN 18182-3 are necessary for fixing plasterboard to timber framing. In the case of gypsum fibreboards, the second layer of boarding can be attached to the first layer with suitable staples.
When fixing plasterboard to the underside of rafters or soffits, use only resin-coated staples with a national technical approval – if staples are considered at all (see table T7).

Anchors
Anchors are used to fix components to a loadbearing substrate. In addition to anchors, powder-actuated fasteners and holding-down bolts are also used, albeit less often these days.
We essentially distinguish between three types of anchors:

- Expanding anchors made from steel or synthetic materials
- Bonded anchors exploiting the composite action with cement or synthetic resin
- Undercut anchors with mechanical interlocking action

Selecting the right anchor essentially depends on the type and magnitude of the load (tension, shear or a combination of the two – inclined tension) and the substrate. Fixings that are anchored in the tension zone of reinforced concrete elements (e.g. the underside of suspended floor slabs) must be expressly approved for this type of application. When choosing an anchor, besides the permissible loads, also adhere to the manufacturer's recommendations regarding edge distances, anchor spacings and minimum component thicknesses.

Fixings for loads
Choosing suitable fixings for walls depends on the eccentricity e, the weight of the load P, the cone diameter of the anchorage points in the wall (spacing of reactions), the thickness, the material and the position of the boarding. For the permissible loads per fastener and, possibly, any installation recommendations to be followed, please refer to the manufacturer's literature. Irrespective of the permissible anchor load, the permissible out-of-plane loads per metre of wall length according to DIN 18183 or DIN 4103-1 must be taken into account.

Attaching light loads (e.g. pictures) with a minimal eccentricity (≤ 50 mm) to the boarding of stud walls can be carried out with standard picture hooks, but also conventional fasteners such as screws, hooks or nails. Light loads can also be carried on the boarding by suitable expansion anchors.

When heavier out-of-plane loads have to be carried (wall cupboards, bookshelves, etc.), as defined in DIN 4103-1 or DIN 18183, special fasteners made from plastic or metal for fixing to hollow surfaces (for carrying axial and transverse loads) or fasteners approved for such use by their manufacturers are required – except when the boarding has a backing of sheet metal or timber, or special cross-rails are used to carry loads. Plastic or metal spring or gravity toggles (for axial tension only) are also used for transferring loads to ceiling or soffit materials. Where the load exceeds 0.06 kN per board span (DIN 18181), the screws or anchors must be fixed into the supporting construction.

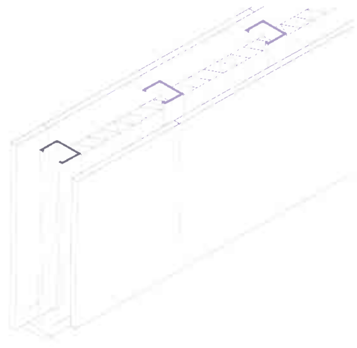
Jointing compounds, joint adhesives and dabs of plaster
Jointing compounds are generally used to fill the butt joints between boards, but they are also suitable for providing boards with a smooth or textured surface finish. Depending on the material composition or formulation chosen, jointing compounds containing gypsum can be used for conventional filling with joint tapes (reinforcing tapes), or without, provided they are approved for such use by the manufacturer.
Jointing compounds without gypsum are generally used as filling or finishing compounds, or purely as surface finish materials. They are generally characterised by their excellent workability with abrasive products.

One-component, moisture-curing polyurethane adhesives are especially popular for gluing the joints between plasterboards on walls and soffits. The transverse tensile strength of the adhesive joint – parallel to the plane of the board – matches the transverse tensile strength of the plasterboards themselves.
Dabs of plaster to DIN 1168 are used to attach gypsum building boards to walls as a dry lining, to attach board-type insulating materials (rigid foam or mineral wool products) and composite boards to masonry or concrete. The additives (e.g. retarder) mixed into the gypsum control the setting process so it is possible to align boards already in position. Other additives increase the water retention capacity and improve the adhesion.
Apply dabs of plaster to the back of each board by hand in approx. 20 mm thick mounds, or directly to the wall by machine in strips. Unevenness in the substrate of about ±10 mm can be compensated for.

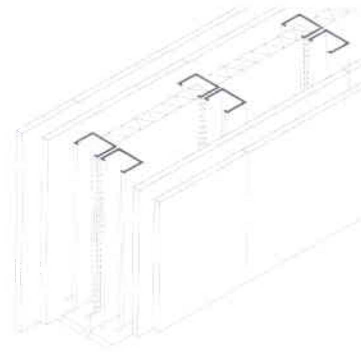
T7: Typical fasteners for dry construction

Type of fastener	Illustration	Applications: Plasterbd. to metal [mm] ≤ 0.7	≤ 2.0	Plasterbd. to timber	Plasterbd. to plasterbd.	Fibreboard to metal [mm] ≤ 0.9	≤ 2.0	Fibreboard to timber	Fibreboard to fibreboard	Timber to timber	Metal to metal	Metal to timber
Self-tapping drilling screw with sharp point		•		•						•		•
Self-tapping drilling screw with sharp point and ribbed countersunk head						•		•	•			
Self-tapping drilling screw with drill point (also with ribbed countersunk head)		•					•					
Self-tapping drilling screw with drill point and pan head											•	
Plain wire nail inserted mechanically, for walls only				•				•		•		
Grooved nail inserted mechanically, prescribed for ceilings				•				•		•		
Hollow head nail, galvanised								•				
Staple				•				•	•			
Aluminium pop rivet 3 x 4.5 mm											•	
Clamping section		•	•	•		•	•	•	•			
Adhesive		•	•	•	•	•	•	•	•			
Crimping tool											•	
Coarse thread (drywall) screw					•				•			

Wall systems



1



2

Wall systems in dry construction

Wall systems in dry construction are stud walls and independent wall linings, i.e. a supporting framework of thin-wall steel sections or timber members plus a boarding material. Depending on the specification and the form of construction, the voids between the members of the supporting framework can be filled with insulating materials for fire protection, sound insulation or thermal insulation purposes. The partitions and independent wall linings considered below have no loadbearing or bracing functions in the building.

Stud walls and independent wall linings fulfil space-dividing and building physics requirements, allow the integration of building services and built-in items, improve the building physics and appearance of existing walls and function as architectural features. Numerous specific wall systems have been developed for certain situations:

- Walls designed to satisfy high sound insulation and fire protection requirements (e.g. party walls, outer walls, fire walls, stair shaft walls, etc.)
- Minimum-footprint, slender partitions with adequate sound insulation and fire resistance values (gain in floor space)
- Walls housing services and inner linings to conceal services
- Demountable partitions, partition systems
- Wall systems with integral heating/ cooling
- Walls with room acoustics functions
- Walls for interiors with high moisture loads
- Highly insulated, non-loadbearing external wall systems
- Wall systems with enhanced structural requirements (e.g. regarding height of wall, surface strength, out-of-plane loads, loadbearing and bracing wall systems)
- Special systems such as radiation screens, bulletproof walls, wall systems for clean rooms, field-free rooms, etc.
- Walls as architectural elements (curves and other shapes, integral lighting, etc.)

All the stud wall systems permit half-height walls, junctions with other walls and corners. Doors and glazing can be integrated to suit users' requirements. The constructional details at junctions plus any additional bracing measures required are, in principle, the same for all systems.

Lightweight prefabricated walls represent the most popular type of partition system. They consist of single- or double-stud walls built using standardised elements. Metal sections or timber members form the supporting framework. The perimeter studs and the top and bottom framing members are affixed to the loadbearing parts of the construction (wall, suspended floor, ground floor); the details include a seal (tape, compound) to compensate for any unevenness. Metal studs are not fixed to the top and bottom framing members (channel sections). The spacing of the individual fixings at floor and soffit may not exceed 1000 mm, and in the case of the lateral fixings to walls the maximum pitch is 700 mm. The details at the junctions depend on the deformations expected in the adjoining components after installing the light-

1 Single-stud wall with metal framing and one layer of boarding each side
2 Double-stud wall with metal framing, two layers of boarding each side and each pair of studs separated by a strip of resilient material
3 Curving walls with shelf space, Hotel Ku' Damm 101, Berlin, 2003, Mänz & Krauss
4 Double-stud wall with timber framing and two layers of boarding each side; the studs can be aligned without touching or staggered to ease the electrical installation, as shown here
5 Plumbing wall: pairs of studs connected with small plates
6 Independent wall lining with metal framing

3

weight wall. In the case of larger deformations, sliding connections are essential (see p. 36). DIN 18183 outlines the principles of metal stud wall constructions.

The boarding – consisting of thin board materials, generally gypsum products (plasterboard and gypsum fibreboard) – is attached with fasteners that can transfer loads to the supporting framework. The normal grid is 625 mm, and the board formats are coordinated with this dimension. Different grid dimensions for the supporting framework are possible. Gypsum board materials can be used to create curved wall surfaces in two and three dimensions. Table T1 lists the main technical features of stud wall systems.

Single-stud walls
Single-stud (or single-frame) walls consist of a supporting framework in one plane that is clad on both sides with one or more layers of boarding (Fig. 1).

Double-stud walls
Double-stud (or twin-frame) walls consist of two parallel rows of studs, each of which is clad on one side with one or more layers of boarding (Figs. 2 and 4). The rows of studs can be aligned (Fig. 2), in which case they should be separated by an insulating tape or a narrow air space, or staggered (Fig. 4). In tall wall constructions up to 13 m high, the stud members should be joined together (Fig. 5) to improve the overall stability of the wall. As a double-stud wall contains two separate supporting frameworks, the two sides of the wall are decoupled from each other and this results in better sound insulation properties when compared to a similar single-stud wall. For reasons of sound insulation and to improve the overall stability, double-stud walls are generally provided with two layers of boarding on each side.

A plumbing wall is a special form of double-stud wall. Such walls are built to integrate building services and are primarily used in conjunction with sanitary facilities. The two rows of studs are erected with sufficient space in between to allow the routing of pipes, also cables, both horizontally and vertically (Fig. 5).

Independent wall linings and shaft walls
Independent wall linings and shaft wall systems consist of a supporting (single-stud) framework erected in front of another component (e.g. an existing structural wall) and clad on one side with board material (Fig. 6). The use of such wall systems enables the building physics properties of the existing wall to be improved with respect to fire protection or thermal insulation. Dry lining in the form of plasterboard or composite boards attached to the wall directly with dabs of mortar, plaster or adhesive provide an architectural cladding to the component behind. The ensuing void can be used for pipes and cables if required.

T1: Properties of stud wall systems

Wall thickness	75–150 mm
Wall grid	1250 mm, seamless
Wall height	up to 13 m
Wall length	unlimited
Weight	approx. 35–68 kg/m²
Sound insulation R'w to DIN 52210	38–67 dB (for walls > 140 mm thick)
Fire protection class	D: F0–F180; CH: REI 90-M

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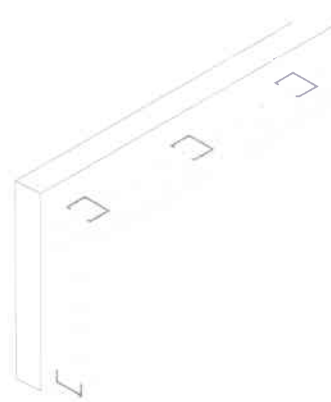

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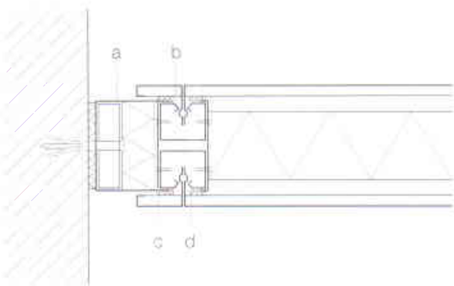

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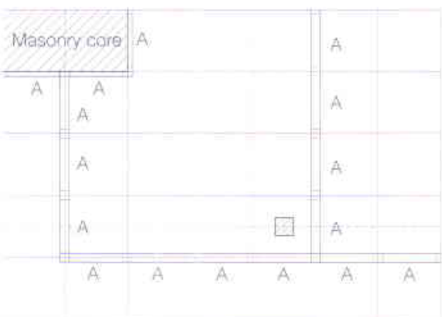

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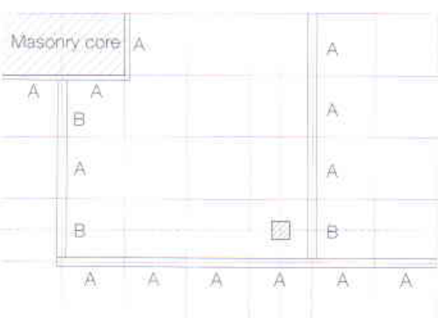

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Demountable partitions
Demountable partitions in dry construction are industrially prefabricated wall systems that, owing to their form of construction using standard elements, can be erected, taken down and re-erected with minimum effort. Besides the wall elements themselves with various modular sizes, the design options include numerous junction sections, capping strips, door frames, door leaves, glazing and finishes. A wide range of painted or coated surfaces and materials is on offer. The use of prefabricated elements inevitably results in joints, which must be evaluated in terms of their building physics, erection and architectural repercussions.

For those systems that adhere to the "classical" modular grid format, junctions are possible at every node. Such systems consist of a succession of identical wall and node elements. Flexible systems based on an axial or linear grid have fewer joints, but are made up of wall and make-up elements in different widths. The make-up elements enable the modules of the wall elements to be matched to the grid of the main structure (Figs. 2 and 3). Compared with conventional prefabricated walls, demountable partitions are less flexible, and their modules, designs and forms less adaptable. Demountable partitions have lower building physics values (e.g. sound reduction index) than comparable stud wall systems. They are available in the form of semi-prefabricated and fully prefabricated walls.

Semi-prefabricated partitions
These partitions consist of a supporting framework, wall, floor and ceiling channels, ready-finished boarding materials and, if necessary, insulation. They are assembled on site to form a complete partition (Fig. 1). The advantages of this form of construction are the low transport weights of the individual prefabricated components and the easier incorporation of building services. Depending on the design, sound reduction indexes of 42–54 dB and fire resistance classes F 30 (CH: EI 30) to F 120 (CH: EI 120) can be achieved.

Fully prefabricated partitions
These partitions are made up of prefabricated wall elements consisting of a supporting framework and boarding, possibly insulation as well, which are delivered to site in units ready for erection. Their easy, rapid installation means that changing the positions of these partitions at a later date is also correspondingly straightforward. The incorporation of pipes and cables is limited to the floor and ceiling channels, the junctions or zones specially designed and reserved for services. Fully prefabricated partitions are usually supplied with surfaces of sheet steel or wood-based board products and optional finishes– melamine-faced particleboard, plasterboard with a sheet steel or machine-applied vinyl foil facing, decorative wood finishes, real wood veneers and solid synthetic sheets.

1 Semi-prefabricated partition with sheet steel trays (plasterboard inlay) clipped directly to the supporting framework, partition–wall junction
a Wall channel
b Special clamping stud
c Wall junction strip
d Element boarding
2 Uniform wall elements and junction options in both horizontal directions due to the node points matched to the modular grid
3 Different wall and make-up elements for subdivisions according to a linear grid
4 Glass modular walls, Stadttor Project, Düsseldorf, 1997, Petzinka Pink Architekten
5 Corridor walls with high-level windows, dental practice, Ku 64, Berlin, 2006, Graft Architekten
6, 7 Glass partition systems
a Ceiling channel
b Sound insulation, 60 mm rock wool
c Frame section
d Gasket
e Glazing
f Window sill
g Floor channel

5

The floor and ceiling channels, which are fitted directly to the partition elements, are adjustable to allow for different room heights. Connections between the partition elements are in the form of special connectors, rails or clips. Depending on the design, the sound reduction indexes lie between 39 and 49 dB, and standard metal constructions achieve a maximum fire resistance of F 30. Table T2 lists the main technical features of demountable partition systems.

Glass partition systems

Glass partition systems are designed either as demountable systems with a finished surface in the semi-prefabricated form of construction or as aluminium fully prefabricated elements with double glazing flush with the wall, or as demountable glass panes. The framing consists of steel studs with horizontal rails (noggings) to ensure the necessary stability. Wall and ceiling channels consist of steel U sections with concealed resilient sealing tapes. The glass panels are factory-glazed so that soiling in the cavity between the panes can be ruled out. A louvre blind can be incorporated in the cavity upon request. The glass used is generally 2–4 mm thick and colourless, but 7 mm panes can be included to satisfy a higher sound insulation specification (Figs. 6 and 7). Table T3 lists the main technical features of glass partition systems.

Structural and constructional requirements for non-loadbearing lightweight partitions

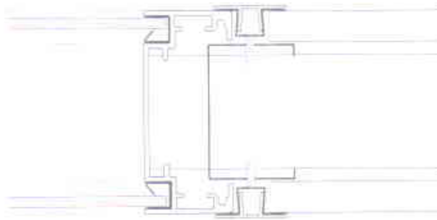
DIN 4103-1 (Internal non-loadbearing partitions; requirements, testing) specifies the requirements to be satisfied by non-loadbearing internal partitions and lightweight internal partitions.

According to the standard, non-loadbearing internal partitions are defined as components that are not required to contribute to the stability of the building, and their own stability is only guaranteed by connecting them to the loadbearing parts of the construction. Furthermore, internal partitions also include demountable room partitions, but not room dividers which can be moved horizontally or vertically, e.g. folding and sliding partitions. DIN 4103-1 distinguishes between two installation areas with respect to the requirements placed on partitions:

- Installation area 1: interior spaces with low accumulations of people (housing, hotels, offices, medical facilities, including the corridors thereof).
- Installation area 2: interior spaces with high accumulations of people (lecture theatres, places of assembly, schools, exhibition facilities, retail premises) and partitions between interior spaces with a difference in height ≥ 1 m between the floors.

Apart from their own weight, stud walls must be able to accommodate any loads applied to their surfaces and transfer these to the adjoining components (walls, floors). Those loads include:

- Wind loads
- Out-of-plane loads (shelves, wall cupboards, wall-mounted WCs, vanity units, etc.)
- Impact loads (accumulations of people, usage-related actions, etc.)



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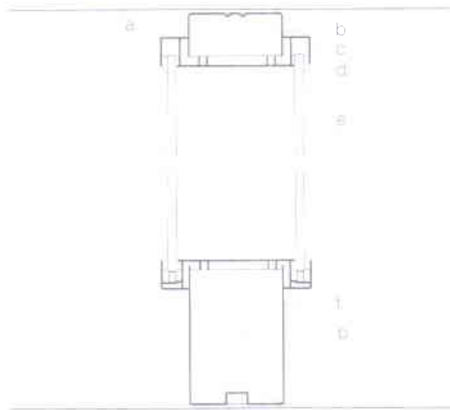

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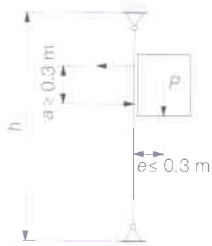
T2: Properties of demountable partition systems

Wall thickness	80–160 mm
Wall grid	400–1250 mm
Wall height	up to 6 m
Wall length	unlimited
Weight	approx. 40–70 kg/m²
Sound insulation R' to DIN 52210	up to 46 dB
Fire protection class	D: F0–F30

T3: Properties of glass partition systems

Wall thickness	80–110 mm
Wall grid	1250 mm
Wall height	up to 8.5 m
Wall length	unlimited
Weight	approx. 30–60 kg/m²
Sound insulation R' to DIN 52210	43–53 dB (for walls > 100 mm thick)
Fire protection class	D: F0–F30; CH: G30

1 Geometry of out-of-plane loads to DIN 18183
P out-of-plane load
e eccentricity (e ≤ 0.30 m from wall surface)
a lever arm of resultant horizontal forces for analysing the connections (a ≥ 0.30 m)
2 Permissible out-of-plane load P per wall side in relation to distance of load application point e (eccentricity) from wall surface (to DIN 18183)
3 Stud wall system with glass elements



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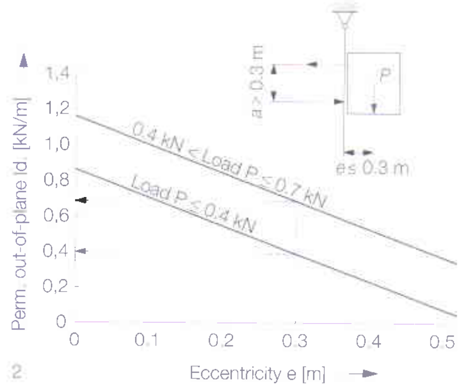

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As non-loadbearing prefabricated walls may not carry any loads from suspended floors, the maximum height of a wall is essentially dependent on any horizontal loads. Wall heights of up to 9 m are possible.

Wind loads
Non-loadbearing internal partitions that, due to larger openings (e.g. industrial doors), are exposed to wind loads will have to be designed to DIN 1055-4, applying half the usual wind pressure load.

Out-of-plane loads
With the exception of transparent walls and wall sections (e.g. glass partitions), partitions must be designed such that they can carry moderate out-of-plane loads (e.g. bookshelves, wall cupboards) attached by suitable means at any point on the wall (Fig. 1). The loads may not exceed 0.4 kN per metre length of wall and the vertical line of action of any load should not be more than 300 mm from the surface of the wall.

DIN 18183-1 (Partitions and wall linings with gypsum boards on metal framing – Part 1: Cladding with gypsum plasterboards) is based on DIN 4103. Out-of-plane loads on walls of up to 1.5 kN/m – and in the case of independent wall linings 0.4 kN/m – are permitted, provided no excessive deformations, cracks or other restrictions on the serviceability ensue. Out-of-plane loads can be transferred into the wall directly via the boarding, the studs or suitable additional constructions (e.g. rails incorporated in the wall). When carrying the loads directly on the boarding, the minimum spacing of fixings should be 75 mm.

DIN 18183 distinguishes between light and other out-of-plane loads (see tables T4 and T5). Light out-of-plane loads, which do not exceed 0.4 kN/m, may be introduced at any point on the wall or independent wall lining.
Larger (i.e. other) out-of-plane loads from 0.4 to 0.7 kN per metre of wall may also be introduced at any point on a single-stud wall, provided the thickness d of the boarding is at least 18 mm. In the case of double-stud walls, the rows of studs must be joined together (e.g. via plates or battens) with a tension-resistant connection.

Deviations from the load P and eccentricity e details given in Fig. 1 are permitted, provided the conditions shown in Fig. 2 are maintained.
Forces due to larger wall loads (e.g. wall-mounted WCs) are transferred via loadbearing studs in the wall to neighbouring studs, bracing members and directly into the floor. The stability of the loadbearing studs is influenced by the height at which they are fixed to the wall profile. A separate analysis according to DIN 4103-1 can be carried out for other out-of-plane loads.

Impact loads
It must be demonstrated that a partition has adequate strength to withstand impact-type loads. We distinguish here between
- soft impacts, e.g. the impact of a human body, and
- hard impacts, e.g. the impact of a hard object.

The basic principle that applies to all stud walls is that damage upon impact is permitted, but it must be guaranteed that they cannot become detached from their fixings (e.g. to walls or suspended floors), that falling parts cannot injure persons and that their total thickness cannot be penetrated.

An analysis of the soft impact involves considering a quasi static loading case in order to assess the behaviour of the entire partition, and may be carried out by calculation or by tests. The incident energy, made up of an effective impact body mass and impact speed, is compared with the resistance energy of the partition.

The behaviour of the partition with respect to a hard impact involves testing to assess the local damage. The structural design, e.g. bracing to the supporting framework when fitting windows and doors or supporting larger out-of-plane loads, must be verified by the manufacturer of the wall system and is achieved through:

- increasing the moment of resistance of the studs (greater web depth, thicker material),
- reinforcing thin-wall sections,
- introducing cross-rails,
- bracing loadbearing components,
- decreasing the spacing of the studs.

Loading assumptions for self-weight
All vertical and horizontal loads that could occur must be included when designing the loadbearing structure. DIN 1055 includes an option for a simplified consideration of the load of lightweight partitions: the load of lightweight partitions can be replaced by a uniformly distributed surcharge of 0.75 kN/m^2 added to the imposed loads (see table T6).

On suspended floors with an imposed load of at least p = 5.0 kN/m^2, the surcharge for non-loadbearing partitions can be omitted, provided the self-weight of the partitions does not exceed g = 1.5 kN per square metre of wall surface.

3

T4: Permissible light out-of-plane loads in relation to the eccentricity e (to DIN 18183)

Eccentricity e [cm]	10	15	20	25	30
Permissible out-of-plane load P [kN]	0.71	0.63	0.55	0.48	0.40

T5: Permissible "other" out-of-plane loads in relation to the eccentricity e (to DIN 18183)

Eccentricity e [cm]	10	15	20	25	30
Permissible out-of-plane load P [kN]	1.00	0.93	0.85	0.78	0.70

T6: Surcharges for the simplified consideration of the load of lightweight partitions

Wall load including plaster	**Imposed load surcharge**
up to 1.0 kN/m	0.75 kN/m² floor area
up to 1.5 kN/m	1.25 kN/m² floor area

Permissible only for suspended floors with sufficient transverse load distribution

T7: Fire resistance classes (CH) of typical metal stud walls with optimised thickness (stud section CW 50 x 06)

Description	Studs	Boarding [mm]		Insulation thickness/ density	Thick-ness [mm]	Mass [kg/m²]	Fire resistence class
	CW 50	12.5	GKF	MW 40/≥30	75	25	EI 30
	CW 50	12.5	GF	MW 40/20	75	34	EI 30
	CW 50	2 x 12.5	GKF	MW 40/40	100	49	EI 60
	CW 50	2 x 12.5	GKF	MW 40/100	100	49	EI 90
	CW 50	2 x 12.5	GF	MW 50/50	100	64	EI 90
	CW 50	3 x 12.5	GKF	MW 40/40	125	75	EI 120

GKF = gypsum fire-reistant board GF = gypsum fibreboard

Owing to their low self-weight (< 1.5 kN/m²), wall systems in dry construction fulfil the requirements of DIN 1055 and can be taken into account simply by adding a global surcharge to the imposed loads.

Building physics requirements

Besides their space-dividing function, partitions mainly have to comply with sound insulation and fire protection requirements as well. In the case of prefabricated walls enclosing an interior space, e.g. partitions between two rooms in a house or two offices, walls to stairs and corridors, fire protection and sound insulation requirements are of equal importance. Depending on the type of construction, typical plasterboard stud walls can achieve fire resistance classes up to F 180 and sound reduction indexes up to 67 dB quite economically.

In terms of the fire protection and sound insulation requirements, the wall surfaces themselves are generally relatively easy to design. Special care must be taken with the following details:

- Vertical and horizontal joints between individual elements
- Junctions with walls and soffits
- The inclusion of transparent/translucent elements
- The inclusion of doors
- The routing of services

The following principles must be complied with in order to conform with fire protection and sound insulation requirements:

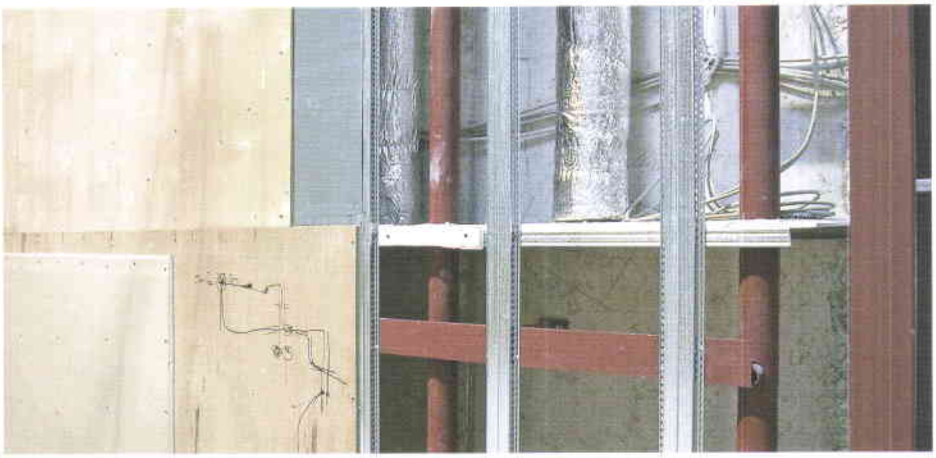
- Compartmentation
- Sealed junctions
- Sealed joints and connections
- Multi-layer boarding to meet higher requirements

In order that partitions satisfy the fire protection and sound insulation requirements, all joints, junctions and connections must guarantee a sealed enclosure. Combinations of components must together satisfy the fire resistance or sound insulation specifications.

Fire protection

The fire resistance is essentially determined by the type and thickness of the board material plus the insulating material in the voids in the wall. DIN 4102-4 contains standardised wall constructions. Numerous other types of construction have been awarded national technical approvals, and include fire wall systems and shaft walls in dry construction (see table T7).

During refurbishment and conversion work, improvements to the loadbearing structure can be compensated for by lightweight fire protection measures. As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walls in dry construction can achieve the same building physics properties for fire protection and sound insulation with a smaller wall thickness, this results in an increase in the usable floor space in a building.

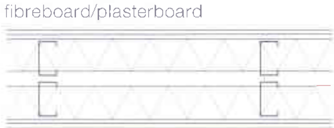
As part of the design work, special attention must be paid to pipe and cable penetrations. The firestopping systems used for fire protection in heavyweight forms of construction cannot be transferred directly to lightweight construction. Their suitability for a specific stud wall system must be established by way of test certificates and approvals (Fig. 4).

Sound insulation
Lightweight partitions, e.g. metal stud walls with a cladding of plasterboard, represent double-leaf components from the acoustics viewpoint. In comparison to a masonry wall, stud walls represent a complex system consisting of several individual components (boards, framing, insulation, fasteners, etc.). The sound-attenuating properties of lightweight stud wall systems are superior to those of solid walls with a self-weight up to 10 times higher (see table T8). The properties of the individual components, the quality of workmanship on site and the constructional boundary conditions all have an influence on the final sound insulation characteristics of a partition (Fig. 3).

The sound insulation is mainly influenced by the properties of the two individual leaves (board material, board thickness, number of layers), the connection between the two leaves (framing, fasteners) and the insulating material in the voids. Table T9 lists the most important factors and Fig. 2 illustrates special metal sections for sound insulation applications. The sound insulation characteristics of lightweight partitions systems can be found on the test certificates for those systems, or in the case of metal stud walls also in DIN 4109, supplement 1. It should be remembered here that alterations to an otherwise undisrupted wall construction will cause changes (usually negative) to the sound-attenuating effect of the wall, e.g.

- built-in items such as power sockets, maintenance openings, lighting units,
- doors, fanlights, glazing,
- weaknesses in the junction details (e.g. shadowline joints at floors and walls, connecting fins on the facade, skirting boards flush with the wall, sliding soffit connections).

T8: Acoustic properties of dry wall constructions compared to heavyweight solid walls

Construction	Component thickness [mm]	Weight per unit area [kg/m²]	Airborne sound insulation index $R_{w,R}$ [dB]	Fire resistance class[1]
Single-stud wall, 1 layer of gypsum fibreboard/plasterboard 	75–125	35–45	40–54	F30-A
Single-stud wall, 2 layers of gypsum fibreboard/plasterboard 	100–150	45–65	47–60	F60-A F90-A
Single-stud wall with "resilient channels", 2 layers of gypsum fibreboard/plasterboard 	approx. 155	approx. 52	approx. 61	F60-A F90-A
Double-stud wall, 2 layers of gypsum fibreboard/plasterboard 	175–275	65–80	59–65	F90-A F120-A
Solid wall of clay or calcium silicate bricks 115 mm, plastered 	145	160–240	42–47	F90-A F120-A
Solid wall of clay or calcium silicate bricks 240 mm, plastered 	270	260–500	48–55	F180-A BW

1 Acoustically effective independent wall lining for concealing building services
2 Examples of special metal sections with improved acoustic properties
3 System components that influence the acoustic behaviour of lightweight partitions
a Material
b Spacing
c Weight
d Spacing between leaves
e Thickness
f Number of layers and thickness
g Type of stud
h Fixings, possibly transverse members
4 Firestopping around pipes and cables when they penetrate partitions with a fire resistance classification
a Fire-resistant jointing compound
b Fire-resistant coating
c Sleeve for combustible pipe

T9: Factors influencing the sound insulation of lightweight stud wall systems

System component	Physical influencing factor	Practical influencing factor with positive effect on sound insulation
Boarding (single leaf)	Rigidity	• Limiting the boarding thickness • Boarding structure, boarding material[1]
	Mass per unit area	• Number of layers • Density of boarding material • Adding ballast to the boarding[3]
Supporting framework, fixings	Decoupling of the leaves	• Studs optimised for acoustic purposes (e.g. special, resilient metal stud sections exhibit better acoustic properties than standard CW sections, which are in turn better than timber studs) • Large stud spacing • Large leaf spacing (component thickness) • Isolated supporting construction, e.g. double-stud wall • Intermediate elements (e.g. transverse battens, insulating strips, resilient elements) • Fixing of boarding (e.g. spacing/type of fixings)
Insulating material	Sound absorption	• 80% of voids filled • Type and properties of insulating material (e.g. sound impedance)

1 Examples of resilient boarding: plasterboard (12.5–15 mm), gypsum fibreboard (10–15 mm) and wood-based board products (13–16 mm).
2 Special acoustic plasterboard products are less rigid than conventional plasterboard.
3 Increasing the mass per unit area by adding ballast to the inside of the leaf in the form of rubber, sheet lead or bitumen sheeting achieves an improvement of 5–10 dB. Stapling or gluing gypsum boards or hardboard on the inside is also possible.

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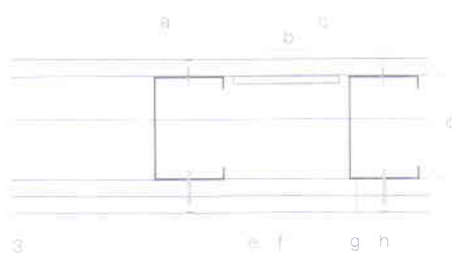

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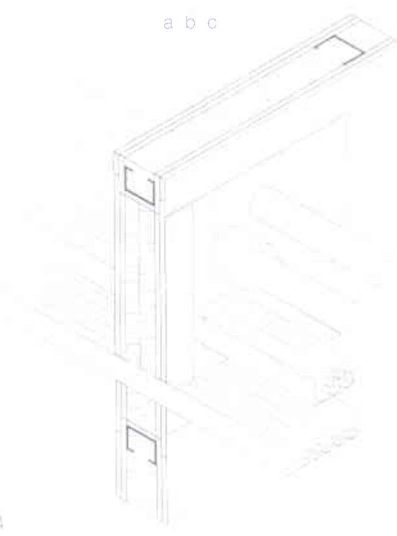

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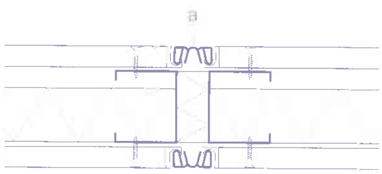
Flanking components (soffit/ceiling, facade/corridor wall, screed/floor system), flanking paths (e.g. cable ducts, pipes) and the junction details between partitions and such components likewise influence the sound insulation properties.

If sound insulation exceeding 42 dB is required, single-stud walls with a double layer of boarding both sides, special stud wall systems or high-quality partition systems will be necessary. Where sound reduction index values > 53 dB are required (e.g. party walls), double-stud walls are the norm.
High constructional flexibility calls for wall systems that can be quickly and economically connected to the structure at any point. Accordingly, the junction details must be simple, and it is normal to connect to the surface of the flanking component. When planning the building, we determine where sound insulation will be required, e.g. where the potential boundaries between different users will be. These boundaries are normally defined by the loadbearing structure, the interior layout, the access arrangements, the fitting-out and the routing of pipes and cables. In the intervening "ancillary areas", a lower degree of sound insulation is usually sufficient, and simpler connections can be used which result in greater flexibility (see table T10).



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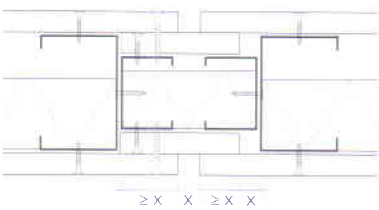

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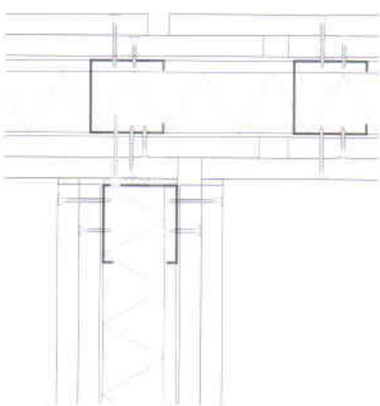

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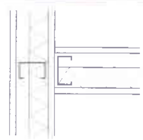
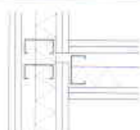
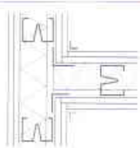
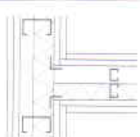
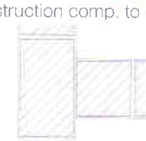
1 Movement joint with special jointing strip
  a Aluminium backing profile with elastic inlay
2 Movement joint, fire resistance class F 30, x = joint width
3 Movement joint, fire resistance class F 30, in corridor wall, joint on inside hidden behind incoming partition (isolating tape plus jointing compound or elastic joint filler)
4 Single-stud wall, corner detail with CW sections
  a Screwed version
  b Stapled version
5 Unsupported end of wall
6 Single-stud wall, corner detail with LW angles

Acoustic junctions for lightweight partitions
When joining lightweight partitions to heavyweight building components, the flanking transmissions depend on the mass per unit area of the solid components. Low flanking transmissions via adjoining lightweight components can be achieved using the measures outlined below (given in order of increasing effect):

- Floor junction: cut through a floating screed at the partition, or omit the

T10: Flanking transmissions at wall–wall junctions (T-junctions) in dry construction and compared to heavyweight solid walls

Flanking wall–partition junction detail	Sound insulation value $R_{L,w,R}$ of flanking wall [dB]	Sound reduction index $R_{w,R}$ of partition [dB]	Resultant sound reduction index $R'_{w,R}$ [dB][1]
1 	53 to DIN 4109, plasterboard	42 plasterboard[2]	41
	57 test certificate, gypsum fibreboard	52 test cert., gypsum fibreboard	49
2 	57 to DIN 4109, plasterboard	52 plasterboard[2]	49
	62 test certificate, gypsum fibreboard	57 test cert., gypsum fibrebd.	54
3 	75 similar to test certificate, gypsum fibreboard	54 plasterboard[2]	54
	75 similar to DIN 4109, plasterboard	60 gypsum fibreboard[2]	59
4 	75 to DIN 4109, plasterboard	60 plasterboard[2]	59
	75 test certificate, gypsum fibreboard	64 test cert., gypsum fibreboard	63
5 	approx. 76 similar to DIN 4109, plasterboard	64 plasterboard[2]	63
	approx. 76 similar to test certificate, gypsum fibreboard	68 gypsum fibreboard[2]	66
Construction comp. to No. 4 	300 kg 17.5 cm KS-1.8	960 kg ~ 420 mm reinforced concrete	63
	400 kg 24 cm KS-1.8	810 kg ~ 350 mm reinforced concrete	63
	600 kg 30 cm KS-1.8	600 kg ~ 260 mm reinforced concrete	63

[1] Sound transmissions via the partition and two identical flanking walls [dB], in accordance with the illustration.
[2] Average value for the construction as shown, determined in a series of tests by the plasterboard industry for metal stud walls with plasterboard.

screed completely at the partition.

- Wall junction: insulate the voids in the flanking wall, provide more than one layer of boarding on the flanking wall, interrupt the boarding at the junction with the partition by means of an isolating joint, or over the entire thickness of the wall.
- Ceiling junction: lay fibrous insulating material (mineral wool) on the ceiling materials, use more than one layer of boarding to a flanking soffit with a closed surface, interrupt the boarding at the junction with the partition by means of an isolating joint, or over the entire thickness of the wall, ensure complete separation of the ceiling void at the junction with the partition by using an absorbent material or board, or by continuing the partition up to the underside of the suspended floor structure.

The values for the flanking transmissions, depending on the construction of the adjoining components and the junction with the partition, can be found in the sound insulation standards and the publications of the manufacturers.
Tables T11 and T12 (p. 32) provide an overview of the governing criteria for wall systems, the boarding in particular.

Junctions and details

Movement joints
Movement joints in the building should continue through stud wall constructions as well. Long walls must be subdivided into segments by movement joints, the positioning and number of which will depend on the constructional circumstances. The distance between expansion joints in plasterboard should not exceed approx. 15 m (DIN 18181) and for gypsum fibre board approx. 8 m.

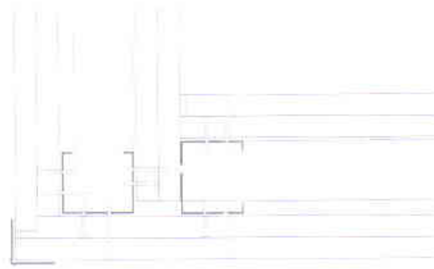
In the case of sound insulation and fire protection requirements, the movement joints should be matched to these requirements as well so that the properties of the wall are not weakened by the joint details. According to DIN 4102-4, fire resistance classes F 30 to F 90 can be achieved with classified movement joints, provided the constructional fire protection conditions with respect to the boarding and the insulating materials are adhered to (Figs. 1–3).

Free-standing wall ends and corners
An unsupported end to a wall more than 2.60 m high must include a 2 mm thick UA section in the supporting framework at that point (Fig. 5). Form wall corners with standard CW sections (Fig. 4) or LW internal corner angles (Fig. 6). Such corner details also satisfy fire protection requirements (F 30 A to F 90 A) and are possible at any angle. To protect against damage, the boarding to an external corner should be finished with an edge bead attached and disguised with jointing compound. The design principles for single-stud walls also apply to double-stud walls and independent wall linings.

Junction systems
Deformations in the joining components can occur depending on the junction system used. Generally, the junction is resilient or sliding. If the deformations of the adjoining components are negligible, a rigid connection is also possible.

We distinguish between the following principal junction types:

- Rigid connections (e.g. junction members connected with anchors, bolts or cast-in steel components)
- Sliding connections (e.g. junction members positioned adjacent to the adjoining components in such a way that the partition can slide, by way of interlocking metal sections or by continuing the boarding beyond the members of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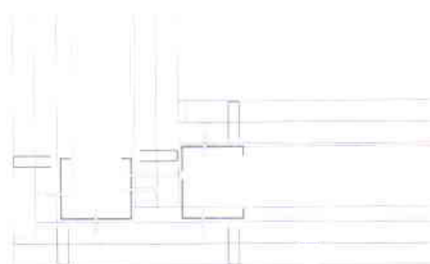
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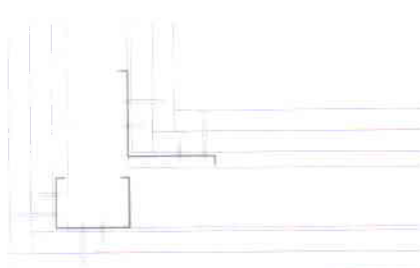
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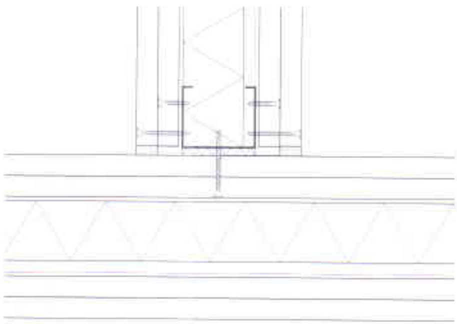

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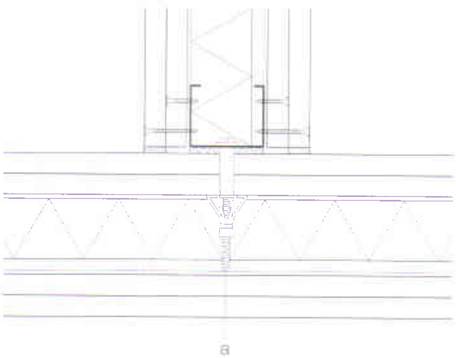

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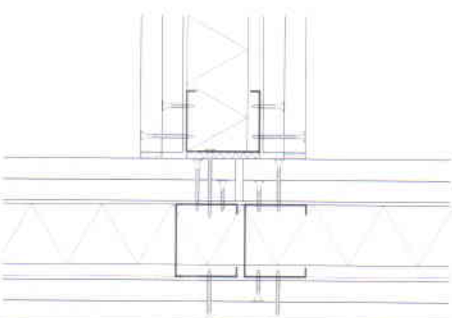

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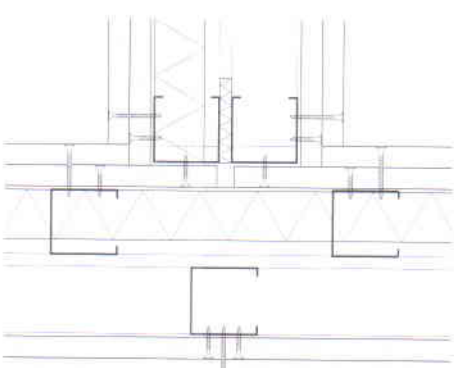

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T11: Checklist for selecting a suitable wall system

System properties	• Wall thickness • Wall height • Wall weight • Flexibility, demountability • Integration of building services • Load-carrying capacity: out-of-plane loads, impact resistance, etc. • Integration of doors, windows, services penetrations, etc. • On-site construction aspects (erection time, waiting time, sequence of operations)
Building physics properties	• Fire resistance • Airborne sound resistance • Sound insulation** • Thermal insulation
Satisfying special requirements	• Radiation screening • Clean room requirements • Projectile resistance, etc.
Appearance	• Seamless or in element form • Curved shapes • Surface finish
Costs	• Production costs • Disposal costs • Cost of moving wall • Cost of subsequent built-in items

T12: Checklist for selecting a suitable board material

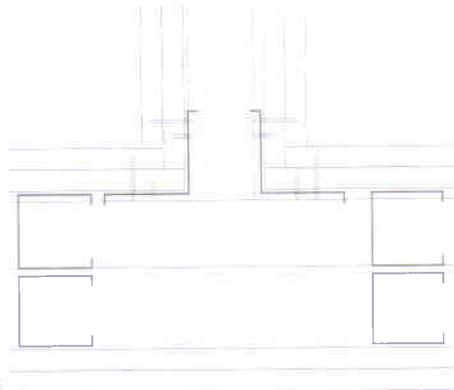
Mechanical properties	• Mechanical strength (rigidity) • Impact resistance • Surface hardness, compressive strength
Building physics properties	• Fire protection (building materials class) • Sensitivity to moisture • Diffusion permeability, sorption capacity • Dimensional stability, expansion behaviour
Surface finish	• Material • Type of cleaning • Suitability for applied finishes (paint, plaster, wallpaper, etc.)
Handling	• Workability, mouldability • Weight (transport) • Dimensions (thickness, length, width) • Fasteners, joints

lightweight frame and prefabricated walls)
• Resilient connections (e.g. resilient materials or screw fixings with springs)

Wall–wall junctions (T-junction)
Wall constructions using plasterboard make use of an isolating tape at the junction with a flanking wall. When using gypsum fibreboard, butt up the inner layer against the insulating tape and stop the outer layer and finish it as a filled joint with isolating tape (Figs. 1 and 2).

In the constructional detailing of junctions between stud walls and flanking dry wall constructions, the construction of the latter is decisive for the acoustic quality of this detail. The greater the amount of sound insulation in the flanking compo-

1 T-junction with continuous boarding, detail for walls with gypsum fibreboard
2 T-junction with continuous boarding and cavity anchor (a) when the wall is erected later (self-drilling tapping screws can be used instead of cavity anchors when using walls with gypsum fibreboard)
3 T-junction on isolating joint
4 Double-stud walls, T-junction with isolating joint
5 Junction between double-stud and single-stud walls, T-junction with boarding cut away, supporting construction of LW angles
6 T-junction with boarding cut away, supporting construction of CW sections
7 T-junction with boarding cut away, supporting construction of LW angles
8 T-junction with boarding cut away, supporting construction of CW sections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nent, the more advantageous is its effect on the final sound insulation characteristics of the system.

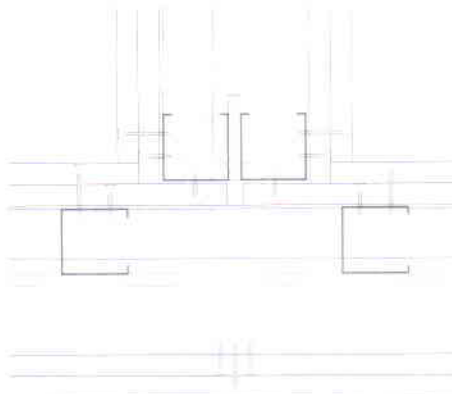
A continuous single layer of boarding as a wall junction is not suitable for high sound insulation requirements. The sound insulation value for a single layer of plasterboard is approx. 53 dB according to DIN 4109, supplement 1. Theoretical values of up to 57 dB are possible with gypsum fibreboard, and up to 53 dB without insulation to the voids of the flanking wall.

With two layers of plasterboard on the flanking wall, sound insulation values of up to 55 dB can be achieved, and up to 62 dB with two layers of gypsum fibreboard. Without insulation to the voids of the flanking wall, theoretical values of up to 57 dB are possible (Figs. 3 and 4).

If we separate the boarding to the flanking wall at the junction with the incoming wall by means of a joint, the sound insulation can be improved by up to 3 dB when using a single layer of boarding. By including a joint, a sound insulation value of up to 57 dB can be achieved with two layers of plasterboard on the flanking wall, and approx. 65 dB when the two layers are of gypsum fibreboard. Prefabricated walls without fire protection requirements may be connected to F 90 walls via an isolating joint.

In the case of an especially stringent sound insulation specification, there are special forms of construction that make use of LW corner angles. In this case, cut away the boarding at the junction with the partition, which will result in an optimum interruption to the flanking transmissions. With a single layer of plasterboard to the flanking wall the sound insulation value is approx. 73 dB and with two layers > 75 dB. DIN 4102 does not contain any such junction details using LW angles, but they are verified by national technical approvals (Figs. 5 and 7). The use of special internal and external angles enable the construction of wall junctions at various obtuse angles.

If CW sections are to be used at a junction instead of LW angles, the sound insulation values are marginally inferior for this slightly more rigid connection (Figs. 7 and 8). In principle, the comments for single-stud walls also apply to T-junctions involving double-stud walls and combinations of single- and double-stud walls.
A T-junction between a double-stud wall and a flanking wall with continuous boarding is, however, worthless from the sound insulation viewpoint.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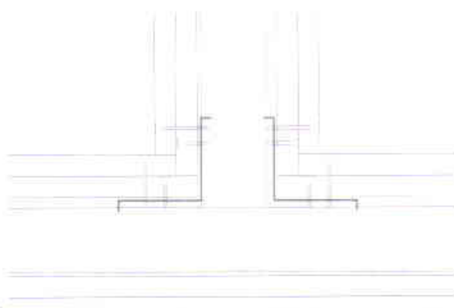
Wall–solid wall junctions (T-junction)
When connecting a stud wall to a solid concrete or masonry wall, we distinguish between two types. If the partition joins on to a structural wall that will later be plastered, attach a self-adhesive isolating tape to the boarding at the junction. This protects the boards against saturation and also ensures a straight isolating joint once the wet plaster has set. Once the plaster is dry, cut off the isolating tape flush with the plaster. Alternatively, cut a slit in the plaster with a trowel or build in a stop bead (Fig. 1).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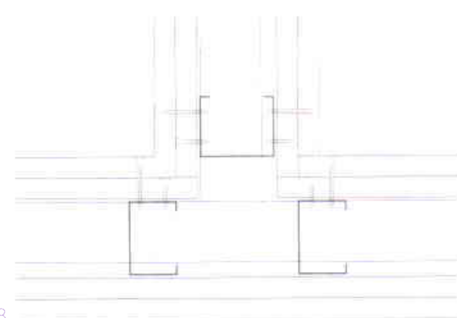
If a prefabricated wall is to be joined to a component whose surface is already finished (e.g. plastered masonry wall, fairface concrete wall), an isolating tape is required and once the jointing compound has set, cut it off flush with the boarding. Alternatively, specify a resilient junction (Fig. 2).

In both of these details, the different materials are quite consciously cleanly and clearly separated.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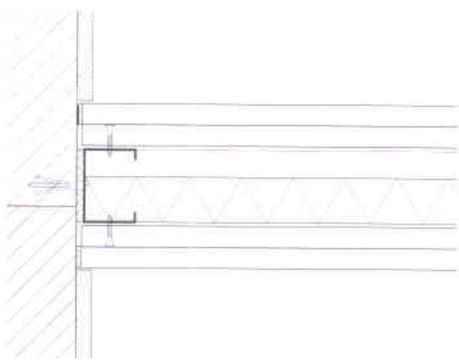
1 Junction between partition and solid wall, wet plaster isolated
2 Junction between partition and plastered solid wall or fair-face concrete wall
3 Junction between partition and solid wall with independent wall lining
4 "Floating" ceiling and wall – a play of light and shadow in dry construction, medical practice, Frankfurt, 2007, Ian Shaw Architekten
5 Junction between partition and external wall with independent wall lining and vapour barrier (a)
6 Junction between party wall and external wall clad with dry lining of composite board plus vapour barrier
7 Junction between party wall and external wall clad with dry lining of composite gypsum fibreboard plus vapour barrier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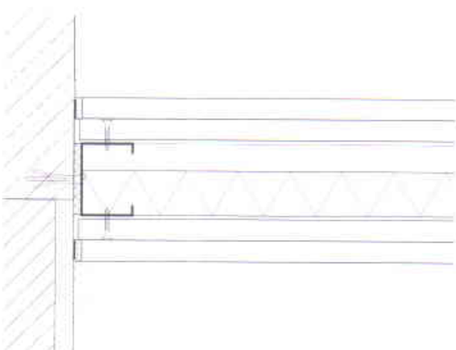
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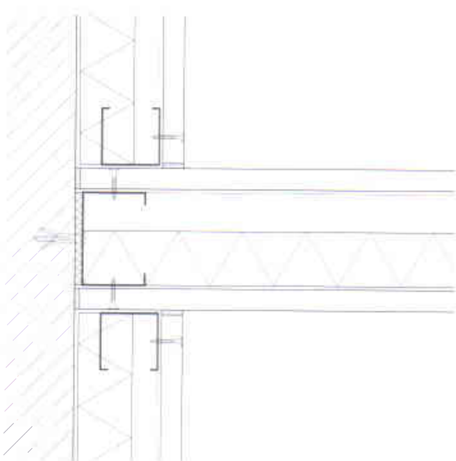
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Junctions with solid wall plus independent wall lining
Wherever partitions join on to a solid wall that will later be provided with a independent wall lining or composite boards (e.g. internal insulation), the junction detail depends on the requirements placed on the independent wall lining (or dry lining) and the partition. In the case of an internal wall with an independent wall lining (or dry lining) that fulfils no building physics requirements, connect the partition directly to the solid wall in order to preserve its sound insulation and fire protection properties (Fig. 3).

But an external wall with independent wall lining usually has to provide at least thermal insulation and moisture control functions. If there are no particular fire protection and sound insulation requirements placed on the partition, simply connect the partition to the independent wall lining to avoid interrupting the thermal insulation and, if fitted, the vapour barrier. Note that the flanking transmissions are high, especially when using composite boards with rigid foam insulation.

Where the partition has to satisfy sound insulation or fire protection requirements (e.g. party walls), the partition must interrupt the independent wall lining. But if there is a vapour barrier, this must remain intact at the junction with the partition. Designing the partition junction detail according to Figs. 5–7 guarantees a continuous layer of insulation and a continuous vapour barrier, and the fire protection requirements are also satisfied.

Junctions with shadowline joints
Wall junctions with shadowline joints (feature joints) are especially popular where solid walls or solid suspended floors are involved. Without any further constructional measures, a junction with a shadowline joint reduces the fire protection and sound insulation values of the partition–up to 7 dB depending on the sound insulation quality. Add a second layer of boarding inside the wall in order to compensate almost fully for this severe reduction in the sound insulation and the insufficient fire protection because there is only one layer of boarding at this point; the larger the web depth of the CW sections used for the studs, the easier it is to do this (Fig. 1).

In the case of a shadowline joint at the junction with a plastered masonry wall or fair-face concrete wall, always include a strip of resilient compound between each of the inner layers of boarding and the wall.

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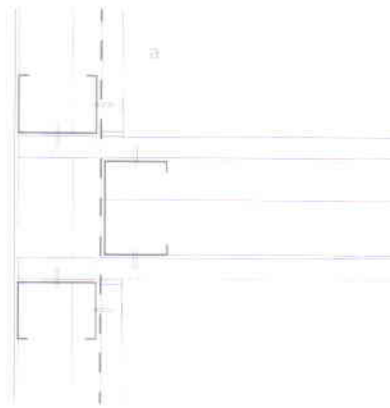

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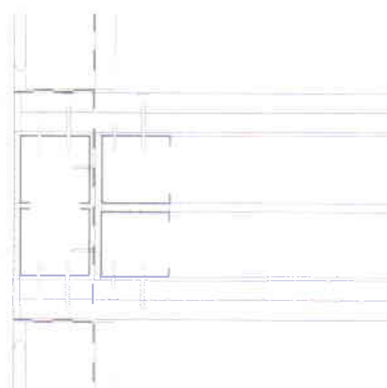

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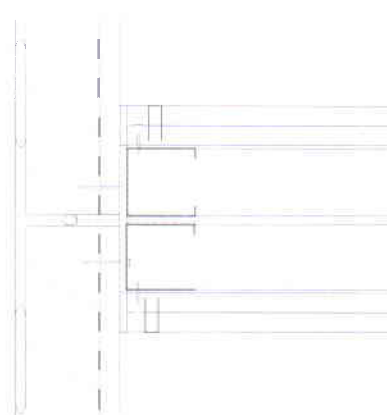

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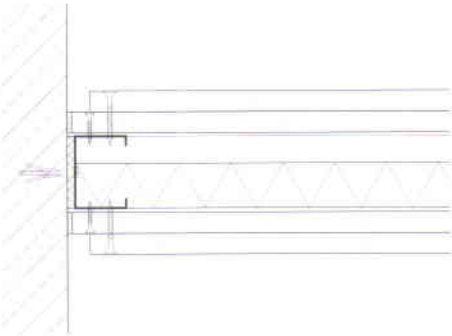
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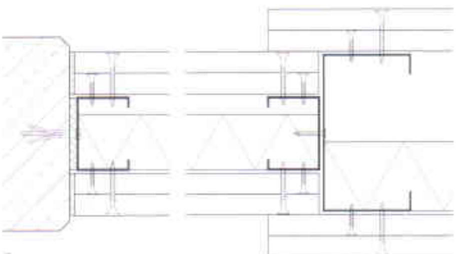
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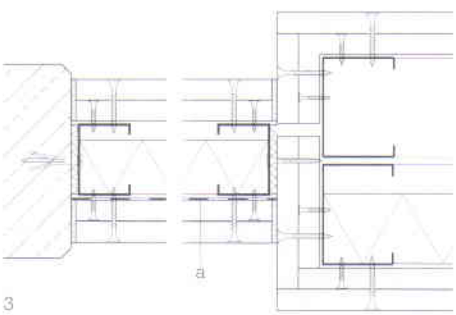

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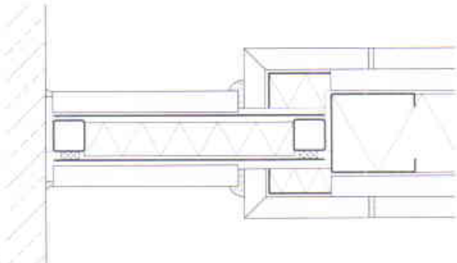
Reduced junctions and sliding wall junctions

It is often necessary to reduce the thickness of the wall to suit the size of the facade sections when connecting stud walls to facades (Fig. 3). Keep the width of this reduced wall segment as small as possible in order to minimise the ensuing loss in the sound insulation quality of the partition. If only a minor reduction in the wall thickness is necessary, the "wall-in-wall" principle represents a good solution (Fig. 2).

As in this detail the thickness of the boarding and the mineral wool filling are retained in the thinner wall segment as well and the fire protection values of the overall construction are not impaired. If such constructions have to satisfy fire protection requirements, it is essential to allow for the same thickness of boarding and mineral wool filling here as in the remainder of the wall.
In the case of a more severe reduction in the wall thickness, make use of the "wall-in-wall" principle. As the wall is very much thinner at this point, the sound insulation quality of the entire wall is diminished. To compensate for this, attach lead foil to one or both sides of the thinner segment, or use boards faced with lead foil (Fig. 4).

Sliding connections are necessary when movement of the flanking element, e.g. a lightweight facade element affected by wind loads, is expected (Figs. 5, 6, 8 and 9).
If at the same time the wall thickness is reduced, it is possible to design the sliding wall connection similarly to the sliding soffit connection using strips of board material to complete the junction (see p. 38).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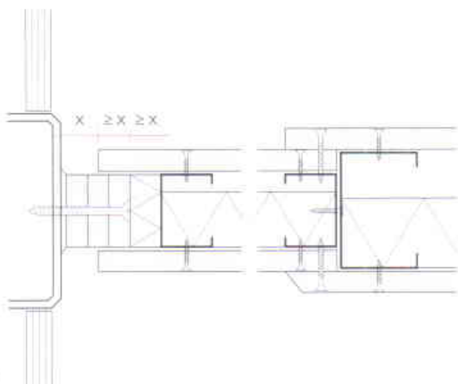

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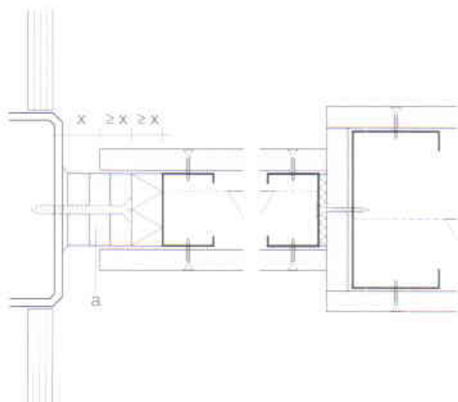

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Junctions involving glass partitions should be designed according to the instructions of the system manufacturer. Where a vertical fin is involved, reduced junctions can often be used as a special solution made from individual elements of toughened or laminated safety glass. Retaining the thickness of boarding and the mineral wool filling as in the remainder of the wall ensures that the fire protection properties of the entire construction are not impaired.

Stud wall–floor junctions

A sealed connection between the partition and the floor is essential for good sound insulation. The provision of sealing materials here is therefore imperative, and if they have to satisfy fire protection requirements as well, they must comply with DIN 4102 class A (e.g. mineral wool strips).

The flanking transmissions via the floor have an effect on the sound insulation of the entire partition. The detail at the wall-floor junction therefore acquires a special significance.

In acoustic terms, a bonded screed forms a uniform solid component together with the structural slab. The sound insulation of the total system depends on the resulting mass of the structural slab plus the bonded screed per unit area. A high figure results in high sound insulation and hence good acoustic properties (Fig. 1, p. 38).

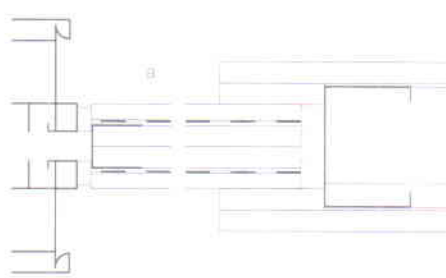
In the case of a floating screed, it is the partition–screed junction detail that is critical for the sound transmission. If the floating screed continues below the partition, the flanking transmissions are very high, and this detail is unsatisfactory for partitions that have to satisfy sound insulation requirements. However, one advantage of this arrangement is that the partition can be repositioned at any time without affecting the floor. From the acoustics viewpoint, a continuous asphalt subfloor is somewhat better than a continuous mineral screed.

High sound insulation requirements require the floating screed to be interrupted at a partition (p. 38, Fig. 2). Providing an acoustically effective isolating joint below the partition represents a compromise which achieves a moderate level of sound insulation (p. 38, Figs. 3 and 4).

If details like those described above are incorporated, no further constructional requirements are necessary in order to satisfy fire protection requirements.

Omitting layers of boarding at the base of the wall, e.g. in order to turn the floor finishes up the wall or to provide skirting boards flush with the wall surface, creates a weak point that reduces the sound insulation and fire protection values of the wall. For instance, depending on the sound insulating quality of the wall, a reduction of up to 7 dB may have to be accepted (Fig. 5).

1 Junction between partition and solid wall, with shadowline joint (feature joint) and not subject to any special requirements
2 Reduced junction in single-stud wall, "wall-in-wall"
3 Reduced junction in double-stud wall, "wall-in-wall", with lead foil inlay (a) in the zone of reduced thickness
4 Plasterboard fin (56 mm wide, R_{w} = 50 dB)
5 Sliding reduced junction, "wall-in-wall", x = joint width
6 Sliding reduced junction, "wall-in-wall", x = joint width
a Strips of boarding material
7 Rounded transition between wall and soffit
8 Slender, sliding reduced junction to satisfy sound insulation requirements, connection to aluminium facade with isolated sections
a 2.5 mm lead foil
9 Sliding junction between partition and lightweight external wall element, "wall-in-wall"



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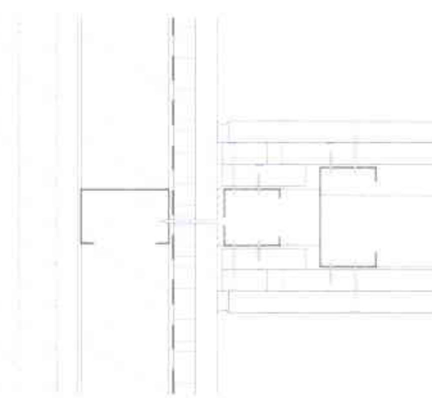

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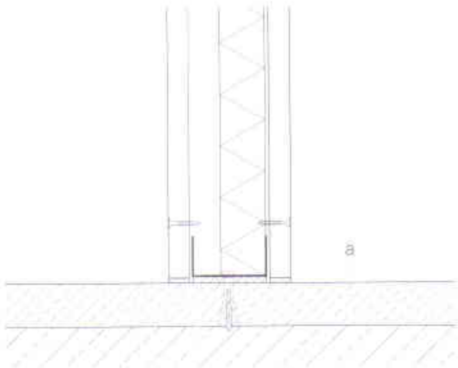

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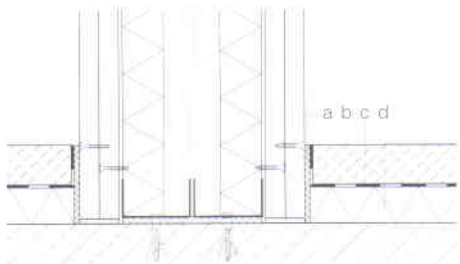

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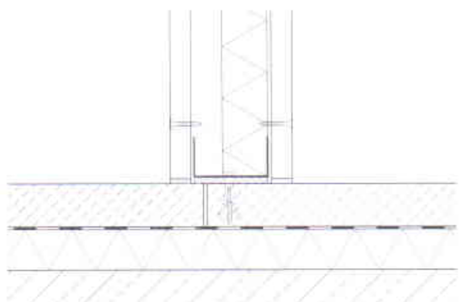

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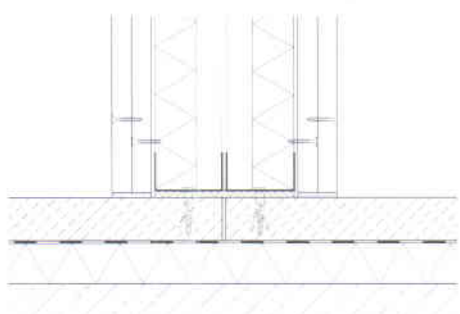

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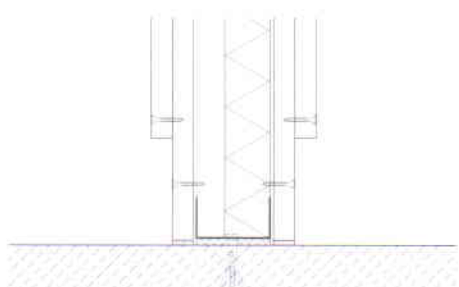

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Stud wall–soffit junctions
A stud wall must always be isolated from the underside of a structural floor slab. An isolating tape is preferred in the case of soffits already plastered or fair-face concrete surfaces (Fig. 7). Where the partition is connected to a soffit that will be plastered later, attach a self-adhesive isolating tape to the top of the boards. This protects them against saturation and also ensures a straight joint between the boarding and the wet plaster (Fig. 8). Cut away the visible part of the isolating tape once the plaster has set. Alternatively, cut a slit through the plaster with a trowel at this point.

It is better to carry out plastering work before erecting the partitions in order to avoid subjecting the board materials to unnecessary moisture loads and hence undesirable shrinkage and swelling processes. Strictly speaking, if dry construction techniques are to be applied rigorously, then plastering and other wet trades should be avoided completely, e.g. by using dry subfloors and dry linings.

At the junction between a prefabricated wall and the soffit of a solid suspended floor, the sound insulation quality depends on the weight per unit area of the floor. If the soffit is clad or a suspended ceiling has been constructed, the construction and details of these components and the junction with the partition govern the sound transmissions.
Figs. 9 and 10 show further junction options. If the stud wall does not continue as far as the underside of the structural slab, it is necessary to brace the partition back to the slab with tension- and compression-resistant members, depending on the loads and the length of the partition (Fig. 12).

If deflections of the suspended floor are expected, but these are less than 10 mm, a sliding soffit connection is not essential. In such instances, shorten the stud sections by approx. 20 mm before inserting them into the ceiling channels. The boarding should also be cut off short. The remaining movement joint up to the underside of the slab can either be designed as a shadowline joint or filled with a resilient material.

Sliding soffit connections
If deflections > 10 mm due to loads or creep are expected, the detail at the soffit should be a "sliding" one. Such details should include a movement joint between the boarding and the underside of the floor slab, the size of which matches the anticipated deflection.
The width of this movement joint should not be greater than 20 mm where the partition has to satisfy fire protection requirements. The width of the strips of boarding material must be equal to the depth of the web of the ceiling channel of the stud wall. A minimum width b is prescribed for fire protection purposes, which depends on the fire resistance class (see table T13).

The total thickness of boarding material strips required is made up of the amount of deflection expected plus the permissible movement joint plus an overlap with the boarding, which should be at least 20 mm.

1 Partition on bonded screed (a)
2 Floating screed interrupted by double-stud wall
  a Strip of insulating material
  b Floating screed
  c Plastic sheeting
  d Impact sound insulation
3 Partition on floating screed with isolating joint
4 Double-stud wall on floating screed with isolating joint
5 Wall recessed at base
6 Framing for a curved wall, acoustic isolation of floating screed


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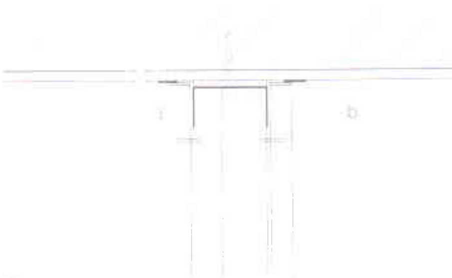

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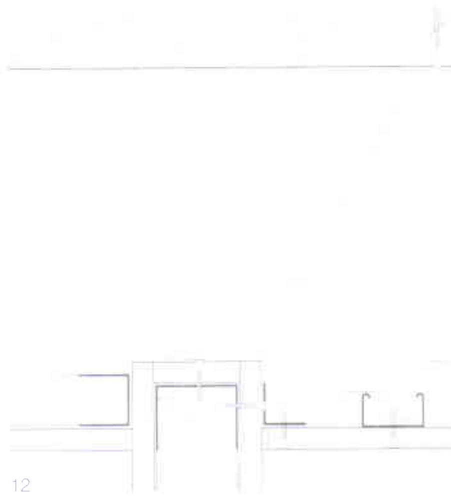
Shorten the stud sections by an amount equal to the width of the movement joint. However, they should still engage with the ceiling channels by at least 15–20 mm. To ensure that the ceiling channel can slide unhindered, only fix the boarding to the stud sections, starting 20 mm below the flange of the ceiling channel. Attach edge beads to the exposed edges of the boarding and cover with jointing compound (Fig. 13).

A sliding soffit detail reduces the sound insulation values by up to 3 dB; the higher the sound insulation of the partition, the greater is the reduction. However, careful design and workmanship will minimise the loss. The details shown here for single-stud walls can be used for double-stud walls as well.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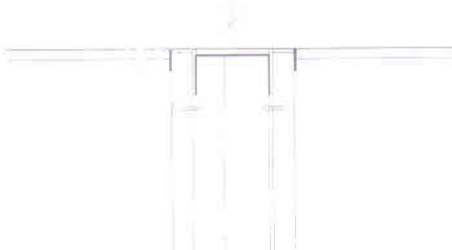
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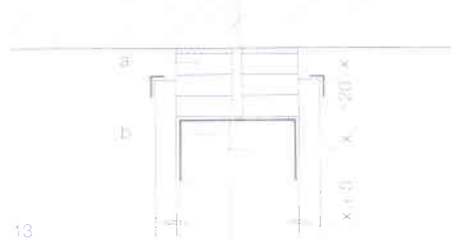

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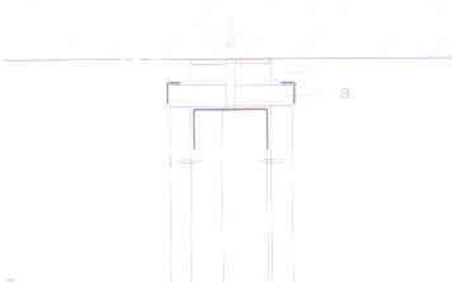

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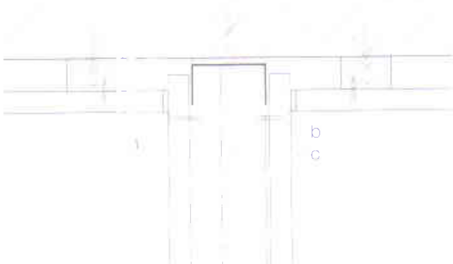

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T13: Minimum width b of strips of gypsum boarding in relation to fire resistance classification

F class	Width b [mm]
F30 to F90	≥ 50 mm
F120	≥ 75 mm
F180	≥ 150 mm

7 Junction between partition and underside of solid suspended floor, wet plaster continuous
a Isolating tape if necessary
b Wet plaster
8 Junction between partition and underside of solid suspended floor, wet plaster isolated
a Isolating tape
9 Head detail of a wall lining fixed directly to the soffit without a ceiling channel
a Strip of boarding material
10 Junction between partition and underside of solid suspended floor, soffit finishes interrupted
a Soffit finishes
b Jointing compound (no floor deflection)
c Jointing compound with isolating tape or resilient joint filler (some floor deflection possible)
11 Junction between metal stud wall and structural slab, and framing for suspended ceiling
12 Partition braced back to structural slab with an adjustable hangar
13 Sliding soffit detail, x ≤ 20 mm for walls with fire protection requirements
a Strip of boarding material
b Top edge of stud

Components and construction

Lightweight soffit linings, false ceilings and suspended ceilings are prefabricated items that form the overhead enclosing surface to an interior space. They are non-loadbearing assemblies that are attached to the underside of structural suspended floor or roof constructions, or self-supporting systems that span between walls. We distinguish between two types of prefabricated ceiling:

- Soffit lining: the timber or metal framing is fixed directly to the underside of the structure (Fig. 1).
- Suspended ceiling: the timber or metal framing is hung below the structure (Fig. 2).

According to DIN 18168 (DIN EN 13964), soffit linings and suspended ceilings consist of the following components (Fig. 3):

- Fixings
- Hangers
- Framing
- Ceiling materials
- Connectors

Fixings

These connect the hangers to loadbearing components. Design the number of fixing points such that the permissible load-carrying capacity of the fixings and the permissible deformation of the framing are not exceeded. Specify at least one fixing per 1.5 m^2 of ceiling area.

Hangers

Systems of hangers connect the framing to the fixings. They normally include a mechanism for adjusting the height. Their function and construction is similar for the majority of ceiling systems (Fig. 5), the main differences being in the parts that support the respective framing sections.

The permissible load-carrying capacity (perm. F) of hangers and fixings must be determined by an approved testing institute and may not be exceeded in use. A rating system employing three load-carrying classes (to DIN 18168-2) is used in Germany:

- Class 1: perm. F = 0.15 kN
- Class 2: perm. F = 0.25 kN
- Class 3: perm. F = 0.40 kN

Framing

These are the parts that carry the actual ceiling materials. All systems consist of main runners/battens, cross-runners/battens and their associated connectors (splices). The framing can remain concealed.

Use CD sections for the framing when a seamless ceiling is required. Use curved main runners for curved ceilings. Many other sections, e.g. T and Z sections, clamping rails, modular grid sections, etc. are available for special technical or architectural functions. The number of accessories for the individual systems (e.g. connecting pieces, bracing members, perimeter angles, wall channels, ventilation sections, etc.) is also correspondingly large.
If the structural slab is not accessible or suitable for fixing the ceiling, use long-span sections. These are normally fixed to loadbearing walls and spans of up to 10 m are possible.

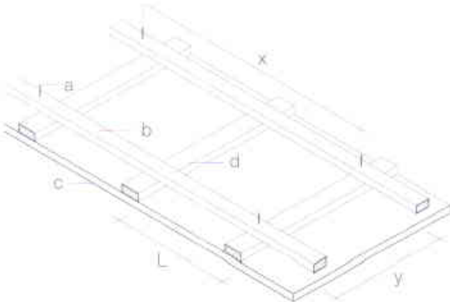
Ceiling materials

Many different building materials are available for the ceiling materials, which form the actual ceiling surface. They differ in terms of material, form and surface finish.

We distinguish between the following:

- Ceiling materials for seamless ceilings
- Ceiling materials arranged on a grid
- Modular panels
- Grid, cell and louvre constructions

Mineral-fibre boards, gypsum building boards, wood-based products, metal



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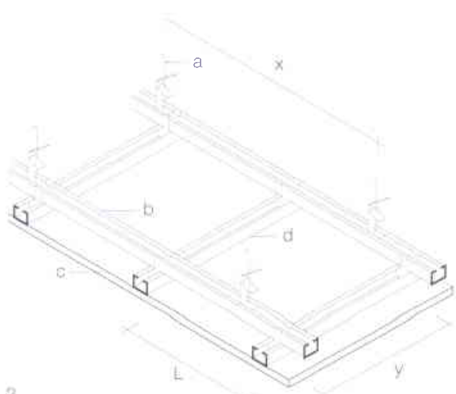

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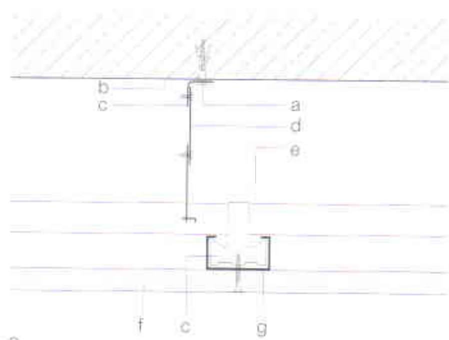

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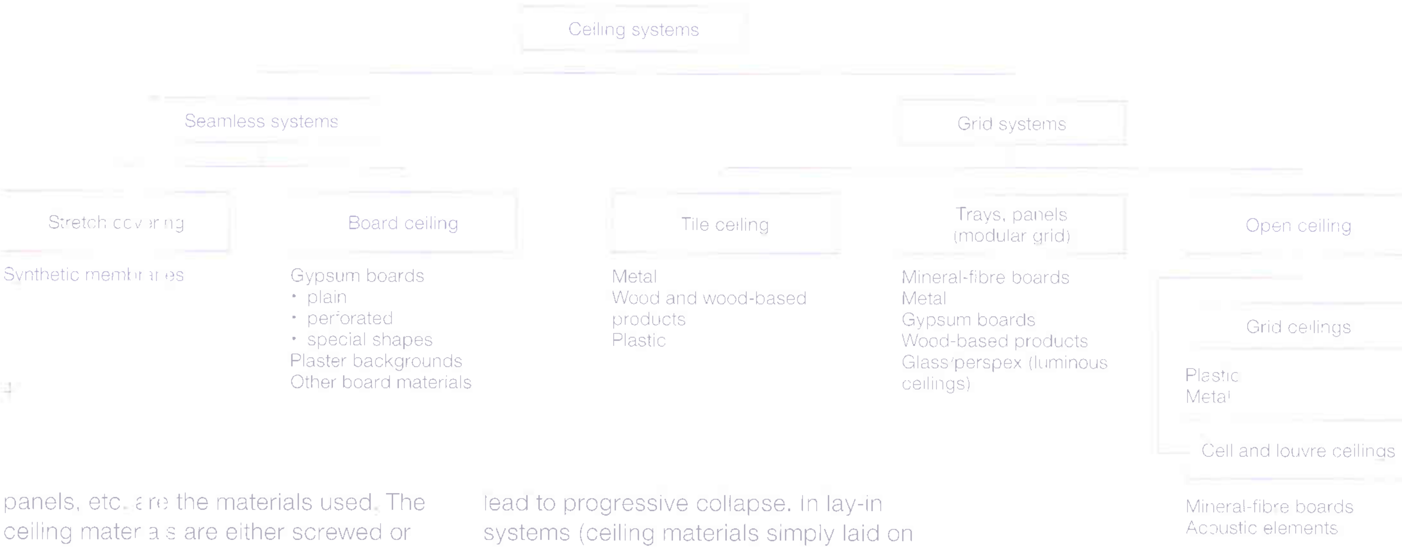

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panels, etc. are the materials used. The ceiling materials are either screwed or clipped to the framing, or simply laid on it (Fig. 4).

A multitude of configurations and designs are available for ceilings, depending on the building physics specification for the suspended floor above and the architectural goals. Seamless, plain ceilings can be achieved by using thin boards (e.g. plasterboard) with plastered joints. Various ceilings are also suitable for plaster (e.g. acoustic plaster). Perforated or slit tiles, modular panels and trays offer chances for architectural variation or additional sound absorption.

Pipes, cables, lights and HVAC installations can be incorporated in the voids above the ceiling. Fibrous insulating materials can be laid in the voids to meet fire protection and sound insulation requirements. Three-dimensional ceiling forms ensure better acoustics (e.g. concert halls) and/or a prestigious interior architecture.

Design requirements
Suspended ceilings and soffit linings must be designed in such a way that the failure of one part of the system does not lead to progressive collapse. In lay-in systems (ceiling materials simply laid on the framing without being fixed), it is essential to prevent lateral movement of the framing. The framing must be designed such that secure fixing or support for the ceiling materials is possible. Deflection of the framing may not exceed 1/500 of the span (e.g. hangar spacing), or max. 4 mm.

Built-in items, e.g. lights, ventilation grilles, should not load the framing beyond its permissible load-carrying capacity. Otherwise, they must be suspended separately from the structure.

When fixing lightweight partitions to soffit linings or suspended ceilings, the lining/ceiling must be able to accommodate any forces caused by the lightweight partitions and transfer these to the loadbearing structure.

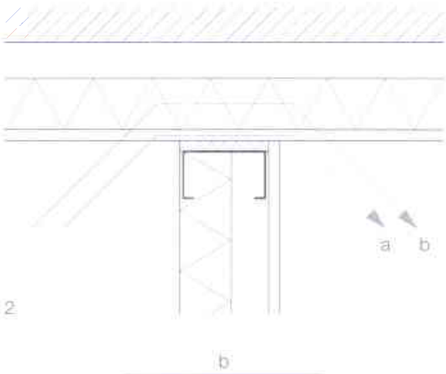
The suitability of a ceiling construction for special requirements regarding impact loads, e.g. withstanding ball impacts in sports halls, must be checked separately. In addition, possible deformations and deflections of the loadbearing structure may not impair the stability of soffit linings or suspended ceilings.

1 Soffit lining attached to framework of timber battens (dimensions x, y and L according to manufacturer's details)
a Fixing to underside of suspended floor
b Main batten
c Boarding
d Cross-batten
x Spacing between fixings
y Spacing of main battens
L Spacing of cross-battens
2 Suspended ceiling using CD sections for the main and cross-runners and rapid hangers (dimensions x, y and L according to manufacturer's details)
a Fixing to underside of suspended floor
b Main runner
c Ceiling materials
d Cross-runner
x Spacing between hangers
y Spacing of main runners
L Spacing of cross-runners
3 Ceiling terminology according to DIN 18168 (DIN EN 13964)
a Fixing
b Loadbearing component
c Connector
d Hanger
e Framing (main runner)
f Ceiling materials
g Framing (cross-runner)
4 Overview of ceiling systems
5 Standard hangers
a Rapid hanger
b Adjustable hanger
c Bracket

5a b c

1

1 Detail of junction between curved ceiling construction and glass rooflight, Office of the Federal Chancellor, Berlin, 2001, Axel Schultes Architekten
2 Flanking transmission paths in ceilings
a via the ceiling materials
b via the ceiling void
3 Bulkhead in absorbent material
4 Bulkhead built from boards plus insulation on the main runner (beam) in a modular grid ceiling
5 Suspended ceiling showing main runner and cross-runner, cross-connector, rapid hanger and butt joint between gypsum boards



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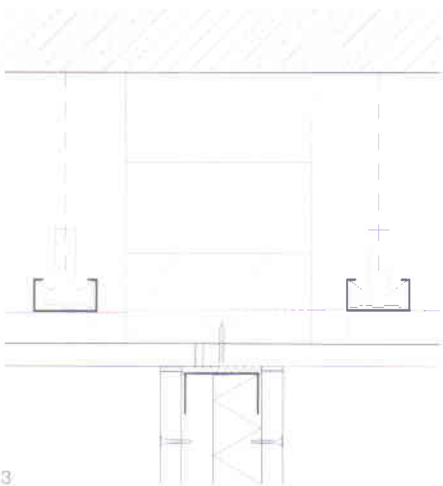

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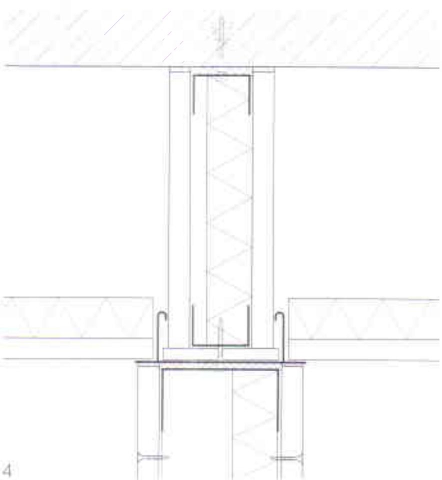

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Applications

Ceiling systems help to provide economic solutions to numerous architectural, building physics and technical requirements. They fulfil, first and foremost, the following tasks:

Fire protection
It is possible to improve the fire resistance of a suspended floor or roof structure, when exposed to fire from below, by adding a soffit lining or suspended ceiling. The fire resistance between successive storeys is in this case guaranteed by the ceiling in conjunction with the structural floor. Besides the construction of the ceiling system, it is the type of structural floor that has a major influence on the fire resistance. We distinguish between suspended floor types I to III for solid floors and timber suspended floors.

Ceilings that are exposed to fire from below but achieve a fire resistance class on their own, i.e. without the structural floor, are known as fire-resistant ceilings.

Besides increasing the fire protection between two successive storeys, such ceilings also protect building services against a fire in the room below. And fire-resistant ceilings also protect the room below against a fire in the ceiling void.

Acoustic functions
Improving the airborne and impact sound insulation of the structural floor
To supplement sound insulation measures on top of the structural floor (e.g. floating screed), it is possible to use ceilings to improve the airborne and impact sound insulation of a suspended floor quite considerably. Ceilings are therefore used almost as standard with lightweight forms of floor construction (timber joist floors, trapezoidal profile sheet metal floors). Seamless, dense ceiling surfaces with resilient fixings (acoustic hangers, resilient channels, etc.), a double layer of thin gypsum boards and a layer of insulating material are particularly effective.

Reducing the flanking transmissions via the structural floor
If the flanking transmissions via the structural floor between two interior spaces, e.g. apartments, are too high, possibly because of the use of lightweight solid flooring systems or continuous floor joists or beams, then a soffit lining or suspended ceiling that is interrupted by the (party) wall between the two rooms can help to reduce the flanking transmissions. And in offices as well, the type of ceiling and the details at partitions are crucial for the sound transmissions between neighbouring rooms (Fig. 2).

Essentially closed ceiling surfaces plus a layer of insulating material, which are interrupted at the junction with the partition, are advantageous. Other measures include the integration of bulkheads made from absorbent or board materials erected above the partitions in the ceiling void (Figs. 3 and 4). However, extending the partitions up to the underside of the structural floor is the best solution for the acoustics.

T1: Maximum spans of plasterboard to DIN 18180

Thickness [mm]	Centre-to-centre spacing L of main runners/battens [mm]	
	perpendicular	parallel
12.5	[illegible]	
15	[illegible]	420
18	[illegible]	

T2: Maximum spans of gypsum fibreboard

Thickness [mm]	Centre-to-centre spacing L of main runners/battens [mm]
10	350
12.5	435
15	525
18	630

5

Room acoustics
Specific acoustic fitting-out measures are usually necessary if a certain acoustic effect is to be achieved in a room, e.g. an agreeable, attenuated noise level. Such room acoustics tasks for interiors not specifically designed for performances or events are almost exclusively assigned to the ceiling. Typical tasks here are, for example, reducing the noise level, regulating the reverberation time, specific sound absorption and sound reflection.

The critical property for the acoustic effect of a ceiling system is its ability to absorb sound. The maximum absorption varies with different systems and occurs at different frequencies. Choosing a ceiling system with a suitable sound absorption coefficient enables the acoustics of a room to be influenced quite specifically. The influencing variables for the sound-absorbent properties of a ceiling system are:

- Ceiling material (and thickness)
- Surface finish
- Sound-absorbent layers or coatings and plaster
- Distance below structural floor
- Three-dimensional arrangement of ceiling materials

Thermal insulation
Soffit linings and suspending ceilings can be used to support thermal insulation materials, e.g. for internal insulation below roofs or the thermal isolation of successive storeys.

Integrating services into ceiling voids
The void between a ceiling and the structural floor above can be used for the installation of building services (HVAC ducts, sprinkler systems, electric/data cables, sanitary pipework, etc.). The respective inlets/outlets and built-in items (e.g. lights, loudspeakers, sprinklers, etc.) can be integrated into the ceiling surface. Heating/cooling ceilings can be used to condition the rooms below.

Interior architecture
A multitude of architectural options ensue for an appropriate interior design depending on the building physics requirements placed on the ceiling and the intended architectural goals. The architectural design freedoms range from simple, plain ceilings to complex, three-dimensional forms (folded, curved, mouldings, etc.). Lighting can be incorporated as an artistic element.

Ceiling systems using gypsum boards

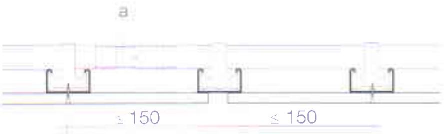
Owing to their numerous architectural and building physics qualities, ceiling systems made from gypsum building boards are very popular. Such systems are generally flat and seamless, but the mouldability of gypsum boards also permits arched and curved ceiling forms to be built as well. There are many gypsum board ceiling systems that have been approved for fire protection and sound insulation functions. Verification is carried out using DIN 4102 or DIN 4109, or the test certificates of the system manufacturers (Fig. 5).

Permissible spans
DIN 18181 specifies the permissible spans of the boards and the spacing of the framing members for plasterboard ceilings. The spacing of the cross-runners/battens depends on the board thickness and the fixing of the boards parallel or perpendicular to the direction of the fibres in the paper covering (see tables T1 and T2). The cross-runners/battens for perforated plasterboard should be fixed at a closer spacing (but follow the manufacturer's instructions).
The spans of the main runners/battens and cross-runners/battens depends on the total load (including built-in items) of the ceiling system (see table T3, p. 44). The spans given in this table can also be used for gypsum fibreboard ceiling systems provided the respective total load is taken into account. The majority of ceiling systems employing gypsum boards without built-in items or additional loads belong to the middle loading class of 0.15–0.30 kN/m². Systems with one layer of max. 12.5 mm thick boards fall within the bottom loading class (up to 0.15 kN/m²).

Attaching loads to the ceiling materials
Lightweight objects (e.g. curtain tracks, lights) can be attached directly to the ceiling materials using various cavity fixings (e.g. plastic or metal gravity/spring toggles, collapsible anchors). Individual loads fixed directly to gypsum boards may not exceed 6 kg per board span and metre. If heavier loads are involved, fix them directly to the framing and consider them as additional loads when calculating the total load of the ceiling system.

Heavy objects, the loads of which exceed the permissible loads of fasteners or the framing, must be fixed directly to the structural floor or to an appropriate supporting construction that transfers the loads back to the structural floor. Do not attach any loads to the ceiling materials or framing where the ceiling has to satisfy fire protection requirements, but instead only to the structural floor.

Design and construction
Movement joints
Movement joints in the structure must continue through any soffit lining or suspended ceiling at the same positions. Any further movement joints required should be incorporated at a spacing of about 15 m in plasterboard and about 8 m in gypsum fibreboard (Fig. 1).



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1 Movement joint in ceiling surface supported on framing member, framing separated adjacent to joint
  a Sliding splice connector
2 Movement joint complying with fire resistance requirements, x = joint width ≤ 25 mm
  a Edge bead for protection if required
  b 100 mm strip of ceiling material
3 Plasterboard ceiling with shadowline joint, which also enables indirect lighting via the ceiling
4 Rigid ceiling–wall junction with perimeter section, joint filled up to isolating tape with gypsum jointing compound
  a Seal (alternative)
  b Perimeter section (alternative)
  c Jointing compound
  d Isolating tape
  e Gypsum board
  f Metal framing (e.g. CD section)
5 Rigid ceiling–wall junction without perimeter section, joint filled up to isolating tape with gypsum jointing compound
  a Jointing compound
  b Isolating tape
  c Gypsum board
  d Metal framing
6 Rigid ceiling–wall junction at metal stud wall with plasterboard cladding, paper jointing tape folded to fit into corner
  a Seal (alternative)
  b Perimeter section
  c Jointing compound
  d Paper jointing tape fixed with jointing compound
  e Gypsum board
  f Metal framing

Furthermore, movement joints are always advisable in long ceilings with relatively large luminaires (e.g. corridor ceilings) or where the ceiling surface cannot deform unhindered. The latter situation sometimes occurs at the transition between a large ceiling area and a small area, around projecting walls or columns and in corridor ceilings with alcoves and projections.

In ceilings that must comply with fire protection requirements, strips of ceiling material placed behind the movement joint should be as thick as the material of the ceiling itself. Join the strips of material to the main ceiling materials on one side only (Fig. 2).

Wall junctions
We distinguish between the following types of junction between soffit linings or suspended ceilings and adjoining walls and other integral components:
- Rigid junctions with gypsum jointing compound
- Junctions with resilient sealant
- Sliding connections
- Open joints (shadowline joints)

Furthermore, the wall construction (masonry, concrete or dry materials) and the boarding material of the ceiling (plasterboard or gypsum fibreboard) have a major influence on the junction details if cracks are to be avoided.
In the case of a rigid junction with gypsum jointing compound, the recommendation is to affix isolating tape (self-adhesive masking tape) to the wall at the junction with the ceiling and to fill the joint up to this tape. Once the compound has set, cut off the isolating tape flush with the ceiling materials. This results in a "controlled" straight hairline crack when the building is in use which is hardly visible. This type of junction detail applies, in principle, to all junctions between solid walls and gypsum fibreboard ceilings (Figs. 4 and 5).
At a junction between a plasterboard ceiling and a prefabricated wall made from the same material, an alternative solution is to fix jointing tape, folded to fit into the corner, with gypsum jointing compound, or to fix jointing tape to the wall, or to omit the jointing tape altogether if a suitable gypsum jointing compound is available (Fig. 6).

If a resilient joint is required between ceiling and wall (e.g. acrylic sealant), form a joint 5–7 mm wide and prime the edges of the boards prior to installing the sealant. The unsupported length of board should not exceed 100 mm. The same applies to open ceiling–wall junctions. Use an edge bead to protect exposed board edges if required.
As a rule, junctions with walls usually employ suitable sections (channels, angles, special shadowline sections). Such sections serve to determine the ceiling level, to fix the ceiling materials to the wall and to supplement the framing. One common solution for this junction detail is to fix a UD section to the wall and insert the main runners into this without fixing them (Figs. 5 and 7).

T3: Permissible spans for framing to DIN 18181

Framing		**Permissible spans[1,2] [mm] for main runner/batten, cross-runner/batten for a total load of**		
		≤ 0.15 kN/m²	> 0.15 kN/m² ≤ 0.30 kN/m²	> 0.30 kN/m² ≤ 0.50 kN/m²
Sheet steel sections to DIN 18182-1				
main runner	CD 60 × 27 × 06	900	750	600
cross-runner	CD 60 × 27 × 06	1000	1000	750
Timber battens to DIN 4074-1 (width × depth) [mm]				
main batten, fixed directly	48 × 24	750	650	600
	50 × 30	850	750	
	60 × 40	1000	850	700
main batten, suspended	30 × 50[3]	1000	850	700
	40 × 60	1200	1000	850
cross-batten	48 × 24	700	600	500
	50 × 30	850	750	600

[1] For main runners/battens, the span is the spacing of the hangers (x) and for cross-runners/battens the centre-to-centre spacing of the main runners/battens (y).
[2] Shorter spans to DIN 4102-4 may apply in the case of fire protection requirements.
[3] Only in conjunction with cross-battens 50 mm wide × 30 mm deep.

3

7 Junction with shadowline joint
a Seal (alternative)
b Perimeter section
c Edge bead or similar (alternative)
d Gypsum board
e Metal framing

8 Sliding junction with shadowline joint
a Seal (alternative)
b Perimeter section
c Edge bead or similar (alternative)
d Gypsum board
e Metal framing

9 Junction with shadowline joint complying with fire protection requirements
a Seal (alternative)
b Perimeter section
c Strip of gypsum board
d Edge bead or similar (alternative)
e Gypsum board
f Metal framing

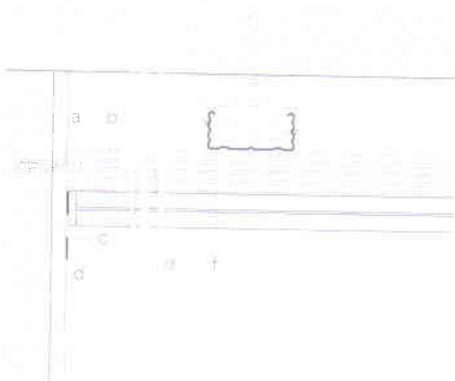
When using gypsum fibreboard, the boards should not be fixed to the perimeter sections. And even with plasterboard, omit fixings if movement of the ceiling is anticipated or movement joints have been included in the ceiling.

Junctions with a shadowline joint have the advantage that cracks at the junction are concealed within the joint (Figs. 7 and 8).

Where there is a sliding joint between a prefabricated wall and the underside of a suspended floor slab, a sliding detail is also required between the ceiling and the wall. If it is not possible to construct a sliding ceiling connection because a filled joint is required between ceiling and wall, e.g. in hospital rooms with high hygiene requirements, position the hangers for the suspended ceiling about 1000 mm from the wall (note permissible hanger spacing) so that minimal deformation of the suspended ceiling is possible at the junction. Connect the ceiling boards to the wall via suitable sections.

Wherever fire protection requirements have to be met, it is generally necessary to place framing sections, rock wool or strips of ceiling material behind the main boarding at the junctions with the neighbouring components. Form shadowline joints with the same material thicknesses (Fig. 9). At the junction between an independent fire-resistant ceiling and a prefabricated wall, it is essential to verify the fire resistance of the junction detail. Build fire barriers within the ceiling void using suitable materials if the fire protection specification requires this (p. 42, Fig. 4).

At junctions between walls and suspended ceilings with sound insulation requirements, the insulation in the ceiling to prevent flanking transmissions must be equivalent to the sound insulation of the



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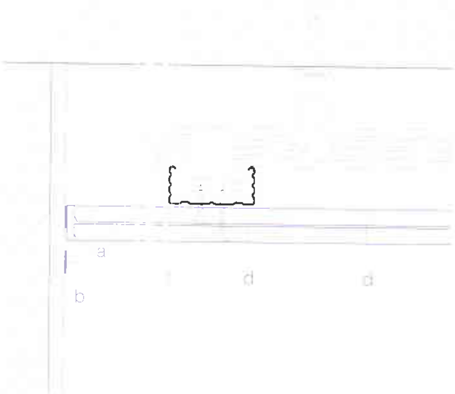

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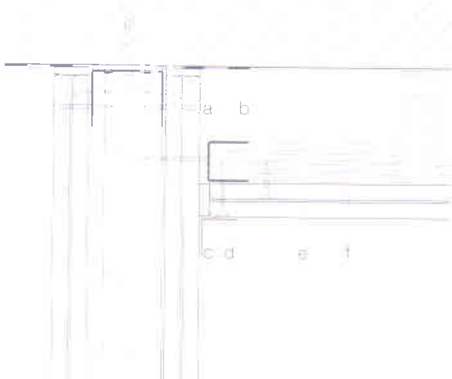

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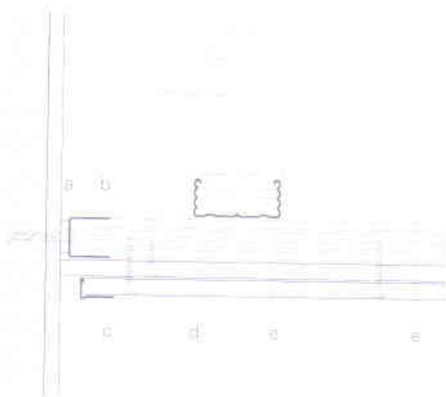

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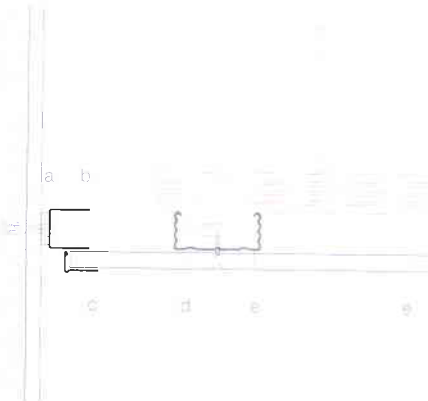

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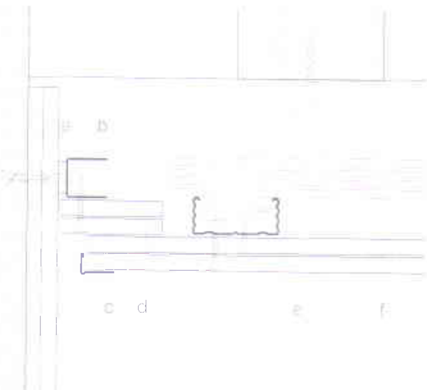

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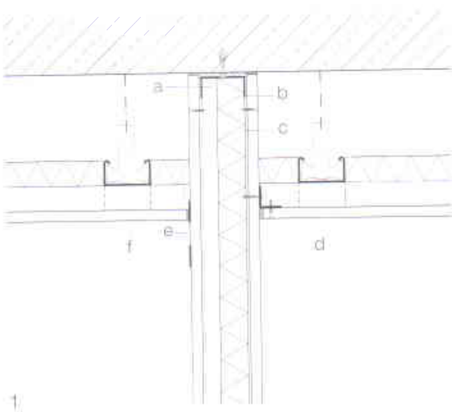

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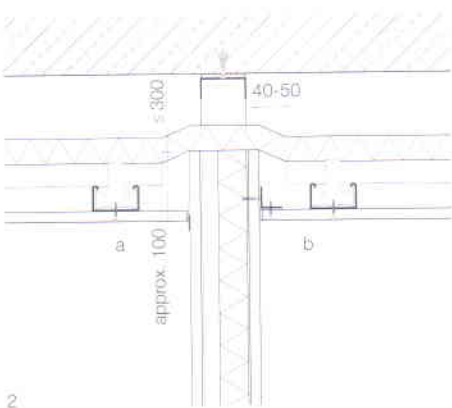

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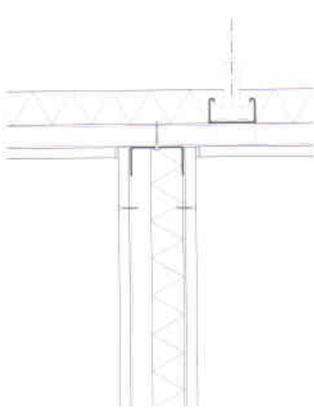

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wall. A continuous fire barrier in the ceiling void has proved worthwhile in such instances. The easiest way of doing this is to continue the prefabricated wall up to the underside of the structural floor (Fig. 1). Equivalent in acoustic terms is the construction of a separate fire barrier that fully guarantees the necessary fire protection.

If services are installed in the ceiling void, terminate the wall boarding about 100 mm above the ceiling but continue the wall framing up to the underside of the structural floor. This detail results in a wall with lower sound insulation than is the case when the ceiling void is completely interrupted. To achieve optimum sound insulation, lay fibrous insulating material over the entire area of the ceiling and continue this across the top of the wall boarding (Fig. 2).

When the wall is connected to the framing of the prefabricated ceiling, it is not possible to achieve the same sound insulation figures as for the previous detail. The ceiling materials are then erected after the wall is complete (Fig. 3).

Where even lower sound insulation requirements are acceptable, connections to ceilings with an isolating joint (interrupting the flanking transmissions) and continuous ceilings are possible (Fig. 5).

In order to transfer loads from the wall (e.g. from internal doors) to the loadbearing suspended floor above, additional bracing in the ceiling void may be necessary at junctions between walls and ceilings, depending on the size of the ceiling area (Fig. 6).

Changes in level
Rooms with fire-resistant ceilings at different heights require special treatment (Fig. 7). Additional hangers are necessary in the region of the change in level (max. difference 1250 mm) in order to carry the load of the vertical construction. Select the hanger spacing depending on the thickness of ceiling materials such that each (height-adjustable) hanger carries no more than 0.25 kN. The vertical construction here should be built like a prefabricated wall with UW and CW stud sections clad on one side, with the spacing of the studs, the ceiling materials and any sound insulation required being chosen to match the ceiling construction.

Built-in items and access panels
According to DIN 4102-4, the inclusion of built-in items (e.g. lights, HVAC equipment, other fittings) is not permitted in ceilings and soffit linings that must comply with fire protection requirements. If, nevertheless, built-in items are to be integrated into a ceiling, the construction should be verified in accordance with the test certificates, which should contain the construction details as well.
During the planning, take into account that built-in items (e.g. lights, access panels) will generally require trimmers and additional hangers. Specifying the positions of built-in items at an early stage reduces the on-site work necessary for adapting the framing. The later integration of built-in items is costly by comparison and involves more extensive changes to the ceiling. Luminaires etc. are normally fitted into a fire-resistant casing made from the same material (in the same thickness) as the ceiling (p. 48, Fig. 3).

If the luminaires require vents to help dissipate heat, suspend the back of the fire-resistant casing separately from the sides in order to create a ventilation opening between the two parts. Support the back part of the casing on materials that melt when the temperature rises (e.g. polystyrene blocks) and therefore close off the vent during a fire (Fig. 4).

The arrangement and details of access panels are very much dependent on products and manufacturers (Fig. 5). Please refer to test certificates and system literature for details. Make especially sure

1 Prefabricated wall continued up to underside of structural floor to comply with fire protection and sound insulation requirements
a Strip of insulating material
b UD section
c CW section
d Plasterboard ceiling, here shown with rigid connection to partition
[illegible] Plasterboard or gypsum fibreboard ceiling, here shown isolated from partition
e Isolating [illegible]
2 Ceiling materials and framing interrupted at partition
a Plasterboard or gypsum fibreboard ceiling, here shown isolated from partition
b Plasterboard ceiling, here shown with rigid connection to partition
3 Ceiling materials interrupted at partition, framing continuous
4 Luminous ceiling, city/university library conversion Frankfurt a. M., 2006, Frankfurt Building Department
5 Partition connected to ceiling, isolating joint in ceiling materials
6 Bracing to ceiling above junction with partition
7 Change in level in fire-resistant ceiling


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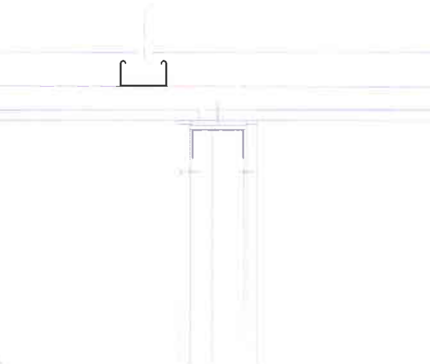
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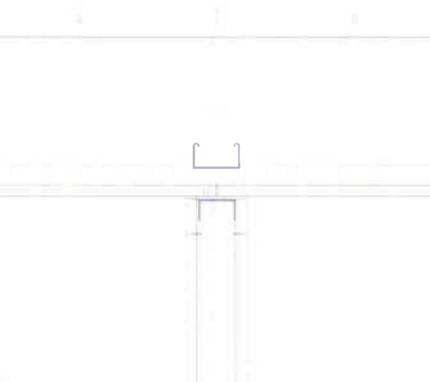
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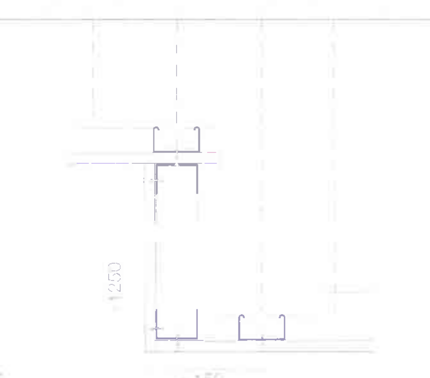

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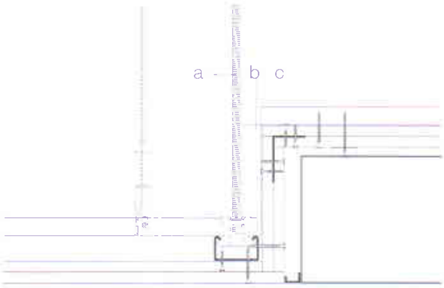

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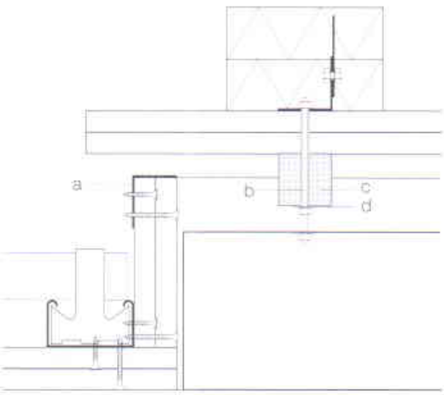

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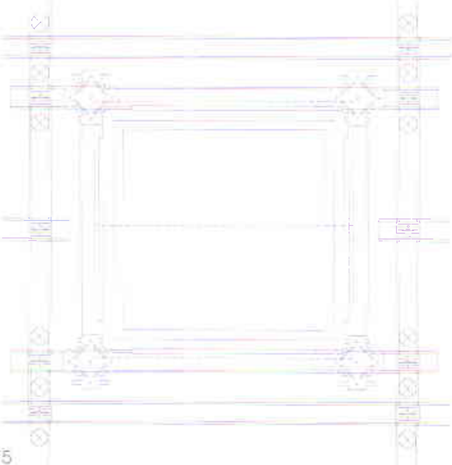
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that the access panels are approved for the particular ceiling systems being used and the associated fire loads (from above/below).

Grid ceiling systems

There are many different ceiling materials that can be laid on the framing without the need for jointing or fixings. The individual ceiling elements remain identifiable as such and so the ceiling takes on a grid-like appearance, which is further emphasized when the framing remains visible.

Various ceiling materials are available in standard formats with different surface finishes and edge profiles. The framing members are fixed at spacings to match those formats so that it is possible to simply lay the ceiling elements on the framing (or clip them in place if necessary). The elements are usually supplied ready finished and only perimeter boards need to be worked or cut to suit at walls or columns.

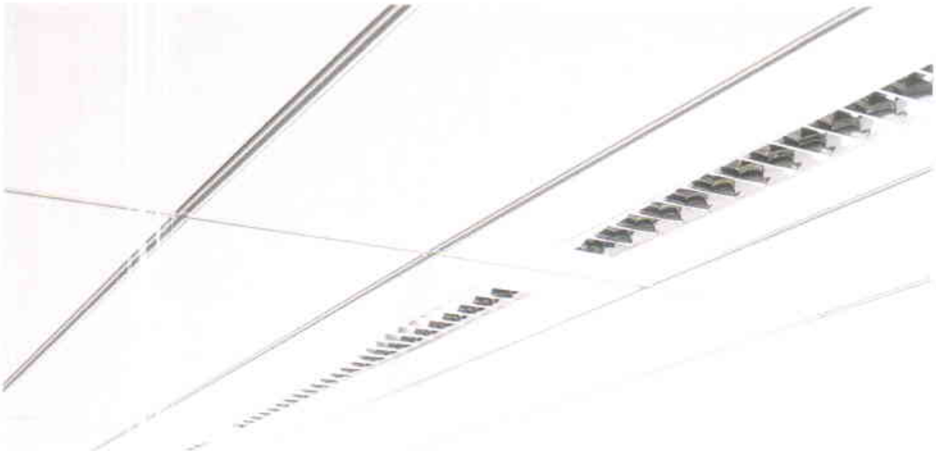
There are very many metal framing systems available on the market. Which ceiling materials and forms of construction are suitable in each individual case depends on the architectural objectives and the technical/physical requirements placed on the ceiling. This leads to a huge number of different ceiling systems.

A brief overview of the standard systems is given below. They all comply with DIN 18168 or DIN EN 13964 and have been tried and tested in practice. The emphasis here is on the very widespread mineral-fibre tile and metal tray (aluminium, steel) systems.

The edges of mineral-fibre tiles can be factory-worked, e.g. grooved or rebated. Other thick materials such as lightweight particleboards, gypsum boards, rigid foam boards, etc. have similar edge profiles and exhibit similar properties and so can be used in a similar way and result in ceilings with a similar appearance. Contrasting with this, the edges of thin sheet metal panels cannot be worked in any way, but are instead factory-bent and folded.

Both systems make use of square or rectangular layouts and elements with or without perforations. Tiles are simply laid on the framing, metal trays are also clipped into place. Modular grid systems and self-supporting corridor ceilings are available.

1, 2 Curving metal ceiling, underground station, Hong Kong
3 Example of a luminaire built into a suspended ceiling to comply with fire protection requirements
 a Hanger
 b C-section runner
 c Angle section
4 Detail of ventilation opening around luminaire
 a Sheet metal angle
 b Threaded bar
 c Polystyrene block
 d Washer
5 Example of framing and trimmers around an access panel



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The sizes of accessories such as luminaires, ventilation grilles, etc. are coordinated with the ceiling grid. The ceiling construction does not need to be adjusted because the standard ceiling materials are simply replaced by special elements where required. Such elements are available for all standard grids, with edges designed so that they fit in with the construction and do not disrupt the pattern of joints in the ceiling. Build-in elements with different formats can be used provided they have support on all sides that can accommodate the cut edges of the ceiling panels and the unsupported ends of framing members cut back to suit. Special elements are usually heavier than the ceiling panels and therefore require additional hangers. Luminaires in ceilings with a fire protection function must be enclosed on all sides with suitable boards (fire-resistant casing).

Access panels in grid ceilings can be in the form of

- any of the ceiling elements in systems where these are simply laid in place,
- individual, demountable ceiling elements where these are fixed.
- standard access panels.

T-systems

In T-systems the metal framing is all on one level. All the framing members are upturned T-sections and the longitudinal and transverse members are permanently connected to each other (p. 51, Figs. 4 and 6). As a result, these systems are only suitable for certain material formats. It is important to consider the later positions of the joints in the ceiling when determining the suspension points. The advantages of T-systems are that they require fewer sections than the Z-systems and simply laying the ceiling materials in place shortens erection times.

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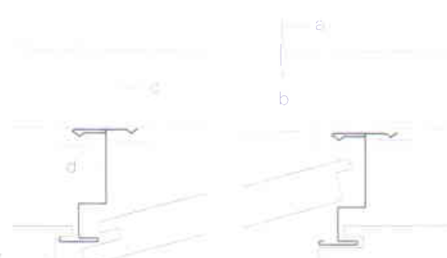
The cross-runners are normally fixed at 600 or 625 mm centres to produce a rectangular grid (600 x 1200 mm or 625 x 1250 mm). Intermediate runners can be inserted between the cross-runners to convert this into a square grid (600 x 600 mm or 625 x 625 mm). The same result is achieved by suspending the main runners at 600 or 625 mm centres and attaching the intermediate runners at right-angles to these. The cross-runners are then superfluous, which means that the spacing of the hangers can be increased. However, the work of suspending and aligning the main runners is more involved and more time-consuming (terminology, pp. 50/51, Fig. 4).

In some systems the flange of the upturned T remains exposed on the underside of the ceiling (exposed grid). Any of the tiles can be removed to provide access to the ceiling void at any point. Approx. 80 mm clearance is required above the tiles in order that they can be inserted and removed.

Figs. 7 and 8 (p. 51) illustrate typical forms of construction using mineral-fibre tiles and metal panels.

6 Mineral-fibre planks and matching luminaires
7 Z-system with demountable mineral-fibre tiles and concealed framing
a Hanger
b T- or C-section main runner
c Connector for cross-runner
d Cross-runner with Z-shaped cross-section
8 Z-system with metal panels and concealed framing
a Rectangular panel
b Square tray



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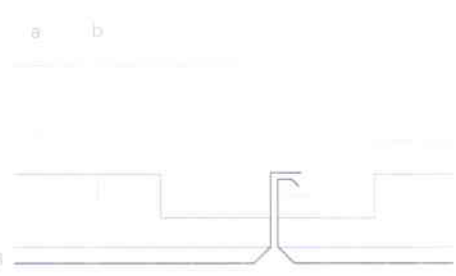

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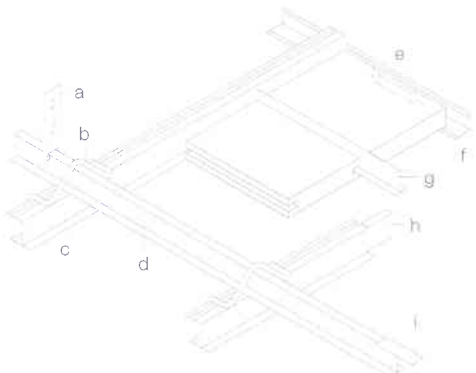

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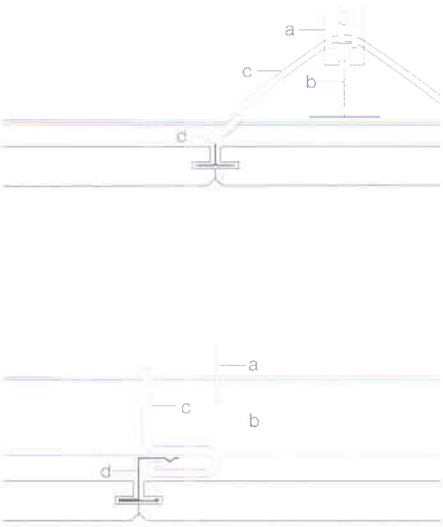

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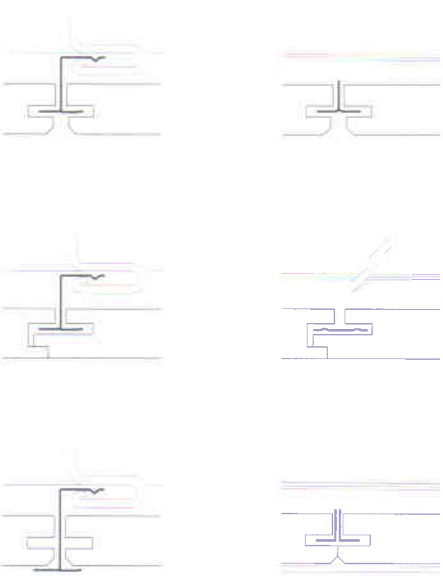
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Z-systems
Z-systems are those ceiling systems in which the framing members resemble a Z in cross-section (p. 50, Figs. 1 and 2). One particular feature of these systems is that the metal framing is arranged on two levels. The main runners form the upper level and the spacings of these members can be varied at will up to a maximum, which depends on the particular system. This means it is possible to attach the hangers to the loadbearing structure at the most favourable points and also to avoid building services and other obstacles.

The second level, below the main runners, is reserved for the cross-runners, which carry the ceiling materials themselves. These sections can be positioned as required so that the pattern of joints in the ceiling is independent of the main runners. The positions and spacings of the Z-sections matches the longitudinal joints between the ceiling materials.

When using soft materials (e.g. mineral-fibre tiles), additional T-shaped intermediate runners are required to stiffen the edges of the boards; the ends of the runners are supported on the flanges of the cross-runners. Perimeter angles are used at the junctions with walls to support the cut edges of perimeter panels.

The particular features of the standard systems are:

- The system is suitable for any length and width of tile/panel, also special formats.
- The positions of the hangers and main runners is not dependent on the pattern of joints in the ceiling and therefore can be adjusted to suit the local circumstances.
- When using tiles/panels with different edge profiles, identical or similar framing can be used for a series of constructional variations, e.g. with exposed grid or demountable tiles.

Figs. 3, 7 and 8 illustrate a number of constructional variations.

Clip-in systems
Besides the lay-in systems, there are also clip-in systems for metal ceiling panels. In these systems, there are lugs on two sides of the panels which are clipped from below into special clamping rails to fix the panel firmly in position (Fig. 9).

1 Grid ceiling with concealed Z-section framing, standard form
  a Hanger
  b Main runner/cross-runner connector
  c Cross-runner with Z-shaped cross-section
  d T- or C-section main runner
  e Spring clip at wall
  f Wall angle
  g T-shaped intermediate runner (for soft materials only, e.g. mineral-fibre tiles)
  h Splice connector between cross-runners
  i Splice connector between main runners
2 Sections through ceiling shown in Fig. 1 (for legend see Fig. 1)
3 Z-system constructional variations with mineral-fibre tiles (longitudinal and transverse sections in each case)
  a Concealed framing with shadowline joints
  b Concealed framing with rebated boards
  c Semi-concealed framing
4 T-system grid ceiling with concealed framing, standard form
  a Hanger
  b T-shaped main runner
  c Cross-runner
  d Intermediate runner
  e Wall angle
5 Mineral-fibre modular grid ceiling with built-in spotlights
6 Sections through ceiling shown in Fig. 4
  a Transverse section
  b Longitudinal section
7 T-system constructional variations with mineral-fibre tiles (longitudinal and transverse sections in each case)
  a Semi-concealed framing with or without shadowline joints
  b Concealed framing
8 T-system with metal panels and exposed framing
  a Rectangular panel
  b Square tray
9 Clamping rail and tray edges with clip-in lugs (schematic diagram)

4

The exact format depends on the particular manufacturer. In certain systems each metal panel can be swung downwards to provide access without having to remove the panel completely from the framing or interfering with other panels. This hinge feature eases occasional work in the ceiling void because access is possible at any point (p. 52, Fig. 3).

Modular grid ceilings
Modular grid ceilings (some manufacturers use the German word *Bandraster* ceiling) are often used in conjunction with lightweight or demountable partitions that do not continue up to the underside of the structural floor, but instead only to the underside of the ceiling, where they must be fixed securely. To do this, particularly wide, stable, exposed main runners (beams) are fixed at certain spacings in the ceiling, which usually correspond to the modular grid in use (p. 52, Fig. 1) and can be 50–150 mm wide, although the standard width is 100 mm. These beams function as supports for the ceiling materials, but also as fixing points for the partitions. As the partitions do not continue


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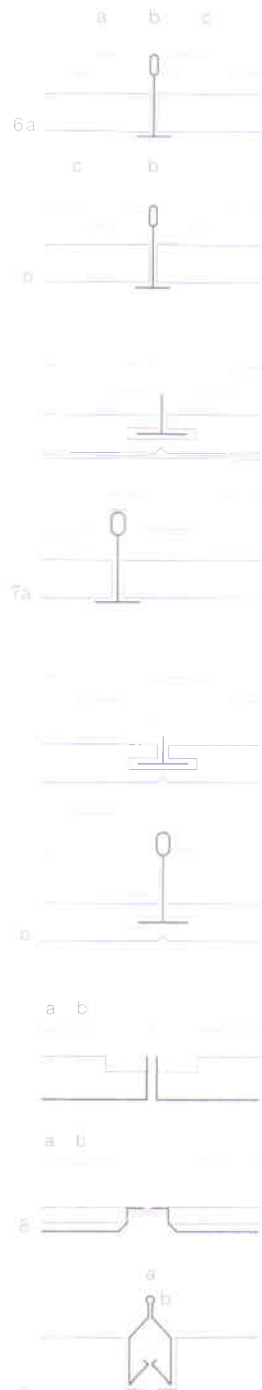

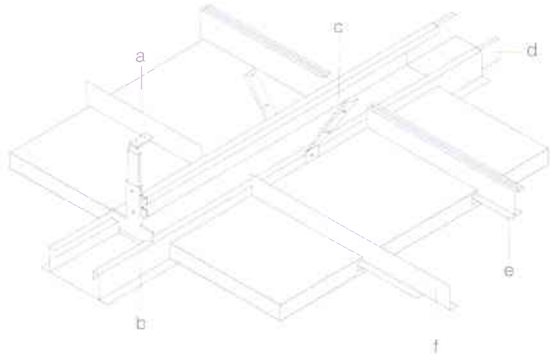

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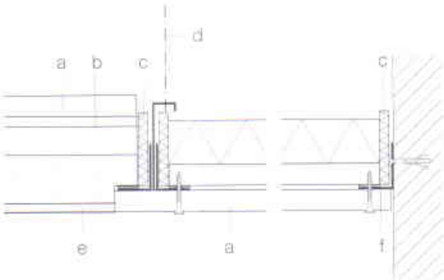

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into the ceiling void, the installation of services is particularly easy over the entire ceiling area.

The advantage of modular grid ceilings is that partitions can be erected subsequently and moved to suit changes of use without affecting the ceiling. The beams require diagonal bracing back to the loadbearing structure every approx. 2 m in order to prevent lateral deflections of the partitions and to resist any shear forces transferred into the ceiling.

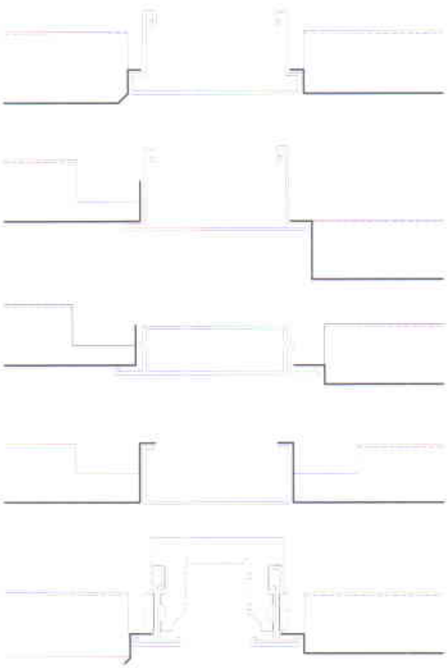
The beams are available in various forms to suit different functions. They are ideal for integrating lights, vents, power supplies, etc. Besides purely parallel arrangements of the beams, grid layouts are also possible. To incorporate luminaires, the beams are either simply replaced by luminaires of identical size, or the luminaires are fitted in the panels between the beams.

Fig. 4 illustrates various beams for modular grid ceilings in combination with metal panels.

Self-supporting ceilings
Self-supporting ceiling systems are constructions that are not suspended from or fixed to the suspended floor above, but instead incorporate framing that spans from wall to wall.

Self-supporting ceilings represent an option in the following situations:

- Where there is restricted access to the loadbearing floor above for fixing hangers (e.g. due to a high services density).
- Where ceilings in corridors have to be removed frequently for maintenance or repair work.
- When the load-carrying capacity of the suspended floor above is inadequate (e.g. in existing buildings).



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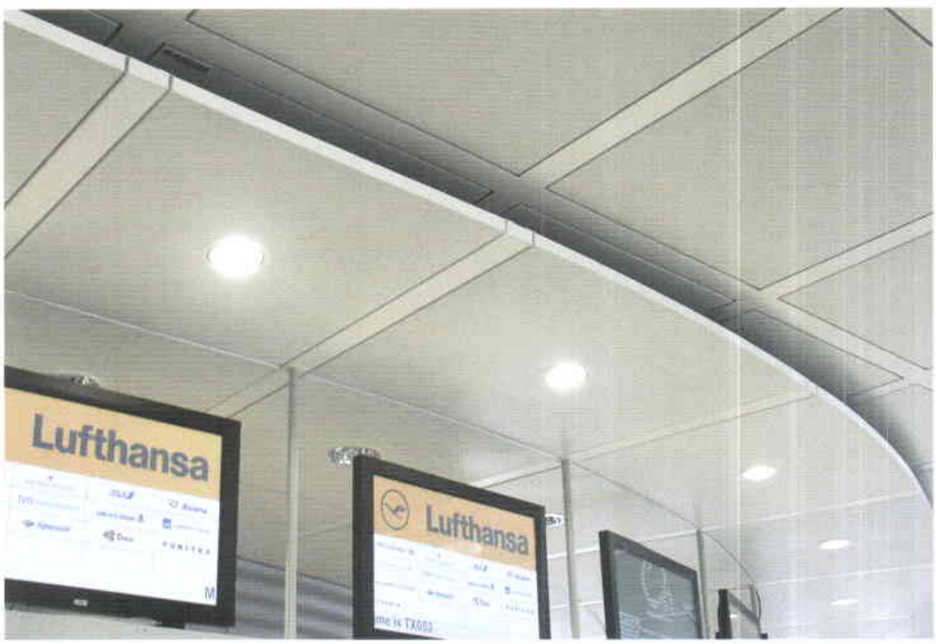

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Self-supporting ceilings are often used in corridors because this is where we often find a high services density. Frequent access is therefore necessary and corridors are usually of such a size that the span is not excessive. Generally, such ceilings are classified as independent fire-resistant elements for exposure to fire from above and below.

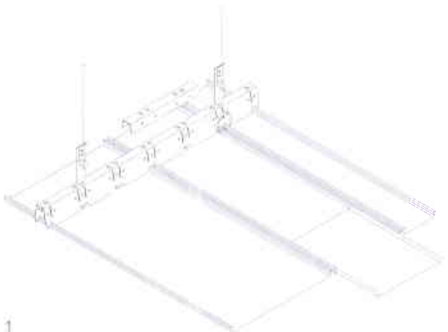
The walls between which the ceiling spans carry the entire load of the ceiling and must continue to do so even in the event of a fire. They must therefore have the same fire resistance as the ceiling itself. All customary forms of construction can be used for the walls supporting such ceilings. The boundary conditions of the test certificates for suspended ceilings must be taken into account – additional layers of boarding or shorter spans may be prescribed for metal stud walls, for instance. Such ceilings cannot usually carry any further loads; the integration of lights or other built-in items may be possible depending on the system and is given in the test certificates.

Spans up to 5 m are possible, depending on the system. The ceiling materials are either self-supporting (e.g. integral stiffeners, box form) or they are fixed to or laid on loadbearing members (e.g. T-sections). Some systems include individual demountable or hinged panels to provide access to the ceiling void. The self-supporting ceiling materials or the loadbearing construction span across the corridor from wall to wall. The edge members along the walls carry the load of the ceiling and any built-in items. Such members are therefore larger and stronger than the usual edge members for ceilings and must be fixed to the wall in accordance with the details given on the test certificate.

It is also possible to use conventional mineral-fibre boards with profiled longitudinal edges into which stiffening sections are inserted so that they can span across a corridor without deflecting excessively. Stiffening sections up to 70 mm deep may be required depending on the span (i.e. corridor width). Special systems with self-supporting mineral-fibre boards can achieve a fire resistance rating of up to F 90 for exposure to fire from above and below.

6

1 Modular grid ceiling with mineral-fibre tiles
   a Rigid hanger
   b Main runner (on modular grid)
   c Inclined bracing
   d Splice connector between main runners
   e T- or Z-shaped stiffening ribs
   f Angle section (2 angle sections used for demountable tiles)
2 Self-supporting corridor ceiling (special fire-resistant tiles in metal trays), supported on perimeter detail, fire resistance class F 90 – AB for exposure to fire from above and below
   a Special fire-resistant board
   b Intumescent strip
   c Strip of mineral wool
   d Threaded bar
   e Metal tray
   f Wall angle
3 Hinged access panel
4 Various main runners for modular grid ceilings
5 Modular grid ceiling with main runners in both directions, square metal trays, Terminal 2, Munich Airport, 2003, K+P Architekten
6 Perforated metal modular grid ceiling (room acoustics) with system luminaires and ventilation via the members on the modular grid, German Centre, Shanghai, 2005, Frank Feng Architects



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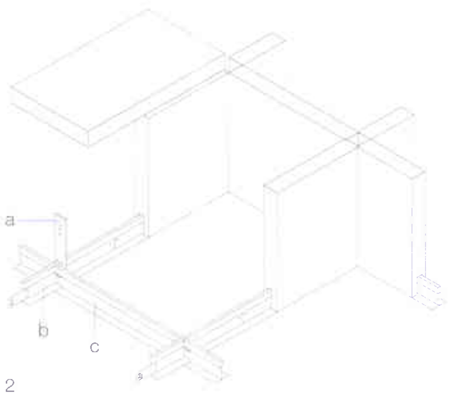

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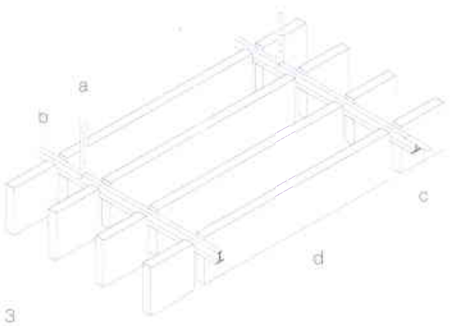

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Self-supporting plasterboard ceilings can consist of folded boards. The permissible spans of such U-shaped elements depend on their web depth. Alternatively, they can be fixed to a self-supporting metal framework. Used in conjunction with a layer of mineral wool, such self-supporting plasterboard ceilings can achieve a fire resistance rating of up to F 90 for exposure to fire from above and below.
Where fire protection is required, ceiling systems with an exposed metal soffit require a layer of mineral board material or mineral wool insulation on the back to guarantee the fire resistance.

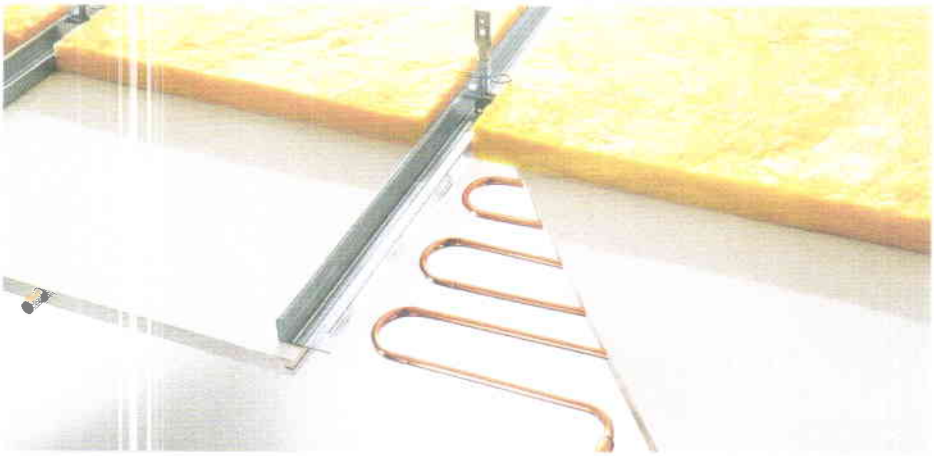
Modular panel ceilings
Modular panels are much longer than they are wide. Metal ceiling systems (aluminium or steel) are laid on or clipped to supporting rails which have lugs underneath at a regular pitch that engage with the bent-up edges of the panels. The lugs on the rails must match the width of the panels; lug width and lug spacing (= system joints) are constant (Fig. 1). The minimum width of a panel corresponds to the lug spacing on the supporting rail. Wider panels must be equal to an exact multiple of the lug spacing and system joints minus one joint.

The supporting rail module is equal to the panel width plus system joint. Selecting a supporting rail module fixes the panel widths (e.g. smallest panel width that can be installed) and the combination of different widths. The supporting rail module determines the number of alternative ceiling modules that can be used. Various panel and joint widths can be chosen depending on the module. The system joint can be left open, or closed with special filler strips.

Modular panel ceilings are suitable for integrating lighting, HVAC items, etc. The panels are available in different colours and surface finishes. Different panel widths, different joint designs and changing the direction of the panels are the main architectural options. Metal panel systems are generally suitable for wet areas and there are also systems available for use outdoors (e.g. constructions designed to resist ball impacts).

Ceiling systems with open soffit
Luminous ceilings consist of suspended open grids with a certain web depth. The grids can have square, rectangular, circular or honeycomb formats, and the materials used are aluminium or steel with various coatings, also plastics. The grids

1 Modular panel ceiling with clip-in metal panels
2 Cell ceiling with square/rectangular format
 a Special hanger
 b Main runner
 c Cross-runner
3 Schematic view of louvre ceiling
 a Hanger
 b T-shaped main runner
 c Splice connector between main runners
 d Ceiling louvres
4 Cooling ceiling system with integral copper coil
5 Cooling/heating ceiling with plain plasterboard
6 Cooling/heating ceiling with metal trays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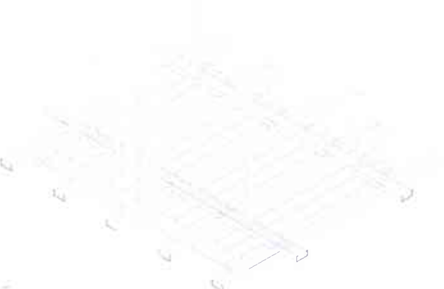
are either supported on T-sections or are joined together seamlessly and suspended directly from the floor above. One typical arrangement is to fit lighting units above the level of the grid, which leads to an indirect lighting effect in the room below, making this system suitable for rooms where glare could be a problem. The spacing between the lights fitted to the underside of the suspended floor should be equal to twice the distance between soffit and suspended grid. Specific lighting effects can be achieved in certain areas of the room below by positioning certain webs of the grid at an angle. Choose the grid size to suit the respective purposes regarding lighting and architectural requirements. HVAC components, luminaires, downlights, etc. can be integrated as required.

Cell (egg-crate) and louvre ceilings are systems consisting of vertical strips or panels, usually made from mineral-fibre board (Figs. 2 and 3). This arrangement means that the sound absorption surface of the ceiling is much greater than is the case with horizontal boards. Lighting units can be installed above the ceiling. The vertical boards allow the light to reach the room below but without causing any glare. Building services installed above the ceiling are readily accessible. It is usual to paint such services in a dark colour so that they remain virtually invisible.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Cooling ceilings

Ceilings are being used more and more to satisfy interior climate functions. In modern office buildings, with their numerous heat sources such as photocopiers, computers and artificial lighting, but also incoming solar radiation, the dissipation of heat is an essential requirement. Instead of conventional air-conditioning systems, which lead to considerable circulation of the interior air and hence also unpleasant draughts and airflow noise, cooling ceilings enable heat to be dissipated over a large area without any of these disadvantages.

A cooling ceiling always has a direct effect on the heat sources in the room below (radiation), but also an effect on the air in the room (convection). The radiation/convection proportions can vary depending on the construction of the cooling ceiling system and the air circulation in the room. The ceiling is normally kept cool by way of closed water or air circuits installed on or behind the soffit materials – generally plasterboard or metal (Figs. 4–6).

In flooring systems we distinguish between dry subfloors and prefabricated floor systems:

- Dry subfloors are mainly used in housing, and in particular as part of refurbishment and renovation measures.
- Prefabricated floor systems such as hollow and raised access floors are used in office and commercial applications.

Table T1 provides an overview of dry subfloors, hollow floors and raised access floors, their applications and the materials used.

Dry subfloors

Dry subfloors are floor finishes without voids that are capable of transferring loads to the underlying structure and are laid over the whole area of a floor without the use of wet trades. Such floors include:

- Timber planks or boards laid on timber joist floors or supporting battens.
- Dry subfloor systems, which are normally separated from the underlying floor (floating) and are characterised by:
- the avoidance of construction moisture,
- the fact that they can be loaded and used more or less immediately,
- low self-weight,
- minimal overall depth.

These properties mean that dry subfloors are ideal for upgrading existing buildings and for refurbishing timber joist floors (see table T2).

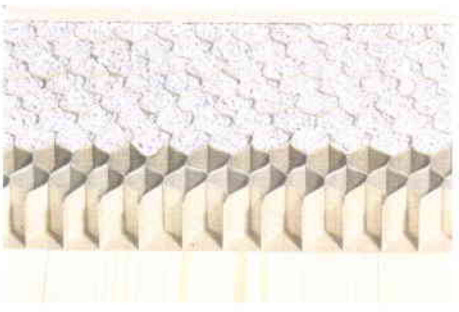
The individual subfloor systems are mainly distinguished by the board materials used, which are determined by the application, the demands placed on the materials by the use of the floor and the intended floor covering. The following dry subfloor systems are in widespread use:

- Particleboard with perimeter tongue and groove joint – min. thickness 19 mm but depends on spacing of supports, 25 mm when laid as a floating floor.
- Gypsum fibreboard subfloor – 2 No. 12.5 mm factory-glued boards with perimeter stepped joint.
- Gypsum fibreboard subfloor made from dense gypsum fibreboard with factory-cut rebated or "click-fit" joints.
- Dry subfloor elements made from three layers of special plasterboard, with tongue and groove joints on long sides, rebated joints on other sides, total thickness approx. 25 mm.
- Dry subfloor elements made from 12.5 mm plasterboard or gypsum fibreboard glued on site
- Cement-bonded wood particle boards laid in one or more layers.
- Mineral boards (cement-bonded, ceramic) laid in one or more layers.

Many dry subfloors are produced as composite elements, i.e. a layer of mineral, wood-fibre or PS rigid foam insulating material is bonded to the underside of the board material to function as impact sound insulation.
The dry subfloor elements are laid on site with staggered joints, simply butted together if not produced with rebated or tongue and groove joints, and secured

T1: Flooring systems in dry construction, properties and applications

Flooring system	Description	Applications	Materials	Fire rating
Dry subfloors	Dry subfloors consist of loose fill for levelling purposes, impact sound insulation and dry flooring materials, depending on requirements. They are offered by manufacturers as composite systems or as individual boards. In the latter case, the boards are simply bonded together on site.	Modernisation, refurbishment; housing, offices, conversion of roof spaces; ideal for floor finishes on top of timber joist floors.	Flooring materials made from plasterboard, gypsum fibre board, wood-based products or mineral boards.	F30–F120
Hollow floors	Screeded floors with closed surface on "vaults" and permanent formwork; the void between structural floor and floor finishes (40–200 mm) provides space for building services. Supports are spaced at 200–300 mm centres. Total overall depth 65–190 mm; especially suitable for heavy loads.	Offices and corridors with high services density; computer rooms, workshops and production facilities with normal requirements regarding flexibility of use and accessibility to services.	Supports made from plastic, metal or stone; permanent formwork made from plaster board, gypsum fibreboard or steel plates; self-levelling screed.	F30–F90
Raised access floors	Flexible flooring systems made from individual panels on a standard 600 x 600 mm grid; raised access floors are supported above the structural floor on pedestals. Various floor depths are available depending on the usage (60–1200 mm and even more). The panels can be removed/replaced at any point.	Offices and corridors with high services density and/or requirements regarding changeability of plan layouts; computer rooms, switchgear rooms, radio and television studios, laboratories, workshops and clean rooms with high requirements regarding flexibility of use and accessibility to services.	Wood-based products, steel, aluminium, metal trays with mineral filling, reinforced light weight concrete or concrete filling, gypsum fibreboard, calcium sulphate.	F30–F60



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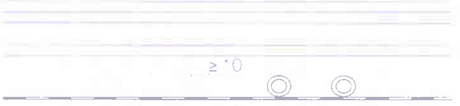

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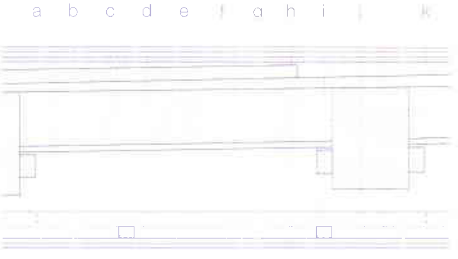

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with glue and/or mechanical fasteners to ensure that loads are spread across the floor. Additional make-up or levelling layers of suitable board materials may be specified to increase the bending strength of a dry subfloor (Figs. 2 and 3).

Preparing the structural floor
Structural floor surfaces without a basement underneath (i.e. ground floors) must be waterproofed according to the appropriate DIN 18195 loading group. Owing to the residual moisture frequently still present in reinforced concrete slabs, a complete covering with a diffusion-resistant material is necessary. On timber joist floors, especially in conjunction with floorboards, a diffusion-permeable material such as corrugated or plain cardboard etc. is required to retain any loose materials/fibres.

Levelling the structural floor
As almost all dry subfloor boards exhibit a low bending strength, they must make contact with the underlying floor over their entire surface area. In the case of any unevenness in the structural floor, this calls for levelling measures, which depend on the extent of the unevenness found (see table T3).

Dry loose fill
To compensate for any unevenness or falls in the structural floor > 20 mm, use a dry loose fill. Loose fill materials can serve as the sole or additional thermal insulation and can also improve the impact sound insulation of a suspended floor construction (Figs. 4 and 5).
Lay a loose fill directly on the structural floor. Some form of sheeting material will be required to retain loose materials on floors with unsealed joints, e.g. timber floorboards. Turn the sheeting material up the perimeter walls.
In order to guarantee that the loose fill material is adequately compacted and can therefore distribute the loads properly, a certain minimum depth is necessary (15–20 mm depending on the material, approx. 5 x max. particle size).

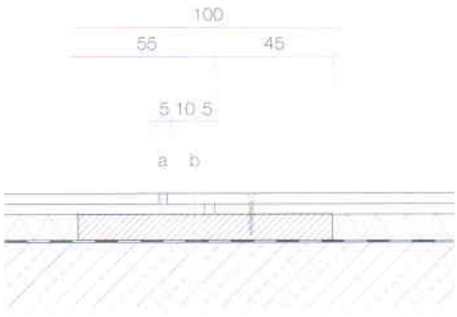
T2: Screed drying times and moisture quantities

Type of subfloor	Min. thickness of flooring material	Drying time	Ready for loading after...	Moisture quantity
Dry subfloor	≥ 20 mm	≤ 24 h	1 day	≤ 0.01 l/m²
Asphalt	40 mm	36 h	1/2 day	0.3 l/m²
Calcium sulphate screed	35 mm	≥ 24 days	3 days	0.8 l/m²
Cement screed	40 mm	≥ 26 days	2 weeks	0.5 l/m²

T3: Measures to compensate for any unevenness in the structural floor surface

Unevenness	Remedial measures
≤ 2 mm	Rigid foam or mineral-fibre insulating boards
≤ 5 mm	Soft foam materials (e.g. made from polyethylene)
≤ 10 mm	Self-levelling screed Binding compound
10–20 mm	Self-levelling compound plus fine-grain aggregate, mixed in the ratio 1:2 (e.g. washed sand, grading curve 0/2.0 mm)
10–25 mm	Cement-sand mixes in the ratio 1:5
> 10 mm	Dry loose fill

1 Gypsum fibreboard dry subfloor on loose fill between cardboard honeycomb
2 Stepped (rebated) joint between boards
3 Tongue and groove joint between boards
4 Dry subfloor on loose fill (load distribution board above loose fill depends on system)
5 Refurbishment of timber joist floor with floating dry subfloor, loose fill to compensate for different levels and suspended ceiling
a Aerated concrete plank for rough levelling
b Loose fill to complete levelling
c Pugging
d Particleboard or floorboards
e Pugging boards
f Impact sound insulation
g Floating dry subfloor
h Ceiling material
i Cross-runner
j Main runner
k Hanger



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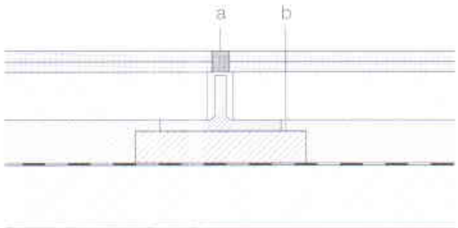

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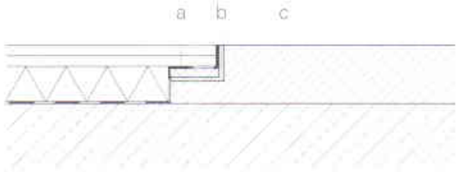

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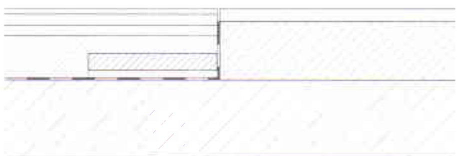

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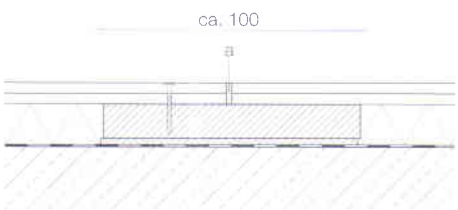

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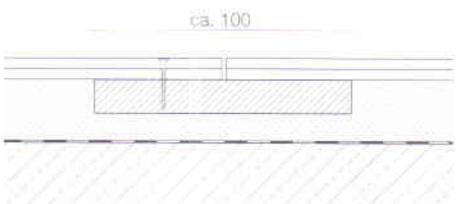

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1 Movement joint detail
  a Resilient joint compound
  b Timber bearing
2 Detail of movement joint over loose fill
  a Resilient joint compound
  b Timber bearing
3 Detail of junction with wet screed
  a Strip of insulation to prevent structure-borne sound transmissions
  b Angle bearing rail
  c Bonded screed
4 Detail of junction with wet screed, with wood-based board product as bearing pad around perimeter
5 Butt joint in doorway
  a Resilient joint compound
6 Butt joint in doorway over loose fill

Depending on the particle structure, some dry fill materials can be spread out to a feather edge (i.e. zero thickness). A layer of loose fill > 40–60 mm deep (depending on material) will require subsequent compaction. If the difference in levels exceeds 60 mm, rough levelling can be achieved by laying additional building or insulating boards so that the loose fill is limited to max. 60 mm.

The loose fill can be laid directly around service installations (cold and hot water, waste water, electric cables, etc.), but always maintain a minimum coverage of 10–20 mm (depending on material) of loose fill material over the service component, measured from the topmost point. Fix all service components to the structural floor with mechanical fasteners so that any dynamic movements do not cause fill material to creep under a component and lift it.

When using dry subfloor systems with tongue and groove or similar joints, it is advisable to lay sheeting over the loose fill to prevent loose fill material infiltrating and obstructing the joints. However, such a covering is unnecessary in systems with overlapping rebates.

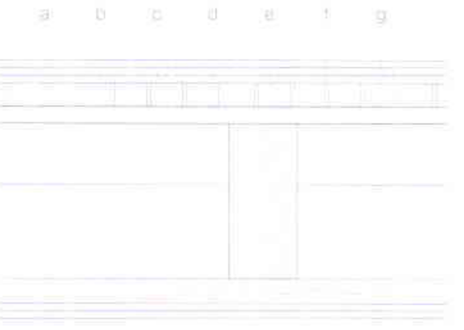
Specification for insulating materials
It is only possible to lay insulating materials directly on the structural floor when the unevenness is minimal; a levelling layer will be required if the unevenness is significant. As dry subfloors have a lower bending strength and lower self-weight, choose an insulating material with a higher compressive strength than would be the case when using a cement screed or similar wet construction. Insulating materials that are too soft, or rather exhibit inadequate stiffness, yield under load (e.g. foot traffic), which can lead to vibrations being transferred to furniture and fittings.

When using hard floor coverings such as ceramic or stone tiles, a bedding that is too soft below the subfloor results in an increased risk of cracking. Rigid foam materials must be grade PS 30 or higher; fibrous insulating materials in the form of impact sound insulation boards are also suitable for dry subfloors.

Floor coverings for dry subfloors
Floor coverings for dry subfloors can be laid as soon as any adhesive used has fully cured. The following floor coverings are suitable:
- Resilient coverings (PVC, linoleum)
- Textile coverings (carpeting)
- Hard coverings (ceramic tiles, wood-block and laminated floors)

Depending on their thickness, products supplied in rolls, e.g. carpeting, PVC, may require a skim coat over the entire floor area so that joints between boards do not show through later. The majority of board materials will also require a min. 2 mm skim coat over the entire floor area if resistance to chair castors is an important requirement. Do not skim-coat floors that are to be finished with tiles or wood-block flooring.

Ceramic and stone tiles should not be larger than 300 x 300 mm. DIN 18155 specifies a tensile bending strength > 25 N/mm^2 for a ceramic floor covering. Use the thin-bed method for laying tiles on a dry subfloor. Mineral-bonded boards (e.g. gypsum boards) are suitable as a backing for tiles, but wood-based board products are not suitable owing to their shrinkage and swelling behaviour. Seal the surfaces of dry subfloors in wet areas (e.g. bathrooms). The tile adhesive, sealant and dry subfloor must all be compatible with each other if the long-term reliability of the subfloor is to be ensured.



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7 Example of a timber joist floor with good sound insulation due to the use of a dry subfloor combined with ballast and a soffit lining fixed via resilient channels
a 2 No. 10 mm gypsum fibreboard dry subfloor
b 10 mm insulating board
c 30 mm cardboard honeycomb with sand filling, g = 1.5 kN/m²
d 22 mm particleboard
e 80 x 200 mm timber joists at 625 mm centres
f 27 mm resilient channel
g 2 No. 10 mm gypsum fibreboard

Owing to their similar shrinkage and swelling behaviour, wood-block flooring is best laid on wood-based board products. Mineral subfloors, e.g. gypsum boards, should be checked with regard to their suitability for wood-block flooring; so-called low-shear wood-block flooring types such as multi-ply glued real-wood parquet laminate flooring or laminated wood flooring are becoming very popular. Depending on the type of subfloor, expansion joints every 10–15 m will be necessary. The expansion joints between wall and subfloor, or between wall and wood-block floor finish, must be at least 10 mm.

Junctions
The acoustic decoupling of the subfloor from adjoining vertical building components (walls, columns) is achieved by laying strips of insulation approx. 10 mm thick along all edges.

Junctions with solid floors, stone flags, ceramic tiles or hollow floors require bearing angles. Joints between dry subfloor elements that occur in doorways require a loadbearing support in the form of strips of subfloor material or timber boards/planks. In order to prevent an acoustic bridge at this point, make sure that the supporting material is also laid on a strip of insulating material (Figs. 1–6).

Impact sound insulation and dry subfloors
Floating dry subfloors can be used to improve the impact sound insulation of concrete and timber joist floors. The improvements in the impact sound reduction index that can be achieved essentially depend on the construction of the structural floor, the make-up of the dry subfloor and the dynamic stiffness of the insulating material, and lie between 17 and 27 dB. The higher values are achieved with a combination of loose fill plus impact sound insulating boards made from a fibrous material.

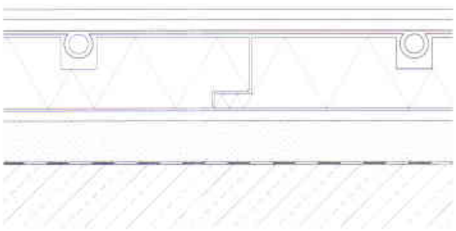
For lightweight suspended floor systems, e.g. timber joist floors, it is not possible to specify an improvement in the impact sound reduction index that is generally valid. The standard laboratory measuring procedure refers exclusively to heavyweight suspended floors. But the acoustic behaviour of floating screeds on lightweight suspended floors is different to that on solid concrete floors. Generally, a dry subfloor on a lightweight suspended floor achieves only about one-third of the impact sound reduction index possible with the same subfloor on a concrete suspended floor. So the values determined for concrete floors cannot be transferred to lightweight suspended floors, and instead serve merely as a guide when comparing the acoustic quality of different dry subfloor systems.
A dry subfloor system can improve the impact sound reduction index of a timber joist floor by 7–17 dB, depending on the construction. The higher values are achieved with a combination of loose fill plus impact sound insulating boards made from a fibrous material (Fig. 7).

Fire protection and dry subfloors
A floating screed or floor covering is required on timber joist floors with a fire resistance rating ≥ F 30 which enclose an interior space and are exposed to fire from above. The screed or covering can also be in the form of a dry subfloor system. In the event of a fire, the dry subfloor protects the loadbearing members against premature failure and, for instance, penetration of the floor.

According to DIN 4102-4, dry subfloors comprising plasterboard and wood-based board products can be used instead of mortar-, gypsum- and asphalt-based (wet) subfloors up to a fire resistance rating of F 60. For other board materials, different types of construction and higher fire resistance ratings (F 90–F 120), please refer to the relevant test certificates.

DIN 4102-4 specifies that layers of insulation below dry subfloors must be made from mineral fibres complying with building materials class B2 at least, with a density ≥ 30 kg/m³. Such materials are, however, unnecessary when plasterboard ≥ 9.5 mm thick or gypsum fibreboard ≥ 10 mm thick is used instead. Additional layers of rigid foam are permitted and do not have a negative effect on the fire resistance, provided they are class B2-compliant. Appropriate loose fill materials can be used instead of a layer of insulation comprising mineral-fibre boards.

Integrating underfloor heating into dry subfloors
Boards with preformed channels for the underfloor heating installation are preferred when underfloor heating is to be installed. The thermal conductivity of the subfloor elements must be compatible with the heating system. In order to improve the transfer of heat from the underfloor heating to the subfloor materials, heat diffusion plates are usually installed between the heating level and the subfloor elements (p. 60, Fig. 1).
In order to achieve an adequate surface temperature in the floor covering over the whole floor area but with a low flow temperature, space the heating pipes no more than 150 mm apart. The temperature at the heat diffusion plates may not exceed 45°C for any extended period of time, otherwise there is a risk of dehydration of the gypsum, which changes the microstructure of the material. The flow temperature should therefore be 45–50°C.



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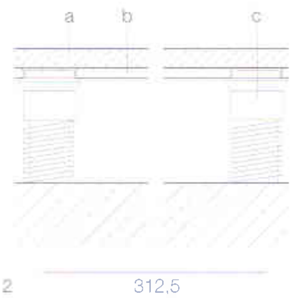

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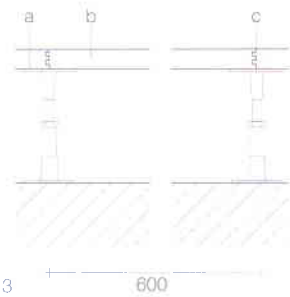

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Hollow floor systems
Hollow floor systems (also called cavity or shallow access floors) are flooring systems with integral voids for routing building services.
Hollow floors are used primarily in areas of the building where there are conventional requirements regarding access to services and no large duct/pipe cross-sections are necessary.

Access to the voids is via planned or retrofitted access panels in the floor level (retractable services supply units).
The features of hollow floor systems are as follows:
- Low overall depth
- High load-carrying capacity
- Advantageous fire protection properties
- Seamless, closed surface

The loadbearing layer is formed by a self-levelling screed laid on permanent formwork or a layer of boards on a supporting construction. Cement screeds or dry subfloors can be used instead of a self-levelling screed (Fig. 2).
Technical requirements, testing methods and loading classes for hollow floors are given in DIN EN 13213.

The following forms of construction can be used as permanent formwork for the layer of screed:
- Deep-drawn PVC material supplied in rolls.
- Resilient moulded panels with factory-formed supports made from screed material or plastic.
- Factory-punched gypsum boards; adjustable PVC screw pedestals are inserted into the punched holes on site so that the floor elements can be levelled.

Hollow floors in dry construction normally consist of dense gypsum fibreboards in thicknesses between 25 and 40 mm. Use a double layer with staggered joints for very heavy loads. Glue together the perimeter tongue and groove joints. The standard support grid is 600 x 600 mm (Fig. 3).

As with raised access floor systems, the supporting construction can be in the form of individual metal pedestals or linear stringers (square metal sections). The type and arrangement of the pedestals (e.g. smaller grid) or the span of the flooring materials between the stringers determines the load-carrying capacity of the floor. To increase the load-carrying capacity, fix additional members between the pedestals as a bearing for the flooring materials. A half-size grid (300 x 300 mm) or additional members between the pedestals are often necessary to strengthen the perimeter zones, which are weaker in structural terms.

The advantages of hollow floors in dry construction are as follows:
- A much lower level of construction moisture, no drying-out times.
- Floors can accept loads immediately and other building trades (e.g. floor coverings) can gain access quickly.
- Low load on structural floors due to low self-weight of hollow floor construction.
- Lower costs compared to raised access floors.

Systems with stringers are widely used for building the terraced constructions required for spectator seating, lecture theatres and cinema auditoriums.

Raised access floor systems
Raised access floor systems (also called platform floors) are industrially prefabricated floor panels supported on special pedestals.

Raised access floor systems are installed where there is a high density of services in the floor with high requirements regarding accessibility and retrofitting of further installations (e.g. computer rooms, transformer substations, corridors in office buildings, computer centres). Every floor panel is simply laid loose on the pedestals and can therefore be easily removed to gain access to the floor void at any point.

In addition to electrical installations, the floor void can be used to route water, waste-water and compressed-air lines, pneumatic tube conveyors or central vacuum-cleaning systems, and can form an integral element in an air-conditioning system (plenum).
Technical requirements, testing methods and loading classes for raised access floors are given in DIN EN 12825.

Normally, raised access floor constructions up to 1250 mm high – and even more – can be achieved, depending on the particular system. When determining the layout of a raised access floor grid in a room, avoid small, narrow perimeter panels. Install pipes and ventilation ducts parallel to the wall at a clear distance of at least 100 mm from the wall so that there is sufficient space to erect the supporting construction (pedestals).

Table T4 shows a checklist for system properties which are suitable for tenders or comparing different systems. The system characteristics specified by the manufacturer should be taken into account, but the designer can also specify minimum values.

1 Dry subfloor with underfloor heating and dry loose fill
2 Hollow floor system with self-levelling screed, plasterboard gypsum fibreboard permanent formwork and adjustable PVC supports
a Self-levelling screed
b Plasterboard gypsum fibreboard permanent formwork
c Adjustable PVC support filled with calcium sulphate screed
3 Hollow floor system in dry construction made from dense gypsum fibreboard and metal pedestals
a Adhesive
b Dense gypsum fibreboard
c Interlocking joint – adhesive
4, 5 Hollow floor system made from dense gypsum fibreboard, DIN 4102 class A1
Highlight Towers, Munich, 2004, Helmut Jahn


4


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T4: Checklist for system properties of raised access floors

Type/manufacturer		**Product data**
System properties		
Board thickness		mm
Board weight without floor covering		kg
Board grid		mm
Min. depth (FFL)		mm
Adjustable up to		mm
Materials		
Boards		
Edge trim		
Finish to underside		
Finish to top side		
Possible floor coverings		
Supports		
Load-carrying capacity		
Point load (f ≥ 1/300)		kN
Point load (factor of safety = 2)		kN
Ultimate load		kN
Fire protection		
Building materials class		
Fire resistance rating		
Sound insulation		
Normalised impact sound pressure level	L	dB
Weighted impact sound reduction index	TSM	dB
Flanking sound reduction index	R	dB
Electrostatic charges		
Earth leakage resistance		Ω
Cost		€/m²

according to RAL 62941 testing specification

Components of raised access floors
Raised access floors comprise two main components:

- Floor panels, which can be made from various materials with various floor coverings suitable for different module sizes.
- Supporting construction consisting of pedestals in various lengths, in various materials and designs, and with various load-carrying capacities.

Floor panels
The standard module for raised access floor panels is 600 x 600 mm. Some manufacturers can also supply 600 x 1200 mm panels.

The following materials are used for raised access floor panels (see table T5):

- Wood-based products (pressed particleboard, plywood) with and without facing materials
- Aluminium
- Steel
- Steel in combination with a mineral filling (calcium sulphate screed, lightweight concrete)
- Fibre-reinforced mineral building materials (calcium sulphate, gypsum, cement, concrete)

The requirements for offices, computer centres and rooms with higher loads can be met by specifying a suitable floor construction, mechanical performance and density for the floor panels plus additional strengthening measures (e.g. bonding sheet steel to the tension zone/underside of wood-based board products or mineral boards). Additional strengthening measures can even permit the use of lightweight fork-lift trucks on such floors. Wood-based board products and mineral boards are generally factory-fitted with plastic edge trims.

The wood-based product used most often for floor panels is dense particleboard (density = 680–750 kg/m³). These are generally finished with sheet aluminium or aluminium foil on the underside to protect against moisture. Such panels are relatively easy to cut to suit the building contours on site. The weight of a standard 600 x 600 mm panel lies between 11 and 15 kg. Ventilation grilles, electrical connections, etc. are very easy to integrate. The disadvantages of wood-based board products are their moisture-related shrinkage and swelling and their combustibility.

Aluminium panels have multiple ribs. The advantages of these panels are their low weight, good dimensional accuracy and moisture resistance. However, aluminium panels are expensive, loud underfoot and difficult to cut on site to fit the building contours. The good thermal conductivity of the material leads to an increased transfer of heat into the floor void, which has a negative effect on the thermal comfort in the room. Although aluminium is incombustible, it fails very quickly in fire due to its low melting point (approx. 500°C).

T5: Overview of common raised access floor panels and their properties

Floor panel	**Strength**	**Weight**	**Fire resistance**	**Combustibility**	**Sound-insul.**	**swelling/ shrinkage**	**Comfort underfoot**
Wood-based board product with aluminium foil on underside	o[1]	++	–	o[2]	o	–	o[1]
Wood-based board product with sheet steel on underside	+	+	–	–	+	–	o
Fibre-reinforced calcium sulphate panel	+	o	++	++	++	+	++
Lightweight concrete panel	+	o	++	+–	++	+	++
Steel tray with mineral filling	+[1]	o[1]	++	++	+–	+	++
Closed, empty metal tray	–	– –	–	++	–	o	o
Closed metal tray with mineral filling	o	o	o	++	o	o	o
Diecast aluminium plate	+	+	–	++	o	o	o
Framed steel plate	+[1]	o	–	++	o	o	o

++ very good; + good; o satisfactory; – unsuitable/unsatisfactory properties
[1] Property depends on actual density of floor panel
[2] Property depends on complex influences due to composition and processing

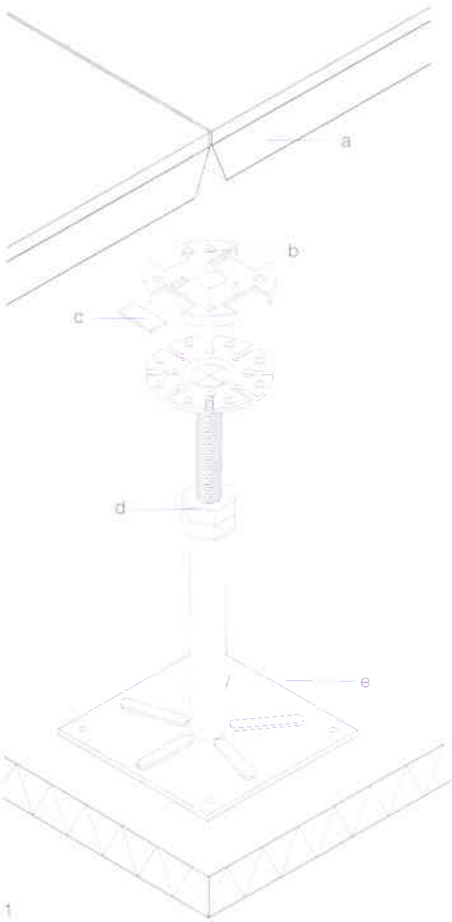
2

which means that flooring systems with aluminium panels do not even achieve an F 30 fire resistance rating.

Steel panels are available in two different versions: a welded construction with spot-welded cover plate and a deep-drawn base plate (tray), shaped to suit structural requirements, plus a spot-welded cover plate. Steel panels behave similarly to aluminium panels, but are heavier and stronger. However, they require some form of coating to protect them against corrosion.

Composite panels made from steel and a mineral material are heavy and provide an essentially homogeneous surface for carrying loads. However, it is very difficult to adapt them to building contours on site. They are incombustible but cannot achieve fire resistance ratings > F 30.

Mineral, fibre-reinforced panels (dense gypsum fibreboard, fibre-reinforced calcium sulphate panels) have the advantage of being incombustible and can achieve fire resistance ratings up to F 60. They are relatively easy to cut to suit building contours on site and a standard 600 x 600 mm panel weighs between 13 and 22 kg. Ventilation grilles, electrical connections, etc. are very easy to incorporate because versions with perforated panels are available.



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Supporting construction
Height-adjustable pedestals, usually metal, support all four corners of each floor panel. The head of the pedestal is fitted with a noise-attenuating plastic pad which also ensures the correct positioning of the panel corners. The pedestals require bracing in the case of high loads, forces in the plane of the floor panels and for heights ≥ 700 mm. This is usually achieved by providing X-bracing or tensioned steel wires (Fig. 1).

The base of each pedestal is fixed to the structural floor by means of mechanical fasteners or adhesive. One-part polyurethane adhesives are suitable; the curing time before the floor can be loaded is approx. 20 hours, but the adhesive takes 1–2 weeks to cure fully, depending on the climatic conditions.
Additional members (stringers) can be fitted between the pedestals to provide a bearing for the flooring materials and thus increase the load-carrying capacity.

Floor coverings
The floor coverings are generally applied directly during the production of the panels themselves. Stone and ceramic tiles, wood-block flooring and HPL (high-pressure laminate) are the hard finishes possible, PVC, rubber and linoleum the resilient finishes. PVC coverings are available in standard, anti-static, electrically conductive and non-conductive varieties. Rubber coverings are available in standard or highly conductive forms. Linoleum is only available with normal conductivity. Flatweave, woven and tufted textile coverings are also possible.

The floor coverings to raised access floors have to satisfy requirements regarding wearing resistance, suitability for chair castors, squareness, accuracy of pattern, cutting resistance, anti-static properties, peeling resistance, light-fastness, compatibility with adhesives, etc.

Ventilation systems in raised access floors
The air management in the void up to the ventilation grilles can be carried out in one of two ways:
- Open ventilation: air supply via underfloor plenum (displacement ventilation)
- Closed ventilation: air supply via pipes or ducts

3


1 Typical construction of a raised access floor pedestal
a Floor panel
b Sound-attenuating bearing pad
c Shim (to aid assembly)
d Locknut
e Bond with structural floor
2, 3 Raised access floor in the form of sheet steel trays with calcium sulphate screed filling. Integration of communications and building services plus underfloor heating/cooling in entrance hall to Bayer offices, Leverkusen, 2002, Helmut Jahn
4 Heating and ventilation plenum under raised access floor

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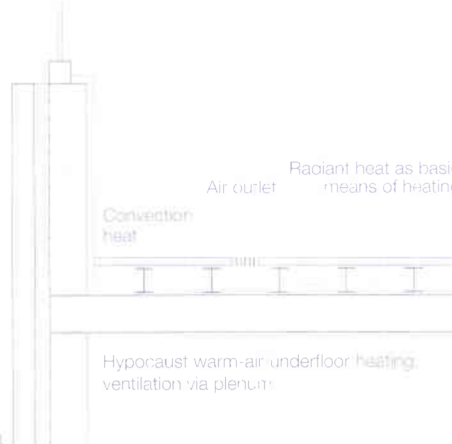

The air is fed into the room above through specific outlets in the raised access floor. The climatic requirements of the usage and the fresh-air supply system determine the choice of air supply to the room.

Air supply via perforated panels or gratings
The overpressure in the floor plenum causes fresh air to flow into the room through the openings in the floor panels. The velocity can be regulated, and by using an appropriate arrangement of perforated or slotted panels, it is possible to achieve conditioned zones and hence a consistent exchange of air. Besides air-handling aspects, the structural properties of ventilation grilles in the floor must also be considered. Ventilation panels can also be fitted with a damper to adjust the amount of incoming air. When using the displacement ventilation principle to ventilate a room, the air supply is via ventilation panels and non-perforated, air-permeable carpeting.

Air supply via floor outlets (diffusers)
These fresh-air outlets can be connected directly to the network of air-conditioning ducts via flexible hoses or can be supplied with fresh air directly from the floor plenum. The use of floor outlets enables conditioning of the interior air and ventilation without causing any draughts. Floor outlets can be fitted with optional dirt traps and dampers to control the inflow of air.

Air supply via gratings
If relatively large quantities of air are to be fed into a room, the air supply takes place via gratings. However, these must be positioned in the room so that they do not cause draughts, e.g. at workplaces.

Warm-air heating
The plenum beneath the raised access floor can also be used for space heating. This system is identical to the ventilation system. To reduce the temperature, the air inlets are closed so that the air simply circulates in the underfloor plenum and gradually cools (Fig. 4).

System accessories for raised access floors
Retractable services supply units
Fittings with connections for retractable services supply units, central vacuum-cleaning systems, built-in fire extinguishers, smoke detectors and air outlets can be integrated into the raised access floor to suit virtually all specifications.

Intermediate floors
A high services density makes it necessary to create additional installation surfaces. Intermediate floors are the answer here, which consist of support brackets on the metal pedestals into which sheet steel trays are fitted. This also increases the resistance to horizontal loads. Such intermediate floors can be designed to accept foot traffic if required.

Bracing elements
Bracing members on the grid lines of the floor or tension wires can be used to improve the structural stability of a raised access floor. In addition, bracing helps to ensure tight joints between the floor panels. We distinguish between bracing members that carry floor loads as well as those providing purely bracing functions. The bracing members are clipped or screwed to the pedestals. Additional bracing is recommended for floor heights ≥ 700 mm.

Bulkheads
Three different types of bulkhead may be necessary below a raised access floor:
- Ventilation bulkhead
- Fire barrier
- Sound barrier (absorbent bulkhead)

Such bulkheads consist of single- or multi-leaf constructions made from mineral wool, gypsum or calcium silicate boards or aerated concrete blocks, depending on requirements (p. 64, Fig. 1).

Expansion joints
The raised access floor may on no account bridge over expansion joints in the structure. In order to accommodate horizontal displacement or differential vertical settlement inconspicuously in the construction, fit preformed expansion joint strips into the raised access floor at suitable points. Horizontal strength is restored by providing tension wires or bracing members (pp. 64/65, Figs. 2 and 6).

Cable trays
Cable trays are used where the building services follow certain routes and the floor depth is ≥ 700 mm. To do this, attach C-sections to the pedestals with clamps at the desired height. The actual cable trays carrying the electric cables, conduits and small pipework are supported on the C-sections. Another advantage of cable trays is that in the event of the sprinkler system being triggered, cables do not lie in a pool of water (Fig. 8).

Underfloor heating
When using floor panels made from thermally conductive materials (gypsum fibreboard, steel, concrete), underfloor heating elements can be positioned as required beneath the panels. The heating elements are made from insulating material with an aluminium heat diffusion plate on the top surface into which the heating pipes are clipped (Fig. 5).

Fascia panels
At stairs, platforms, etc. it is necessary to fit fascia panels to the sides to conceal or close off the floor void. If these fascia

1 Bulkhead beneath raised access floor
2 Raised movement joint profile
3 Fascia panel
4 Void below floor showing services tract
5 Example of underfloor heating suspended below raised access floor
a Floor finish
b Calcium sulphate screed
c Heating pipe
d Heat diffusion plate
e Thermal insulation
f Support member
g Pedestal
6 Flush movement joint profile
7 Perimeter detail, fascia panel or perimeter pedestals must be braced back to the structure with tension wires
8 System of trays for pipes and cables


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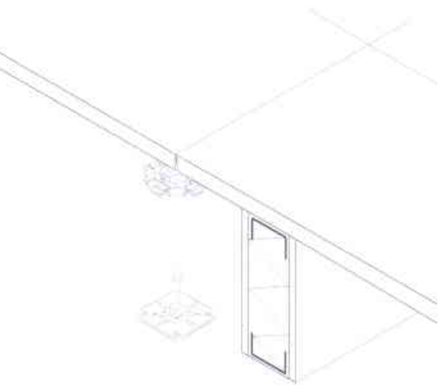
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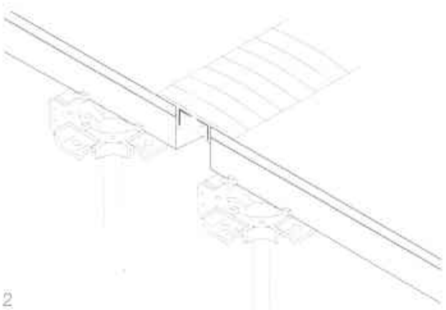
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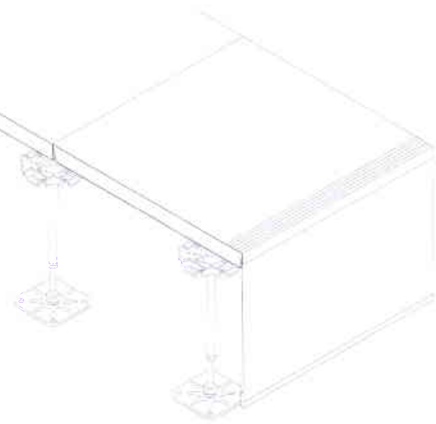
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panels are exposed, the top edges are fitted with stair nosing trims. An angle bracket at the base and a tension wire attached to the top guarantee a rigid construction (Figs. 3 and 7).

Junctions
Transitions between raised access floors and other floors (e.g. structural floor, screed), also junctions with hollow floors, require special preformed sealing strips or perimeter angles.

Bridge sections
Constructional circumstances may require that certain pedestals be left out and the raised access floor must be able to bridge over such areas.

Mechanical requirements to be met by floor systems
The estimate of the loads to be expected forms the basis for planning and selecting a floor system. Besides the distributed static loads per unit area, point loads, dynamic loads and abrasion are the action effects that floor systems have to withstand.

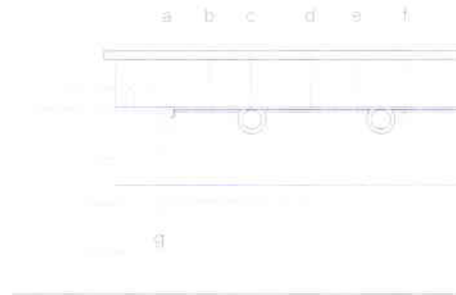
Point loads
When determining a point load, we simulate a local static load (e.g. table leg or shelving post).

Distributed loads
A distributed load is assumed to be a static load per square metre of floor area. The minimum loading capacity requirement for a floor system construction depends on the type of use.

Dynamic loads
Many factors determine the calculation of dynamic loads (e.g. due to fork-lift operations). As a rule, an appropriate safety factor is determined and the static load (e.g. permissible total load of vehicle) is multiplied by this. When selecting a floor covering for the raised access floor, make sure that the covering and its adhesive are suitable for such dynamic loads.

Loading classes
Floor systems are allocated to loading classes 1–6 to DIN EN 13213 (hollow floors) and DIN EN 12825 (raised access floors) depending on the application (see table T5). The main criterion for assessing the load-carrying capacity of a floor panel is the point load measured at the weakest point using a 25 x 25 mm steel stamp.

A nominal point load of 3000 N has proved to be adequate for office and commercial applications, but up to 5000 N may be required for computer rooms. A safety factor of 2 based on the ultimate load is



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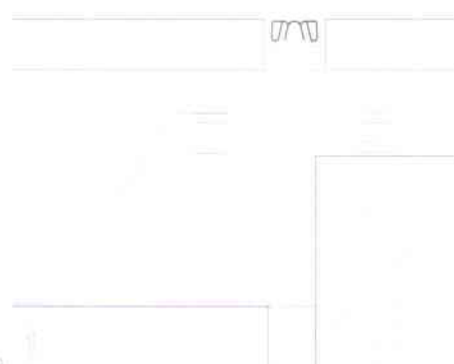
T5: Loading classes for floor systems to DIN EN 13213 (hollow floors) and DIN EN 12825 (raised access floors)

Class[1]	Ultimate load N	Nominal load[2] N	Loading step[3]	Examples of applications and uses
1	≥ 4000	2000	2	Offices with low occupancy rate
2	≥ 6000	3000	3	Standard offices
3	≥ 8000	4000	4	Rooms with higher static loads, lecture theatres, training centres, assembly rooms, treatment rooms, design offices
5	≥ 10000	5000	5	Light industrial operations, storage zones, work shops with light operations, libraries
6	≥ 12000	≥ 6000	6[4] and higher	Floors for fork-lift trucks, industrial and workshop floors, safe vaults

[1] Loading class to DIN EN 13213
[2] The nominal load is obtained by dividing the ultimate load by the safety factor $\nu = 2$.
[3] Loading classification according to the application guidelines for hollow floors
[4] Higher ultimate/nominal loads may be necessary for hollow floors subjected to high demands in specific cases. These should be specified in steps of 2000/1000 N.



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used here. The above loads are static, i.e. steady-state loads causing a maximum permissible deflection of 2 mm. The maximum load is 6 kN, but higher loads are possible with special systems. In the case of moving loads, a dynamic factor of up to 1.4 will need to be considered depending on the method used.

Additional framing members (trimmers) or pedestals must be provided where a floor system is weakened by cut-outs or openings.

Thermal and moisture requirements
Floor systems are designed for use in normal climatic conditions, i.e. a temperature of 15–30 °C and a relative humidity of 40–60%. Air-conditioning installations in the floor void must be designed in such a way that there are no extreme temperature or moisture differences in the void. In practice, defects are mostly attributable to unsuitable climatic conditions during the building phase.

Acoustic requirements
Floor systems have to provide sound-insulating properties (impact sound, airborne sound) with respect to sound transmissions between storeys and between adjacent rooms (flanking transmissions) (p. 66, Fig. 1).

The vertical airborne sound insulation is achieved by the floor system in conjunction with a heavyweight structural floor and a suspended ceiling. Board materials with a high weight per unit area and heavyweight ceramic or stone floor finishes result in improved airborne sound insulation due to the increase in the overall mass per unit area.

A floor system improves the vertical impact sound insulation of a suspended floor. The degree of improvement mainly depends on the increase in the impact sound reduction index ($\Delta L_{w,R}$) of the floor covering, the detail of the bearing of the floor panel on the top of the pedestal (e.g. via insulating plastic pad) and the bearing of the pedestal on the structural floor (e.g. adhesive with intermediate pad of insulating material) (see tables T6 and T7).

Special attention must be given to horizontal flanking transmissions between adjacent rooms beneath partitions built off the raised access floor. The insulation

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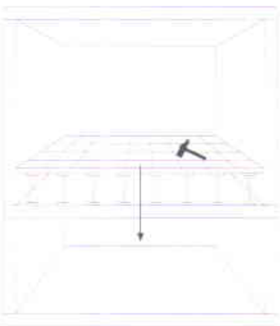

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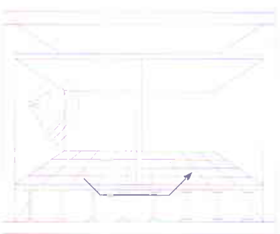

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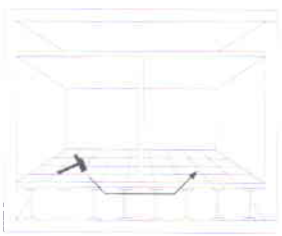

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to prevent such flanking transmissions is critical here, although the flanking transmissions via a raised access floor built using individual panels is less than a hollow floor with a continuous flooring material. As with ceilings, the sound transmission takes place mainly via the void. By building an absorbent bulkhead in the floor void beneath a partition, it is possible to reduce flanking transmissions due to airborne and impact sound (Fig. 4). The flanking sound reduction indexes of floor systems lie between 45 and 50 dB (and up to 58 dB is possible with an absorbent bulkhead) and are therefore generally better than the sound reduction indexes of the partitions above floor level.
When it comes to reducing the horizontal propagation of impact sound, heavy mineral floor panels are better than panels made from wood-based products or metal because more sound energy is dissipated in the sound transmission from panel to panel. The positive effect of a floor covering with a higher increase in the impact sound reduction index is noticeable. Such a floor covering attenuates the transfer of impact sound into the floor panels right from the start (see tables T6 and T8).

Fire protection requirements

A high services density in the void below a floor system can result in a not inconsiderable fire load. Furthermore, floor systems generally include openings and ventilation grilles. For these reasons, floor systems may be required to comply with certain fire protection requirements.

The fire resistances and building materials classes of the individual elements of a floor system and all associated built-in items (e.g. vents, electric sockets, etc.) must be verified in tests. An assessment of a floor system's reaction to fire according to DIN 4102 is not advisable because owing to the relatively small volume in conjunction with the unfavourable ventilation conditions, the fire load in a floor void does not represent a "standard fire situation". The "Model Directive Regarding Fire Protection Requirements for Hollow and Raised Access Floors" specifies the requirements that such floors must satisfy with respect to fire. The Model Directive makes a distinction between

- clear void depths < 200 mm, and

1 Four paths for sound transmissions in floor systems
a Airborne sound
b Impact sound
c Airborne sound flanking transmissions
d Impact sound flanking transmissions

T6: Insulation values that can be achieved for airborne and impact sound in hollow floors for vertical and horizontal sound transmissions

	Airborne sound insulation		Impact sound insulation	
	Sound path		Sound path	
Construction	horizontal $R_{L,w}$ [dB]	vertical R_w [dB]	horizontal $L_{n,w}$ [dB]	vertical ΔL_w [dB]
Monolithic	42–55 49–55[1]	50–55[2]	83–50	10–28
Multi-layer	42–57 50–57[1]	55–56[2]	69–62	10–28

[1] with isolating joints
[2] with 150 mm structural floor
The above figures are laboratory values and are valid without floor covering.


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- clear void depths > 200 mm, with special requirements for
- clear void depths between 200 and 400 mm.

The Model Directive lays down requirements that take into account the special features of floor systems and go beyond the requirements of DIN 4102. With the exception of corridors, verification of the space enclosure is not required – depending on the depth of the raised access floor. This means that in some cases a temperature increase of 180 K above the requirements of the standard can be tolerated as an average value provided the load-carrying capacity is assured. We refer here to an "F 30*" fire resistance rating. The other requirements depend on the depth of the floor void.

Requirements for floor voids < 200 mm
With this size of floor void, walls that are required to meet fire protection requirements, e.g. walls bordering generally accessible corridors or other occupancy units, may be built off the raised access floor, provided

- such walls together with the floor construction concerned are tested with respect to the fire resistance class necessary for the walls, or
- the floor construction complies with the requirements of fire resistance rating F 30 to DIN 4102 for exposure to fire from underneath, or
- the walls concerned border generally accessible corridors within one occupancy unit.

The above conditions are linked with "or", i.e. if one of these conditions applies, the wall does not need to continue as far as the structural floor. With floor depths < 200 mm, it is not necessary to construct a bulkhead in the void below a partition that satisfies the above conditions and is built off the floor system.

Floor systems with a void depth < 200 mm must be built from materials (panels and pedestals) that comply with the requirements of DIN 4102 building materials class B2 at least. If the void also forms part of the interior ventilation system (plenum), it must be ensured that smoke detectors located in the void or in the vicinity of the air outlets can shut down the ventilation system immediately in the event of a fire. At least one smoke detector should be provided for every 70 m² of uninterrupted plenum area.

Generally accessible corridors must also comply with the following requirements:

- The materials of the floor system must generally meet the requirements of DIN 4102-2 class A.
- Ventilation outlets are not permitted.
- Access and retrofitting openings are only permitted when fitted with sealed panels made from incombustible materials.

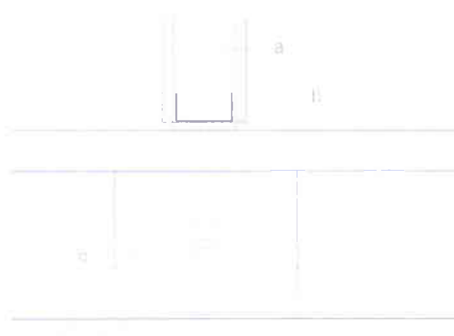
2 Steel supporting framework under construction, plenary chamber, Bavarian Parliament building, Munich, 2005, Staab Architekten
3 Hollow floor, terracing and backrests made from dense gypsum fibreboard, spectators' gallery, Bavarian Parliament building, Munich, 2005, Staab Architekten
4 Sound insulation bulkhead in floor void (absorbent bulkhead)
a Stud wall (lightweight partition)
b Floor panel
c Pedestal

T7: Examples of airborne and impact sound insulation for raised access floors with flatweave carpeting for vertical sound transmission

Airborne sound reduction index	R'_w	Structural floor alone	48 dB
		with raised access floor	53 dB
Weighted normalised impact sound pressure level	$L'_{n,w}$	Structural floor alone	81 dB
		with raised access floor	61 dB
Increase in impact sound reduction index	ΔL_w		20 dB

T8: Examples of airborne and impact sound insulation for raised access floors with flatweave carpeting for horizontal sound transmission

			Depth of floor 200 mm	500 mm
Airborne flanking sound reduction index	$R'_{L,w}$	w/o absorbent bulkhead	43 dB	46 dB
		w. absorbent bulkhead	54 dB	58 dB
Weighted normalised impact sound pressure level for horizontal transmissions	$L'_{n,w}$	w/o absorbent bulkhead	62 dB	56 dB
		w. absorbent bulkhead	53 dB	44 dB



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The conditions regarding ventilation outlets and access/retrofitting openings also apply to stair shafts.
Stair shaft walls and fire walls should generally continue as far as the structural floor, which means they cannot be built off the floor system.

Requirements for floor voids > 200 mm
Services in the void below a floor system may penetrate walls when there is no risk of the spread of smoke or fire, or appropriate preventive measures have been taken (e.g. bulkheads to DIN 4102 part 9 or 11 matching the fire resistance rating of the wall). Such precautions are not necessary where the walls concerned border generally accessible corridors within one occupancy unit.

Furthermore, walls may only be built off floor systems with a void > 200 mm deep if these have been tested together with the loadbearing construction for the fire resistance rating necessary for the wall. A bulkhead is required in the void below such walls unless the walls concerned border generally accessible corridors within one occupancy unit.

For floors with a void between 200 and 400 mm deep, the floor system must either comply with the requirements of DIN 4102 class B1 or satisfy at least the F 30 stability requirements according to DIN 4102. Verification of the room enclosure, i.e. maintaining the temperature limits, is not necessary for this size of void (F 30*).
If the floor system does not have an F 30 certificate, but complies with the class B1 requirements, the pedestals must be made from incombustible materials with a melting point ≥ 700°C.

Where the depth of the void is more than 400 mm, the floor must comply with the F 30 requirements, at least regarding stability; the class B1 requirement is then no longer adequate on its own. In addition, floor systems in generally accessible corridors must meet the requirements of fire resistance rating F 30 – AB.
Again, if the floor void is a plenum forming part of the interior ventilation system, the same requirements apply as for floor voids ≤ 200 mm deep.

Electrostatic requirements
Walking across raised access floors can cause a build-up of electrostatic charges. Such charges must be quickly and safely discharged to earth in order to avoid the negative consequences of static electricity, e.g. the malfunction of, or damage to, electronic components, or the ignition of combustible materials caused by sparks.

The relevant variable here is the earth leakage resistance RE, which is measured in ohms (Ω) between the surface of the floor covering and earth potential. The earth leakage resistance should never be lower than the maximum resistance of an individual element in the discharge direction: floor covering – adhesive – floor system panel – sound-attenuating bearing pad – pedestal. With an earth leakage resistance of 10^{10} Ω, charges in persons can decay in approx. 1 second. Below 10^{8} Ω, a floor covering is sufficiently conductive to prevent the risk of flammable dusts and gases being ignited by electrostatic discharges as people walk across the floor. Below 10^{6} Ω, a floor covering is also suitable for interiors where explosive materials are produced and stored.

1 Stepped hollow floor made from dense gypsum fibreboard, Bavarian Parliament building, Munich, 2005, Staab Architekten

Fire-resisting casing systems in dry construction are primarily used for the following:

- Loadbearing and bracing constructions (e.g. columns, beams)
- Cable and service ducts
- Ventilation ducts
- Pipes

Beam and column casings

Preventive fire protection measures for steel beams and columns, possibly also timber, are required in order to guarantee escape routes for as long as possible in the event of a fire. Steel loses its load-carrying capacity above a temperature of about 500 °C (critical steel temperature). So depending on the fire load, the dimensions of the steel component, the constructional details, the structural system and the reserves of strength in the steel component, uncased steel components retain their load-carrying ability for only 8–15 minutes on average. If steel components are to attain the necessary F 30 to F180 fire resistance ratings, appropriate measures must be taken to guarantee that the loadbearing capacity of the steel is maintained for the required length of time. Besides applying coats of plaster or intumescent paint, steel components can also be encased in fire-resistant dry materials. Steel components generally also require a protective casing even if they are already partly shielded from fire because they are behind a suspended ceiling or within a wall.

The following criteria must be considered when determining the fire-resistant casing required:

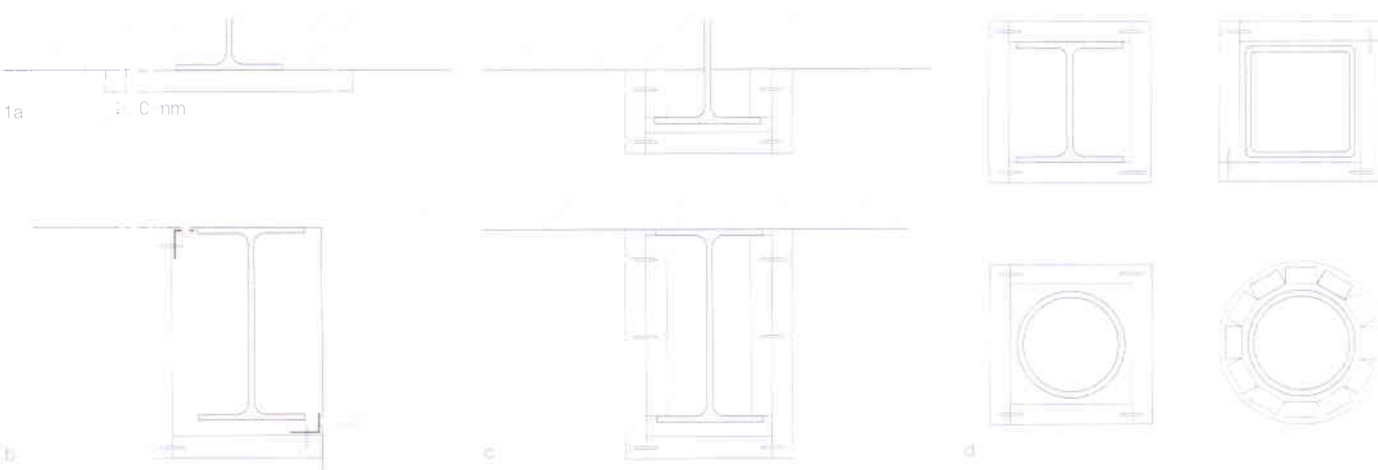
- Type of component to be encased
- Fire resistance required
- Exposure to fire load (one, two, three or four sides, Fig. 1a–d)
- Type and thickness of boards for casing
- Timber: species, cross-section, h/b ratio
- Steel: section factor (U/A ratio)
- Fire protection verification (DIN 4102-4 or test certificate)

DIN 4102-4 contains overviews for beams and columns encased in gypsum fire-resistant board (GKF). In addition, there are many proprietary fire-resistant casing systems available that have been tested and are more economic or offer a better performance than the standardised solutions. The following board types are widely used for fire-resistant casing systems:

- Special gypsum boards
- Cement-bonded fire-resistant boards
- Calcium silicate boards
- Mineral-fibre boards

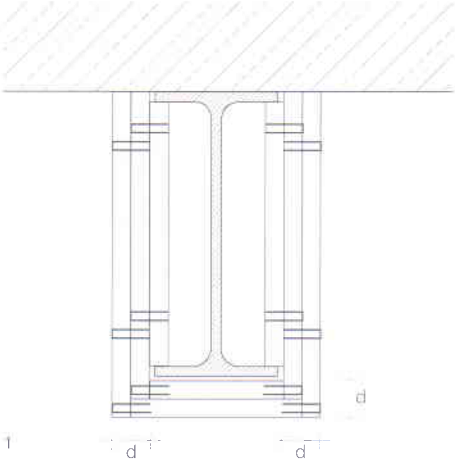
The mechanical strength of some of these boards means their edges are stable enough to accept mechanical fasteners (screws or staples) directly without the need for any internal framework.

Stocky steel sections with thick webs and flanges behave better in fire – and thus require thinner casings – than slender, thin-walled sections. This physical law has resulted in the development of a design method that is based on the ratio of the perimeter (U) of the casing (box-like when using boards) to the cross-sectional area (A) of the steel section. The required casing thickness depending on the U/A value for standard steel



1a b c d

1 Box-type casing for exposure to fire
a on one side
b on two sides
c on three sides
d on four sides



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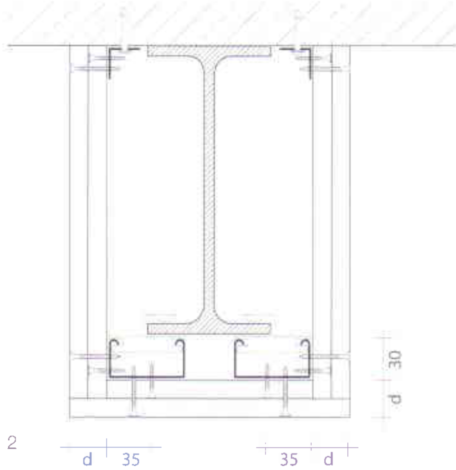

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sections can be found in tables provided by the board manufacturers. The U/A value is limited to ≤ 300 m⁻¹ for such steel sections. If steel sections with U/A values > 300 m⁻¹ have to be assessed, tests according to DIN 4102-2 will be necessary in order to classify the components. Where loadbearing or non-loadbearing steel components requiring a certain fire resistance are connected to steel components that do not require fire protection, then both the connections and these latter steel components must be encased. This encasement must continue for a length of at least 300 mm for fire resistance ratings F 30 to F 90, and at least 600 mm for F120 to F180 (depending on the U/A value of the steel components requiring fire protection).

Beam casings
A beam is exposed to fire on three sides when, for example, the top flange of the beam is protected because it is in contact with the soffit of a concrete floor slab. The casing to such a floor beam must continue right up to the underside of the floor slab (Figs. 1 and 2).

Casings made from gypsum fire-resistant board (GKF) and classified according to DIN 4102-4, and gypsum fibreboard established as equivalent to GKF board for fire protection purposes by means of tests, must satisfy the following conditions with respect to the constructional details:

- The maximum permissible span (i.e. spacing of supporting members) for fixing the casing to the internal framework is 400 mm.
- When using a single layer of casing material, strips of gypsum fire-resistant board or gypsum fibreboard must be fitted behind the joints.
- When using more than one layer of casing material, every layer must be fixed separately, all joints in each layer must be filled and the joints between layers must be offset by min. 400 mm.

Column casings
Casings to columns must extend over the full height of the column on all sides – from the top of the floor finishes (top of the structural floor when using class B flooring materials) to the underside of the structural floor above. The conditions listed above for beam casings also apply to columns (Fig.1).
Alternatively, gypsum boards may also be connected directly to a column instead of an internal framework. In such situations, every layer of casing material must be fastened in place by steel straps or wires every max. 400 mm.

Ventilation, cable and service ducts
Fire loads due to, for example, electric cable insulation and pipe lagging, are not permitted in escape routes, generally accessible corridors or stair shafts, including their exits to the open air. Consequently, such fire loads must be encased in dry materials in order to guarantee smoke-free escape routes. Fire risks due to building services can be encased in one of three ways:

- Fire-resistant ceilings (see p. 40)
- Floor systems (see p. 56)
- Service shafts and ducts

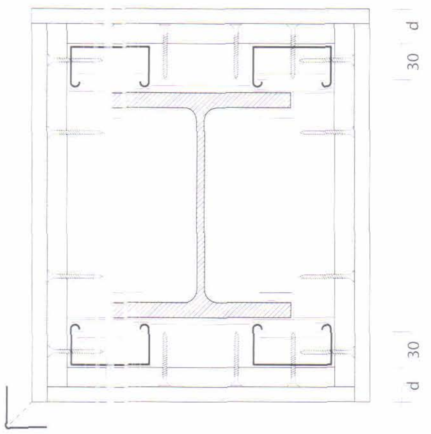
The basic construction principles of ventilation, cable and service ducts are similar. Escape routes, corridors and adjoining rooms are protected against fire by encasing the fire loads to suit the duration of fire resistance required. Casings consist of one or more layers of boards in various thicknesses depending on the fire resistance rating required. The fire resistance is established by tests.

I-class cable ducts stop, for instance, in the event of a cable fire, the fire spreading beyond the duct and so prevent escape and rescue routes against the effects of a cable fire. The fire is contained in the duct and cannot spread to, for example, a ceiling void. Service ducts are tested in accordance with DIN 4102-11 and are awarded an I rating (I = internal, ratings from I 30 to I 120). The maximum internal dimensions of I-class ducts tested are width b ≤ 1000 mm and height h ≤ 500 mm (Figs. 4 and 5).

E-class cable ducts guarantee the functions of the services within the cable ducts in the event of a fire outside the duct. Systems relevant to the safety of the building, e.g. fire detectors, emergency lighting and power, sprinkler systems, smoke and heat vents, must all continue working for the specified duration of the fire resistance. Such cable ducts are tested in accordance with DIN 4102-12 and are awarded an E rating (E = external, ratings from E 30 to E 90). The tests assess the length of time until the loss of an electrical function due to a short-circuit or broken wire. The maximum dimensions of E-class ducts tested are width b ≤ 600 mm and height h ≤ 250 mm (Fig. 6).

L-class ducts (separate ventilation ducts) with a fire resistance rating from L30 to L120 must guarantee supply or extract ventilation for the duration of the fire resistance. Ventilation ducts have to satisfy requirements regarding airtightness and thermal stability. They are tested according to DIN 4102-6.

The most economic systems consist simply of a box made from boards fixed together without the need for any internal framework. The fasteners used to connect the boards depend on the material, but self-drilling screws and steel staples are widely used. A subsequent skim coat of



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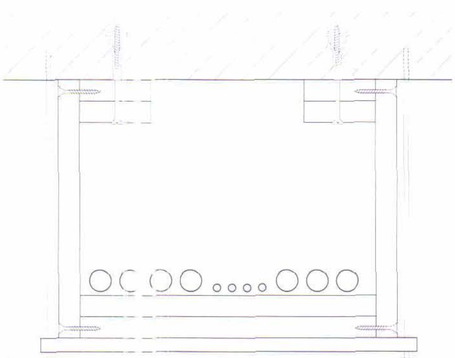

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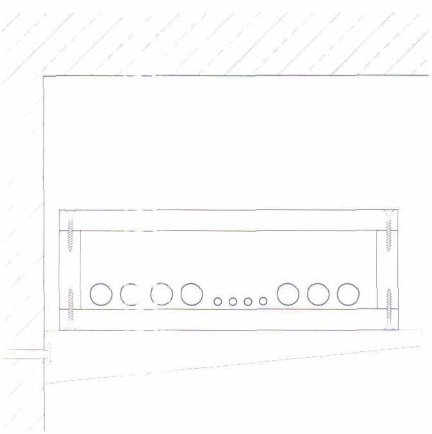

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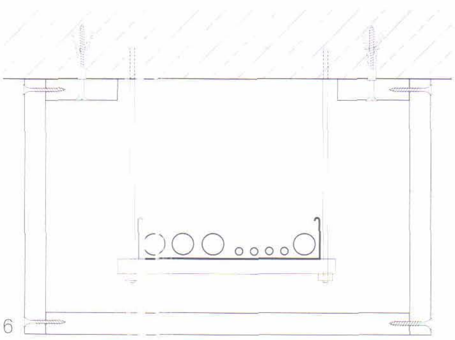

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plaster is not usually required for fire protection purposes.

We distinguish between two-, three- and four-sided ducts. Whereas walls or suspended floor slabs form the other sides to two-and three-sided ducts, a four-sided duct must be supported on wall brackets or suspended below the soffit of a structural floor using threaded rods etc.

Certain boundary conditions must be taken into account with this suspension arrangement. The anchors used must have a national technical approval; steel expansion anchors ≥ M8 are normally required, and they must be inserted to twice the depth given in the approval, but at least 60 mm. When checking the stresses in threaded rods, a lower permissible steel stress of 6 N/mm^2 must be used in the design for the fire situation.

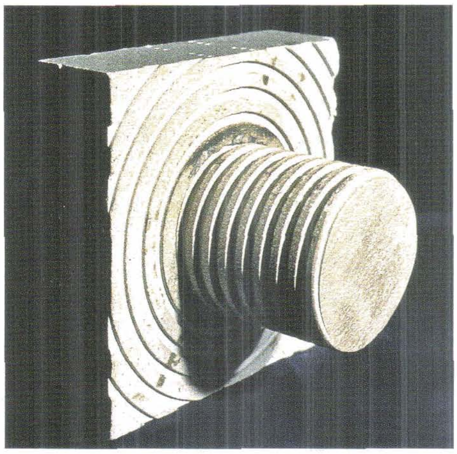
Important for the planning is not only the size of the cable duct, but also the density of the services in kg/m. The weight of potential retrofitted services should also be taken into account at the planning stage. The use of cable trays depends on the type and number of cables, but if the test includes cable trays, they must be used in practice.

Access panels are usually in the form of loose covers that permit modifications, retrofitting and repairs in the duct to be carried out quickly and easily. The number and/or thickness of boards depends on the cross-sectional dimensions and the fire resistance required. Access panels in the sides of ducts must be secured with mechanical fasteners (e.g. screws).

Where cable ducts pass through walls satisfying fire resistance requirements, the details of I- and E-class ducts differ according to their functions. E-class ducts can continue through the wall without interruption, whereas a weak point should be built into the wall for I-class ducts. The bearing strips for the cables should therefore not continue over the weak point of the duct splice.

1 Beam casing without internal framework using special fire-resistant boards stapled together, d = casing thickness
2 Beam casing on metal internal framework, d = casing thickness
3 Double-layer column casing on internal framework, d = casing thickness
4 Example of three-sided I-class duct
5 Example of four-sided I-class duct on wall bracket
6 Example of three-sided E-class duct

Dry construction is a way of bringing together lightweight and dry building techniques. This approach is, as such, not new, but its influence on all facets of building is: high-performance composite materials, conductive plasterboard, coil heating/cooling elements integrated into dry construction systems, ceiling, wall and floor systems with high sound insulation values, board materials faced with wood, glass, stainless steel and aluminium. Those are just a few examples of a development whose potential technical and architectural innovations seem to know no bounds.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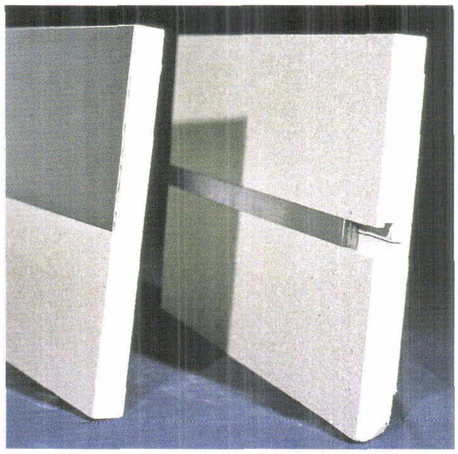
Even plasterboard and gypsum fibreboard – on the face of it mundane products – are composite materials optimised for the functions they have to fulfil – and development is still ongoing. These board materials can be improved for virtually all demands by changing their structure and including additives: resilience for sound insulation, surface texture for sound absorption, density and proportion of pores for thermal conductivity, bound water of crystallisation proportion and microstructure cohesion for fire protection, paper strength and fibre bonding for loadbearing capacity, additives for moisture resistance or for increasing the heat storage capacity, reduced mass for saving resources and, last but not least, elasticity and flexibility for unrestricted shaping and moulding.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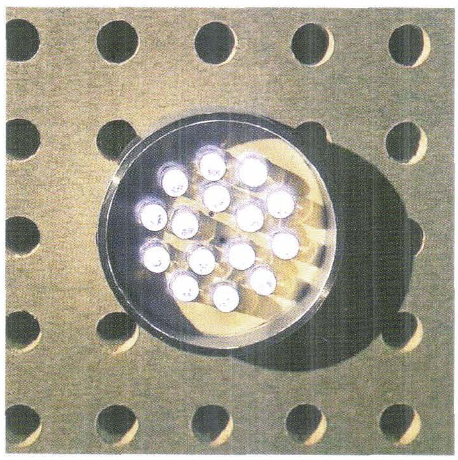
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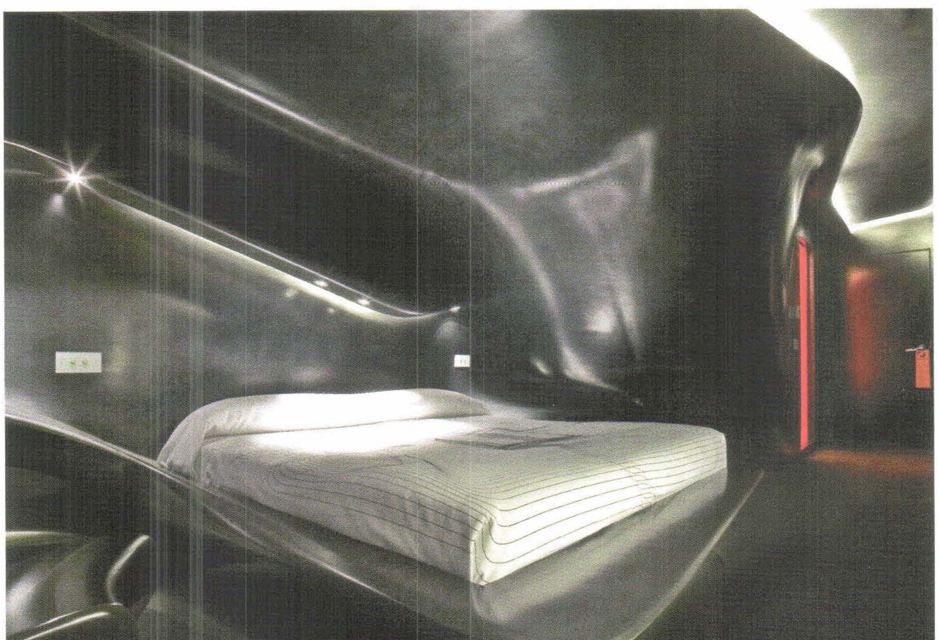
1 Unrestricted mouldability of gypsum fibreboard materials
2 Unrestricted choice of surface finish and joint form for gypsum fibreboard
3 Conductive finishes on plasterboard enable lighting without cables.


1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1, 2 Freedom of forms thanks to the interplay of various materials, Hotel Puerta America, Madrid, 2005, Zaha Hadid
3 Stainless steel and glass, Hotel Puerta America, Madrid, 2005, Plasma Studio

It is important that we understand the properties of the materials chosen for each particular application. The mechanical properties of the board materials that enclose and thus form our interior spaces are in turn only one variable in the equation of interior architecture options for dry construction systems. The use of the most diverse materials and their application according to their properties are characteristic of dry construction. The degree to which we can conceive and plan these systems will become clear below, how besides form and surface finishes, the functional efficiency of the systems can be adapted.

If the establishment of this form of construction was not at the same time derived from a sensible, economic and – in terms of design – multifaceted system, we could not explain the production of more than 1.5 billion square metres of plasterboard. But dry construction is too often regarded as a purely functional form of construction. The objective shortcomings regarding how the specific materials and their properties can be employed are probably an indicator for the as yet insufficient attention paid to the creative possibilities of this form of construction. Appropriate treatment would lead to an inexhaustible repertoire of architectural and functional solutions.

From flat surfaces to free forms

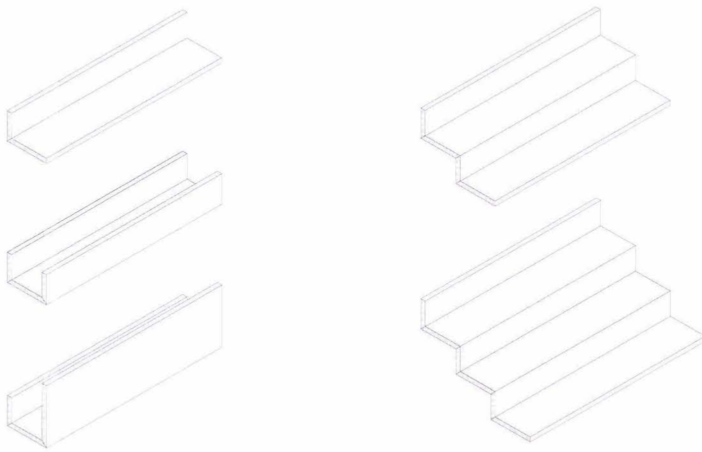
The interplay of shapes and light, e.g. curving, flowing forms (arches, barrels, domes), and indirect lighting often determine today's interior architecture. As economic issues are never far from clients' minds, the majority of complex fitting-out structures make use of modern dry construction methods and systems. They can turn the contours specified by the architect into practice with maximum precision, at the same time minimising the load on the structure. In addition, they comply with the requirements regarding fire protection, sound insulation, thermal insulation, lighting effects and room acoustics in interiors, and also permit the integration of building services.

Many architecturally demanding public, commercial and residential structures of recent years have made it clear that this development in no way risks a return to an exaggerated interior architecture.

Frank O. Gehry's Guggenheim Museum in Bilbao is a first-class example of how dry construction methods can underscore the expression of design and the creation of structures and spaces. The materials and the space-forming constructions are just as bold as the external form of this building. Its solid and hollow sculpted architecture plus the demand for a lightness of form could not be even remotely realised credibly with a monolithic form of construction, e.g. concrete (p. 76, Fig. 2).

The use of new materials is fashionable at the moment because there are no boundaries to the language of forms. Hotel Puerta America in Madrid is another example of just what is possible when we use modern materials properly (Figs. 1 and 2).

Design and construction also means using the right materials at the right places, which also involves combining different building materials or building component elements. The choice of the right material and surface finish has a significant influence on the ambience and import of an interior (p. 76, Fig. 1). This development has led to building systems in dry construction in which – due to functional and technical reasons – it has become necessary to bring together layers of building materials that often exhibit different mechanical and building physics parameters.



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These dry construction systems pursue the axioms of lightweight building systems (see p. 9). What we understand by that is the principle of achieving synergy effects through the addition of materials to form a system. For example, combining thin-walled sheet steel sections with little loadbearing capacity with non-rigid board materials results in a lightweight wall construction with a high loadbearing capacity.

Cars, high-speed trains, ships' hulls and aircraft all use the same construction principle. The interest here no longer focuses on the assembly of individual constructional loadbearing ribs, but rather the complex behaviour of systems whose weight has been minimised and functionality optimised (p. 73, Figs. 1–3).

An almost limitless choice is available for interior architecture applications these days: cylinders, cones, ellipses, domes, rotundas, barrels, waves, shells, etc. Dry construction systems enable the realisation of any forms – stable and precise, quickly built with reliable cost estimates. The complexity of the forms is limited only by the designer's imagination.

Moulded parts and specially designed products enable economic architectural options. The bending radius of curving shells depends on the thickness and the type of board material employed. Board materials specially modified for bent forms can achieve radii as tight as 300 mm. Even tighter bends are possible with machining, casting and deep-drawing.

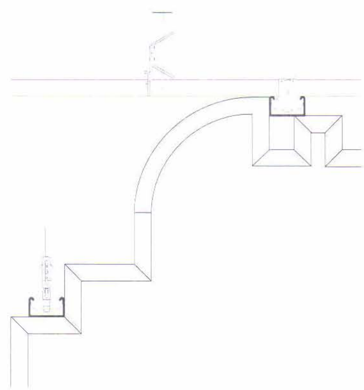
The board length is also the maximum development length of fit-together shaped boards and is generally 3 m. Joints can be featured, or filled to create a seamless surface, but then light sanding of the joints is necessary. Where multi-axial curved interior surfaces need to satisfy structural or building physics requirements, several layers of boards can be bonded together to create stable curved forms (p. 77, Fig. 5a–b and p. 78, Fig. 3a–c).

V-notches can be cut in boards so that they can be folded to form sharp edges. Such products are either supplied flat but cut ready for folding and gluing on the building site, or can be supplied factory-folded and glued.

Spherical curving ceilings and barrel vaults can be factory-prefabricated, including the supporting framework. Individual fabrication based on modular dimensions enables an unrestricted choice of diameter and rise, which eases the architectural and constructional coordination with the specific installation conditions on the building site.
Besides building services components such as coil heating/cooling systems, vents, sprinklers and fire detectors, it is also possible to incorporate individual lighting concepts into wall and ceiling constructions. Services can be modified to absorb sound, either through the design of the board material itself, e.g. by indenting, perforating or punching the material, or by adding appropriate sound-absorbent surface finishes.

"Acoustically hard" curved surfaces help to achieve a specific scattering or focusing of sound waves for defined zones. As with specific lighting effects, such measures create significant places for conscious experiences. Where interiors are designed primarily for emotional experiences, e.g. theatres, cinemas, carefully selected curved surfaces can underscore the desired interior effects (interior design in synchronicity with the experience). This linking of the power of expression of inte-

1 The principle of the folding technique showing examples of prefabricated angles, channels and steps
2 Entrance foyer, Guggenheim Museum, Bilbao, 1997, Frank Gehry
3 Folding technique: construction using multiple angles and radiused element
4a, b Special folded edge
5a, b Stepped corner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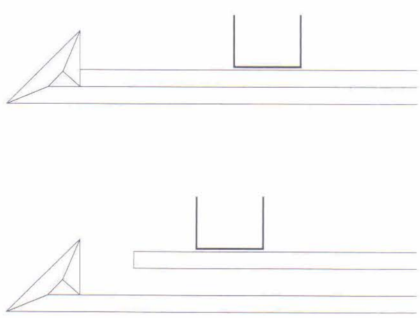
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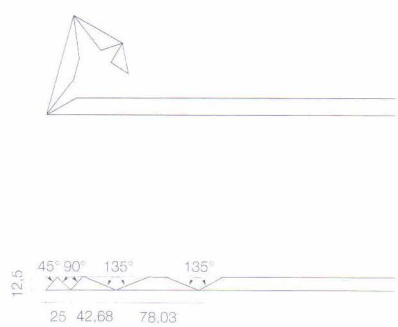

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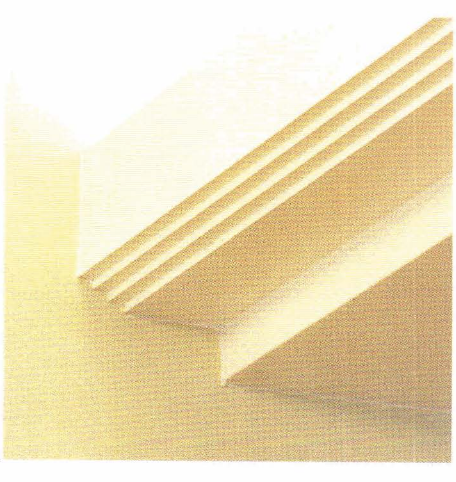
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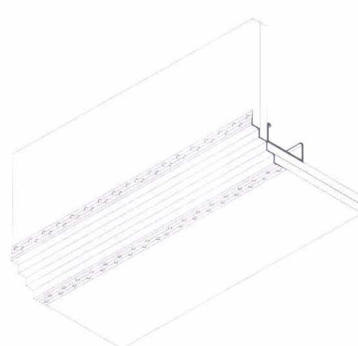
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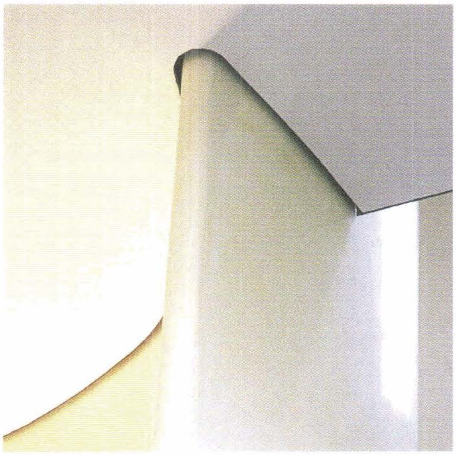
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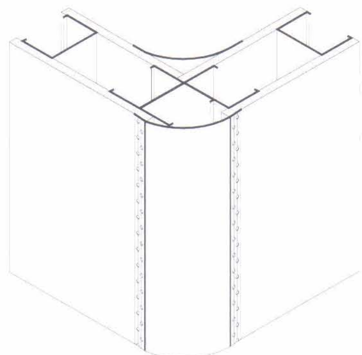
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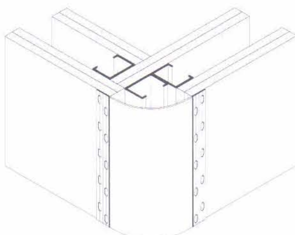
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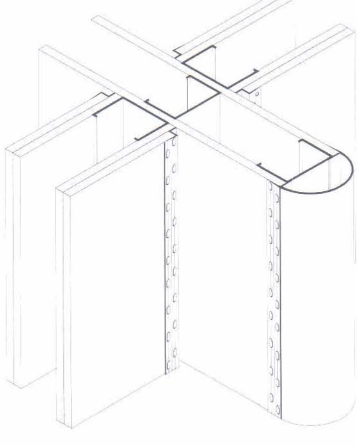
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1, 2 Moulded parts for rounded wall corners and ends
3 Moulded parts for rounded wall corners and ends
a Moulded parts for rounded internal/external wall corners
b Example of a rounded external corner in a stud wall with two layers of boarding both sides
c Rounded end to a wall
4–7 Moulded parts for rounded wall corners/ends and rounded wall–ceiling junction
8a, b Stepped transitions made from plasterboard

rior design and the physical reinforcement of emotional perception effects generally calls for the help of specialists (e.g. acoustics and lighting consultants).

Curved metal framing is factory-bent to the desired radii. To achieve an assembly free from residual stresses, the entire surface is broken down into pieces and segments curved in three dimensions.

Two factors determine the choice and further development of the technologies: the cost of erection on the building site on the one hand, and the prefabrication costs plus transport on the other. Factory prefabrication means a reliable timetable plus more reliable costs.

The advantages of factory prefabrication are to be found in the cost-savings due to the lower proportion of joints, which means minimum filling of joints on site, faster erection and precise fabrication to suit individual specifications.

Glass fibre-reinforced moulded parts enable the realisation of unusual constructions such as complex domes, spherical forms and free forms in a high quality. Large areas of linings to soffits, walls, columns and floor beams are also possible.

Surface finish requirements and qualities

Surface finish requirements and qualities describe the architectural features of the finished surfaces. Different, often subjective, measures are frequently applied in practice, which besides the flatness are mainly concerned with visible features such as marks on the board surface or the "shadowing" of joints through the final declaration (so-called joint photographing). Four quality levels are in use for distinguishing the quality of the surface finish prior to final decoration:

- Quality level 1
  (Q1, basic finish)
- Quality level 2
  (Q2, standard finish)
- Quality level 3
  (Q3, special finish)
- Quality level 4
  (Q4, full skim coat)

If special lighting conditions are used to assess a surface finish (e.g. strong side-lighting or artificial lighting near the surface), equivalent lighting conditions must be ensured even during the building work itself.

Quality level Q1
The basic finish is adequate for any surfaces not required to satisfy any architectural requirements. The Q1 surface finish embraces:

- Complete filling of butt joints between plasterboard
- Covering the visible parts of any fasteners (spotting) or accessories

Tool marks and ridges are permissible. The basic finish includes the application of jointing tape where this is necessary for constructional reasons. When using more than one layer of boards, it is sufficient to fill the butt joints between the boards of the lower layers; spotting the fasteners of


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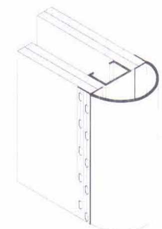
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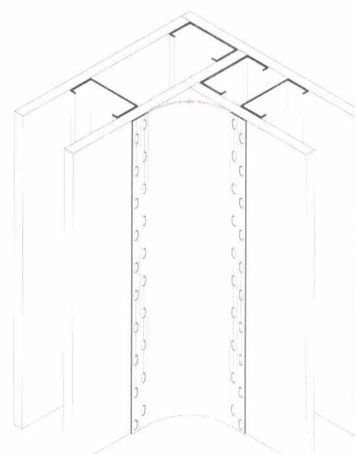
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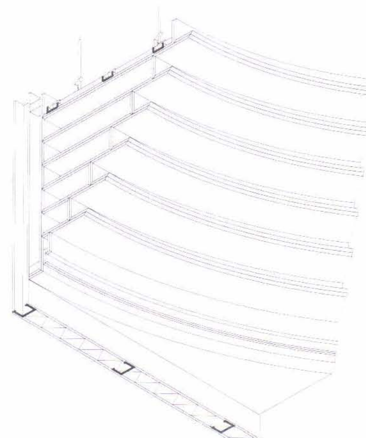
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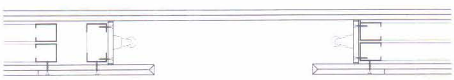
1, 2 Indirect lighting for a display cabinet made from plasterboard
3a–c Stepped transitions made from plasterboard
4 Multiple steps with openings for lights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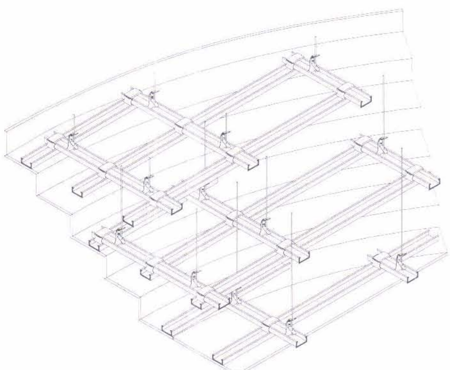
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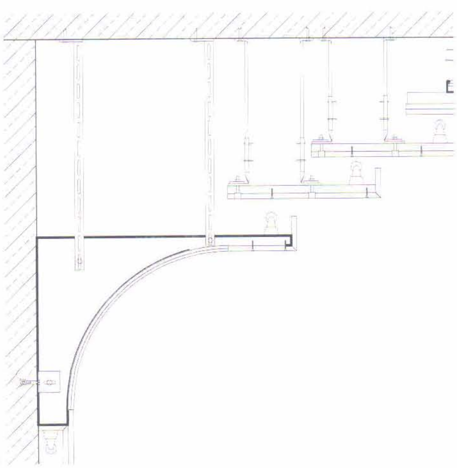
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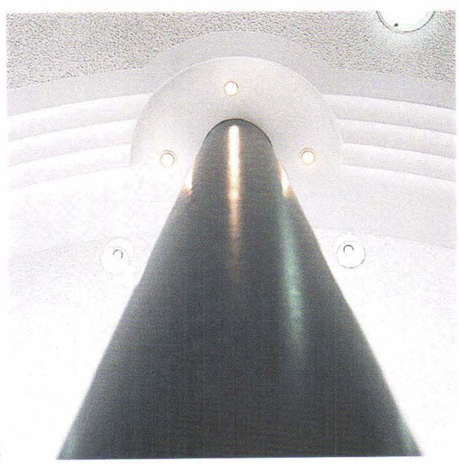
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the lower layers is unnecessary. However, closing off the vertical and horizontal joints between the lower layers of boarding is necessary for fire protection and sound insulation reasons.

Quality level Q1 is sufficient for surfaces that are to be covered with ceramic boards (tiles) or stone finishes. Instead of conventional gypsum-based jointing compounds, the joints can also be filled with the dispersion or epoxy resin adhesives intended for use with ceramic finishes.

Quality level Q2

A Q2 finish is adequate for walls and ceilings in everyday situations. The aim of filling the joints is to conceal them by providing a seamless transition between the board surfaces. The same applies to the fasteners and accessories at internal and external corners, also the junctions with other components. The Q2 surface finish embraces:

- Filling butt joints and spotting fasteners as for level Q1
- Applying a further coat of filling compound until a seamless transition between the board surfaces is achieved

Tool marks and ridges are not permitted. Filled areas should be lightly sanded if necessary. This surface finish is suitable for:

- Moderately and coarse textured wall finishes such as paper or woodchip wallpapers
- Matt, lightly textured, gap-filling paints and coatings (e.g. matt dispersion paints) which are applied manually
- Finish plaster coats with grain sizes > 1 mm
- Wooden linings and veneer finishes with thicknesses ≥ 1 mm and bonded over the whole area
- Metallic surface finishes with adequate

thickness (normally ≥ 0.5 mm) bonded over the whole area

If quality level Q2 is chosen as a base for wall linings, paints and coatings, shadowing of joints, especially in the case of strong sidelighting, cannot be ruled out. Such effects can be reduced by specifying quality level Q3.

Quality level Q3

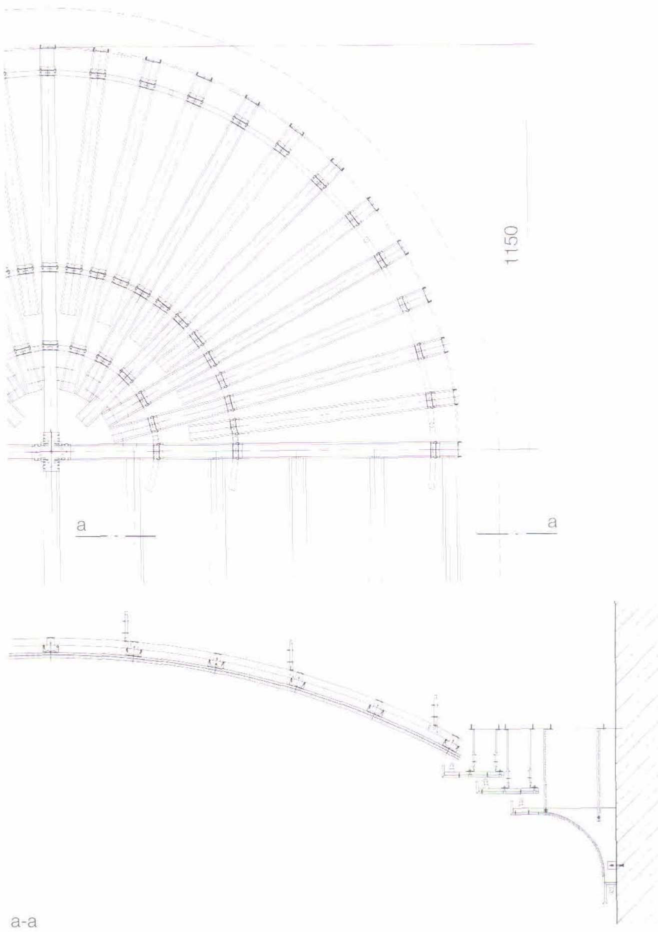
Wherever surfaces have to achieve a higher standard of finish, it is necessary to employ additional measures that go beyond the basic and standard finishes. The Q3 surface finish embraces:

- Finishing as for level Q2
- Extensive flushing-out of joints plus skimming the paper surface to seal the pores with gypsum material

The filled and skim-coated areas may need to be lightly sanded in some circumstances. This surface finish is suitable for:

- Finely textured wall coverings
- Matt, non-textured paint/coatings
- Finish plaster coats with grain sizes < 1 mm, provided they are approved by the plaster manufacturer for the respective plasterboard system

Joints may still be just visible with quality level Q3 in the case of strong sidelighting. However, the degree and extent of such defects are much less than with quality level Q2.



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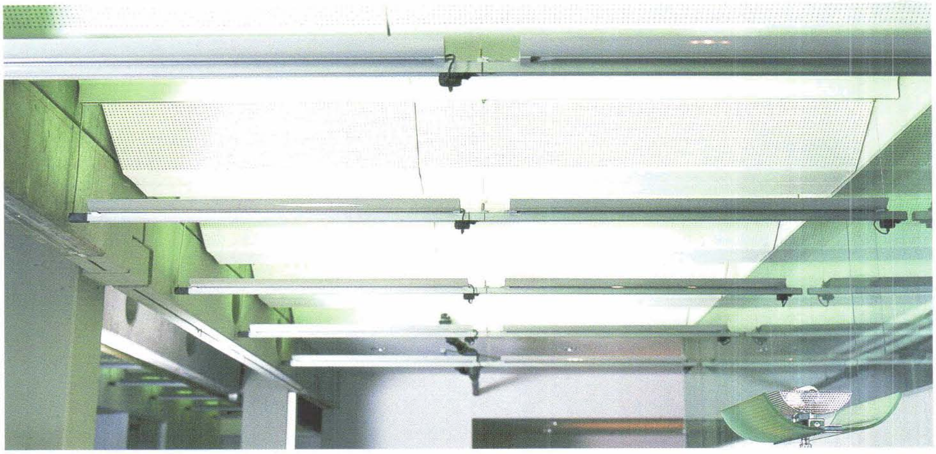
5, 6 Domes and curved ceiling surfaces, dome dia. = 3100 mm



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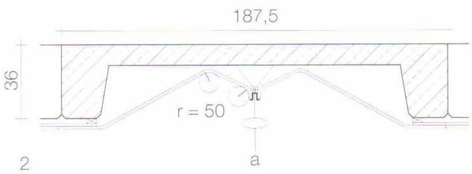

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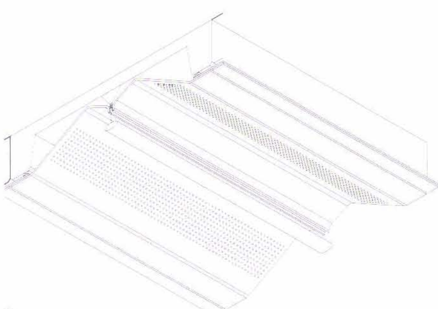

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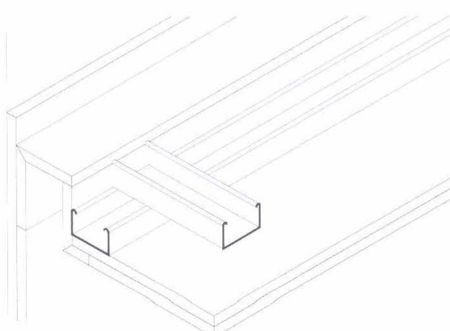

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Quality level Q4

The difference between this and level Q3 is that the entire surface is covered with a generous skim coat of gypsum compound or plaster to satisfy the highest surface finish demands.

The Q4 surface finish embraces:

- Finishing as for level Q2
- Extensive flushing-out of joints plus complete coating and trowelling of the entire surface with a suitable material (coating thickness up to about 3 mm)

This surface finish is suitable for:

- Smooth or textured glossy wall coverings (e.g. metallic or vinyl wallpapers)
- Glazes, paints or coatings up to a medium gloss finish
- Scagliola or other high-quality surface finishing techniques

A surface treatment that satisfies the highest demands according to this classification minimises any blemishes on the surface and the shadowing of joints. Where intensive lighting effects could influence the appearance of the finished surface, undesirable effects, e.g. alternating shadows on the surface or minimal, local blemishes are essentially ruled out. However, such defects cannot be excluded entirely because lighting effects vary over a wide scale and cannot be unequivocally classified and assessed. Furthermore, the limits of manual skills must be taken into account. In some cases it may be necessary to carry out further measures in addition to quality level Q4 in order to prepare the surface for the final declaration, e.g. for high-gloss paints or coated fabrics.

Bathrooms and wet areas

Dry construction methods are used for bathrooms and wet areas in hotels, hospitals, schools, office buildings and also residential buildings, regardless of the form of construction used for the rest of the structure. The use of dry construction in these situations and the details necessary when used in conjunction with tiles and boards taking into account defined moisture loading classes are described below.

Typical applications are as follows:

- Kitchens, WCs and bathrooms, including showers (also barrier-free without shower trays)
- Private living areas
- Hotels and medical treatment facilities
- Communal residences (e.g. student accommodation)
- Senior citizens' and nursing homes

The work usually involves the following elements:

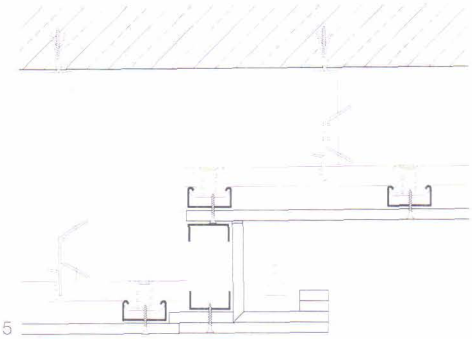
- Walls
- Independent wall linings
- Plumbing and shaft walls
- Wet and dry subfloors
- Prefabricated services systems
- Bathroom modules and sanitary pods

Areas with low and moderate moisture loads are not covered by building regulations. Table T1 (see p. 86) provides definitions of the moisture loads. The waterproofing systems for areas with "high" moisture loads according to Table T2 (see p. 86) are, however, covered by building regulations (p. 86, Fig. 1a–e).

Requirements for substrates

Critical for the waterproofing of dry construction systems are the properties of the underlying materials, which have to satisfy the following requirements:

1–3 Prefabricated ceiling elements with acoustically effective perforations as the soffit lining to a precast concrete suspended floor
a Hoffmeister light
4 Detail of a shadowline joint
5-7 Stepped ceiling details with indirect lighting



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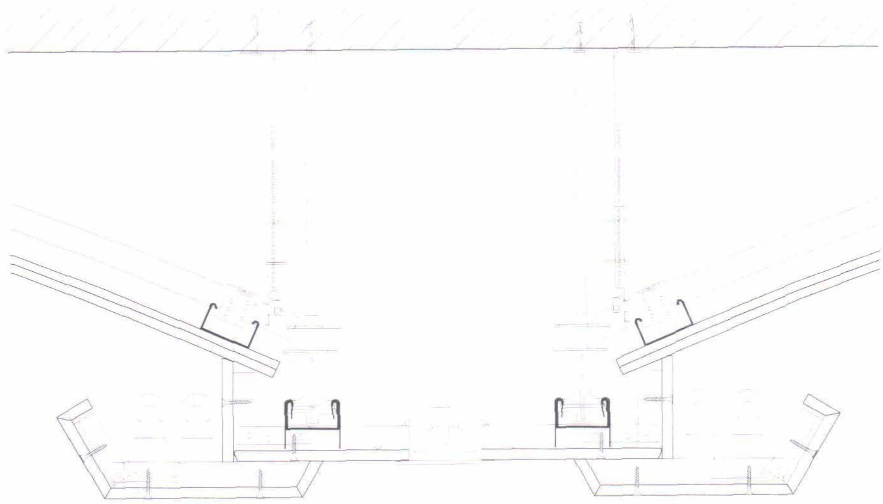

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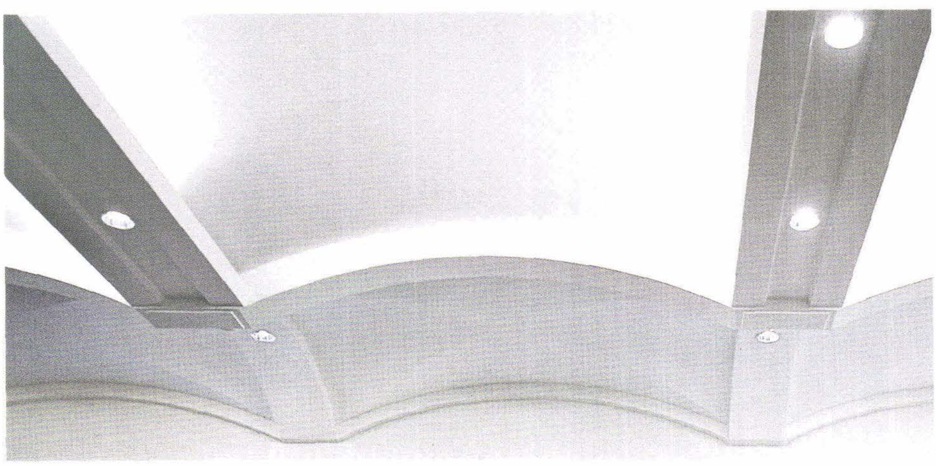

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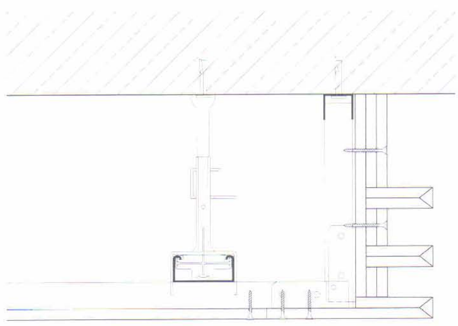
1, 3 Unrestricted form – louvre ceiling made from plasterboard
2 Curving walls with shelf space, from plasterboard
4 Indirect ceiling lighting with curving coves according to the section shown in Fig. 5, Hotel Ku' Damm 101, Berlin, 2003, Mänz & Krauss
5–7 Stepped ceiling details with indirect lighting
a Boards glued

- Flatness (flatness tolerances to DIN 18202)
- Adequate loadbearing capacity and dry
- Dimensionally stable and limited deformability within the tolerances acceptable to the final finishes (e.g. tiles)
- Free from penetrating cracks, oil and grease, loose constituents and dust

Table T3 (see p. 87) lists the materials approved for the individual loading classes.

Gypsum plasterboard, gypsum fibreboard
Gypsum building materials are able to soak up and dissipate moisture peaks caused by increased humidity in the air, as can happen, for example, when showering. The deformations due to moisture loads are low. However, constant saturation of the material reduces its strength. It should be noted that impregnated plasterboard (type GKBI or H) absorbs less water, but is not water-resistant (see p. 13).

Cement-bonded building boards
Such boards are made from cement, water and reinforcing fibres. Building boards without organic aggregates are



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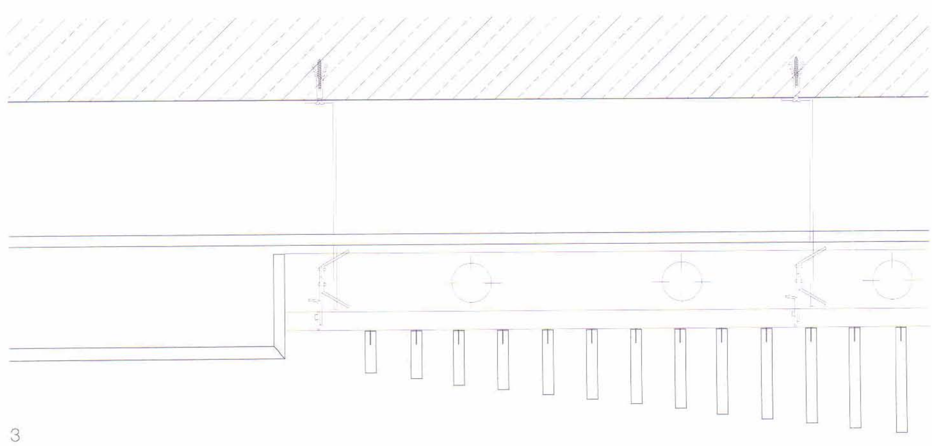

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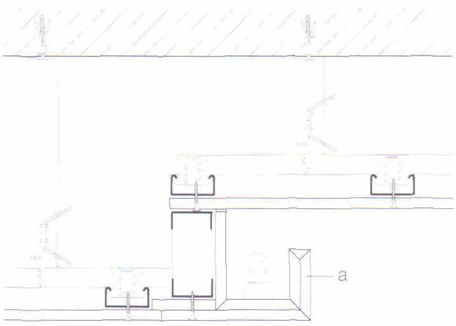
moisture- and frost-resistant, essentially resistant to aggressive atmospheres and do not deform when subjected to thermal loads. The deformation behaviour of the boards under moisture loads must be taken into account specifically according to the application.

Cement-faced rigid foam boards
These boards consist of a rigid foam core covered with a glass-fibre fabric and then coated with a cement mortar improved with the help of synthetic additives. Cement-faced rigid foam boards are moisture-resistant and do not deform when subjected to thermal or moisture loads.

Waterproofing systems for dry construction
Waterproofing systems for areas with high moisture loads require a national test certificate (abP) and must have been awarded the German Ü-mark (conformity symbol). Waterproofing systems in areas with low or moderate moisture loads are, however, not covered by building regulations. In principle, all the materials used for high moisture loads can be used here as well. The answer for areas with low and moderate moisture loads would seem to be to use systems comprising a combination of lining and covering made from tiles plus boards (e.g. liquid waterproofing, sealing tapes and thin-bed mortar). The waterproofing to the floor must be sealed at the junctions with the perimeter walls.

Wall constructions
The supporting frameworks for walls in dry construction are in the form of single- or double-stud assemblies. When using gypsum building boards, the stable substrates that, for example, ceramic tiles require, call for a single layer of min. 12.5 mm thick boards with a stud spacing ≤ 420 mm, or 18 mm thick boards or a double layer of 12.5 mm thick boards and



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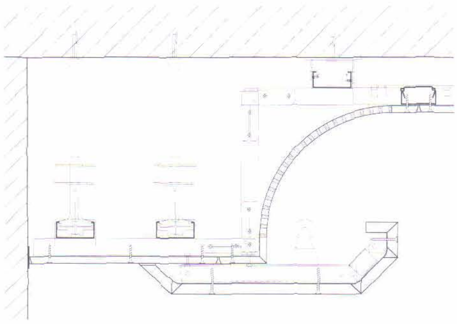

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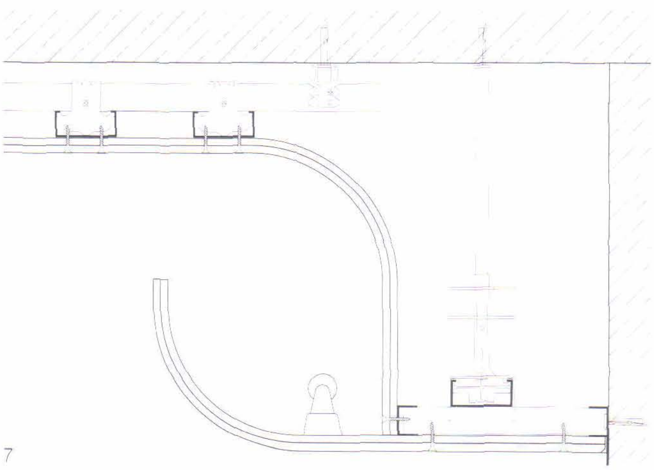

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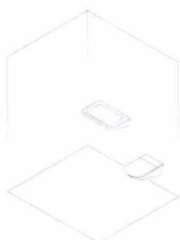

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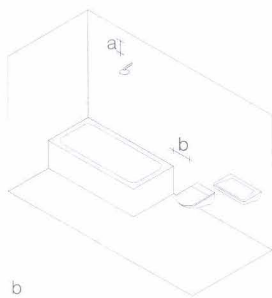

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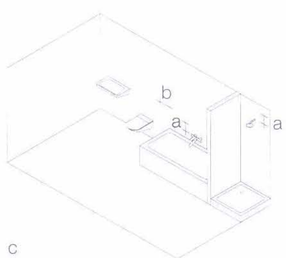

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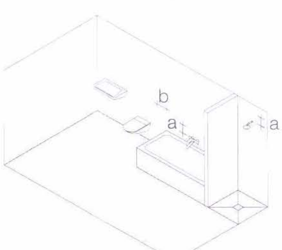

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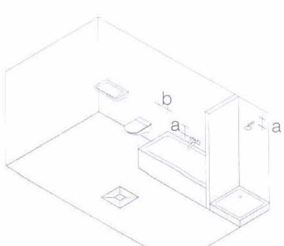


e

a stud spacing ≤ 625 mm. In the case of gypsum fibreboard, a stud spacing of ≤ 50 x board thickness must not be exceeded with a single layer of boarding. And when using composite boards, e.g. wood-based products, they must be at least 10 mm thick and be covered by an additional layer of min. 9.5 mm thick plasterboard.

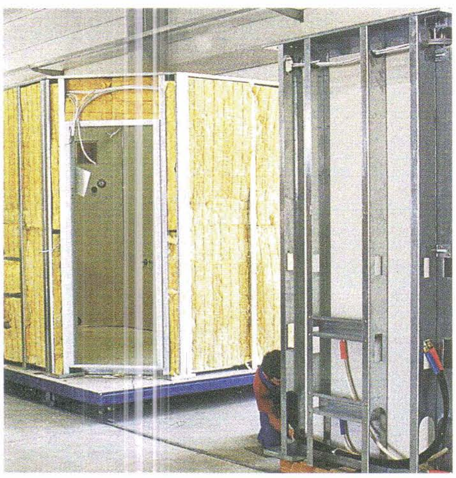
The loads of sanitary fittings must be transferred into the wall constructions via the studs or special frames. Horizontal board joints in walls within the waterproofed area should be avoided wherever possible, and if this is not possible, then supported by the construction directly or glued. It is generally necessary to make sure that any deformations, whether due to the construction, physical influences or sanitary fittings, do not lead to cracking. Horizontal surfaces in zones exposed to splashing water, e.g. shelves behind baths and shower trays, must be integrated into the waterproofing measures for the walls.

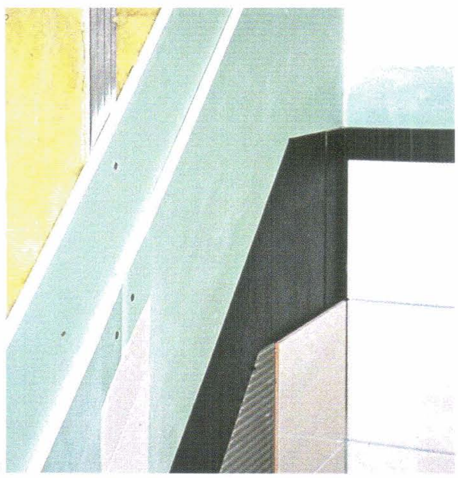
T1: Moisture loading classes for areas not covered by building regulations

Loading class	Exposed zones	Examples
0	Wall and floor surfaces only exposed to minimal amounts of splashing water temporarily and briefly	• WCs without shower/bath • Household utility rooms • Kitchens for normal domestic usage • Walls around sanitary fittings, e.g. washbasins and wall-mounted WCs
A01	Wall surfaces only exposed to moderate amounts of splashing water temporarily and briefly	• In the direct splash zones of showers/baths in bathrooms for normal domestic usage
A02	Floor surfaces only exposed to moderate amounts of splashing water temporarily and briefly	• In bathrooms for normal domestic usage with and without a floor outlet in regular use, e.g. barrier-free showers

T2: Moisture loading classes for areas covered by building regulations (high load)

Loading class	Exposed zones	Examples
A1	Wall surfaces exposed to large amounts of washing and cleaning water	• Walls in public showers
A2	Floor surfaces exposed to large amounts of washing and cleaning water	• Floors in public wet areas, e.g. swimming pools
B	Wall and floor surfaces in swimming pools indoors and outdoors (with hydrostatic pressure from inside)	• Wall and floor surfaces in swimming pools
C	Wall and floor surfaces in contact with large amounts of water and in conjunction with chemical loads	• Wall and floor surfaces in rooms with a limited chemical load (except areas in which cl. 19 of the Water Management Act applies)

2 

3 

Junction details for surfaces in the splash zone

The junctions between walls and between walls and floors must the waterproofed in areas exposed to splashing water. The waterproofing must be such that the expected deformations can be reliably accommodated by the sealing system (p. 88, Fig. 1).

The floor–wall junction details in the splashing water zone must include a sealing tape in the waterproofing level, possibly with additional loops to accommodate movement due to any impact sound insulation present or possible screed or floor finish deformations caused by loads.

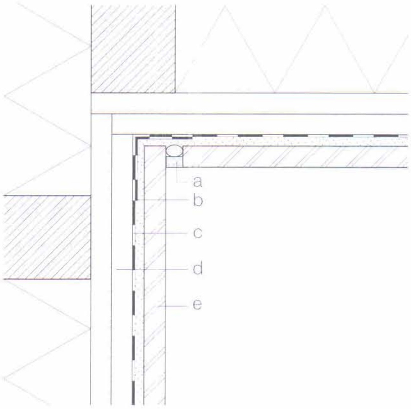
Elastic sealants in the form of rectangular beads or triangular fillets can be used for the secondary sealing. Please refer to the manufacturer's instructions regarding the maximum extensibility of the sealant and joint depths and widths (Fig. 2).

T3: Substrates for waterproofing and ceramic finishes

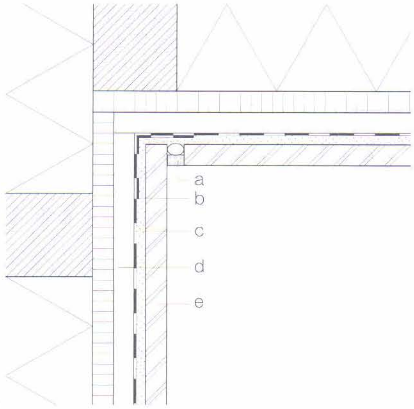
Substrate	**Moisture loading class**			
	Wall		**Floor**	
	0 low	A01 moderate	0 low	A02 moderate
Plasterboard[1]	○	●	○[2]	●[3, 2]
Gypsum fibreboard	○	●	○	●[3]
Other gypsum building boards, e.g. special fire-resistant boards	○	●	–	–
Gypsum plasters	○	●	–	–
Lime-cement plasters	○	●	–	–
Calcium sulphate screeds	–	–	○	●[3]
Cement screeds	–	–	○	○[5]
Mastic asphalt screeds	–	–	○	○[5]
Cement-bonded building boards[4, 2]	○	○	○	○[5]
Cement-faced rigid foam boards[2]	○	○	○	○[5]

[1] Application according to DIN 18181
[2] Follow manufacturer's instructions
[3] Not permitted in conjunction with floor outlets in regular use (e.g. barrier-free showers)
[4] Except for cement-bonded building boards with organic aggregates (e.g. cement-bonded particle-board)
[5] Perimeter details and movement joints must be in accordance with p. 31
– Application not permitted
○ Area where waterproofing is not absolutely essential (only when regarded as necessary and instructed by the client or planner)
● Waterproofing necessary

1 Examples of zones exposed to splashing water
clearance a = 200 mm
clearance b = 300 mm
a WC without shower/bath
b Domestic bathroom with bath for showering as well
c Domestic bathroom with bath (not used for showering) and separate shower
d Domestic bathroom with bath (not used for showering) and separate shower with floor outlet in regular use in shower area
e Domestic bathroom with bath (not used for showering), shower and floor outlet not in regular use
No or little exposure to splashing water, loading class 0
Moderate exposure to splashing water (splash zone), loading classes A01, A02
2 Prefabricated sanitary pods in dry construction
3 Detail of layers in a bathroom wall



1a



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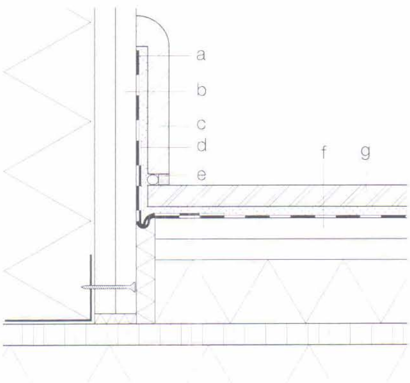
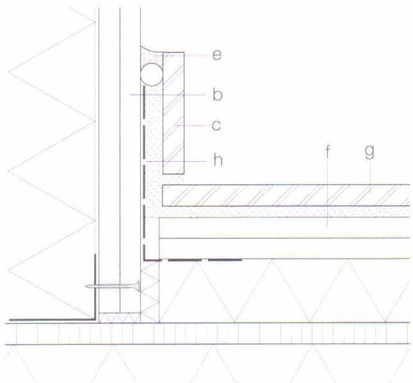


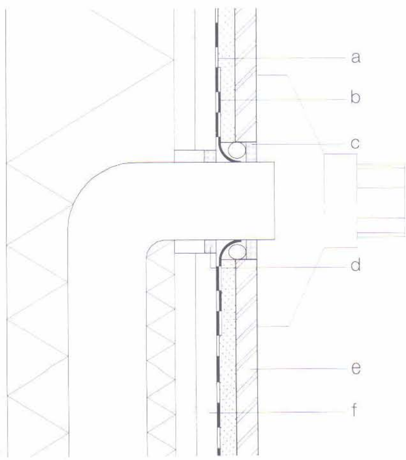
2a



b

1 Example of a waterproofing detail at an internal wall corner
a Secondary seal
b Sealing tape
c Waterproofing to surface
d Boarding/lining
e Ceramic tiles in thin-bed adhesive

2 Example of a floor–wall junction with ceramic tile skirting and waterproofing to floor
a Waterproofing to surface
b Boarding/lining
c Ceramic tile skirting
d Sealing tape
e Secondary seal
f Dry subfloor
g Ceramic tiles in thin-bed adhesive
h Tile grout or adhesive



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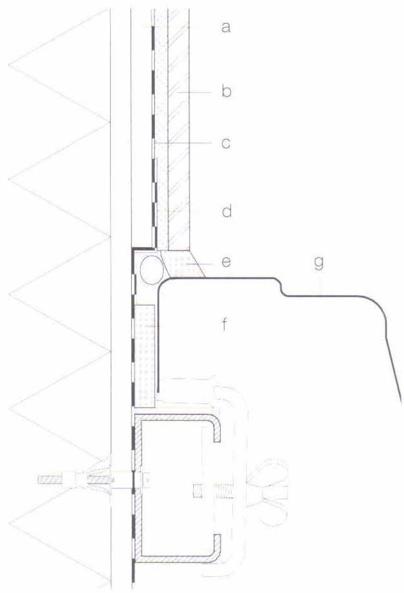
Junctions between baths/showers and enclosing walls in the splash zone
Movements, both horizontal and vertical, of shower trays or baths relative to the surrounding walls must be ruled out around joints to be sealed. Both primary and secondary seals are always essential. The primary seal is the hidden seal between edge of bath/shower and the boarding forming the wall, and can be in the form of elastic materials, preformed gaskets, foam sealing tapes, etc.

The secondary seal is the visible joint between edge of bath/shower and the ceramic tiles, and is usually in the form of a suitable elastic sealant. Where settlement of up to 2 mm is expected, a sealant with a residual extensibility of, for example, 25% will make a joint width of 8 mm necessary.

In dry construction systems, baths and shower trays with upturned edges or suitably designed bearing rails on the walls with an additional waterproof inlay are to be recommended (Figs. 4–7).

Penetrations by pipes and fittings
In areas not exposed to splashing water, it is sufficient to close off openings provided for pipes and fittings with an elastic sealant. Suitable lagging is necessary around cold-water pipes in order to prevent condensation. In the splashing water zone, the sealing around penetrations must be joined to the general surface waterproofing. This requires the installation of sealed glands, sealing gaskets or special fittings. When selecting flush instead of surface-mounted fittings, check that these are suitable for dry construction and that they can be incorporated into the general surface waterproofing (Fig. 3).



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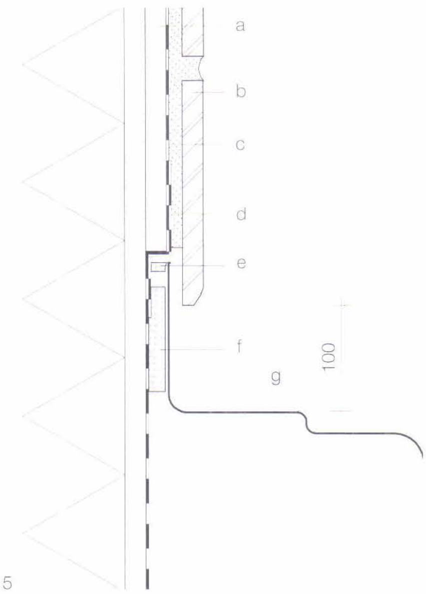

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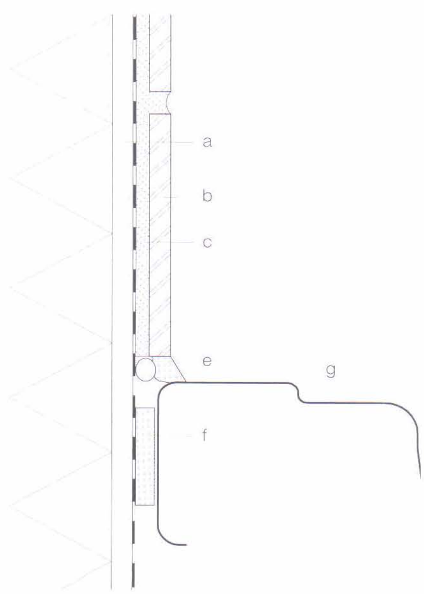

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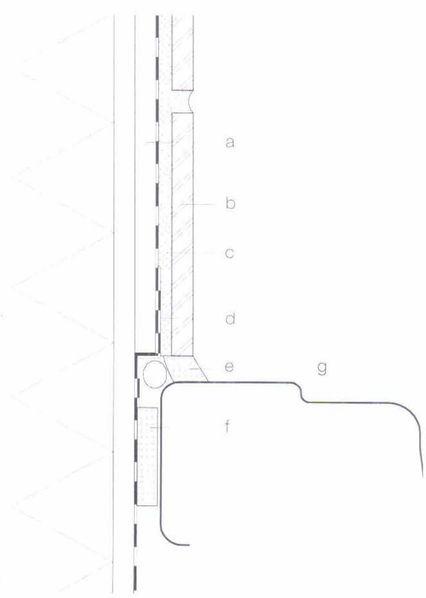

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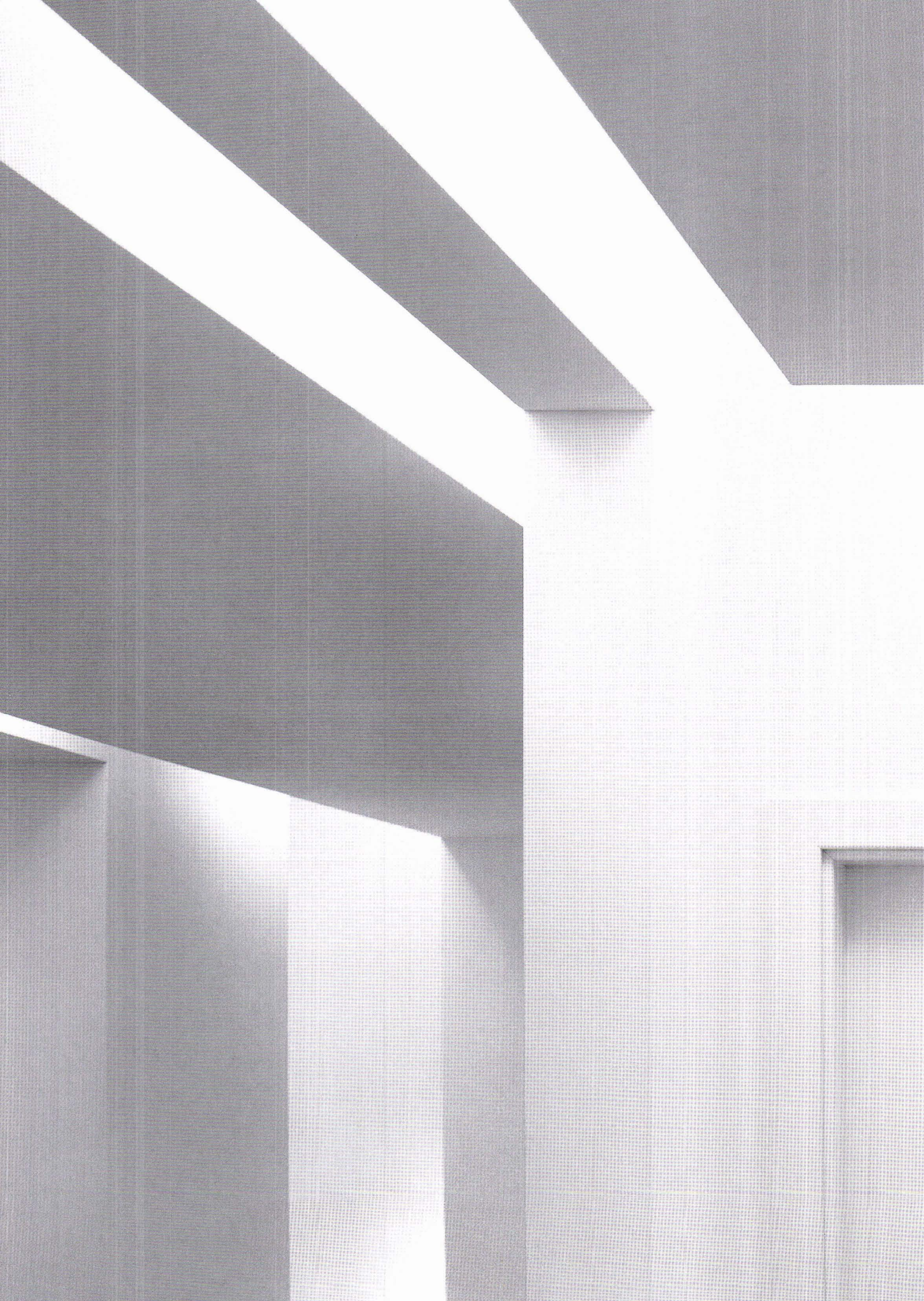
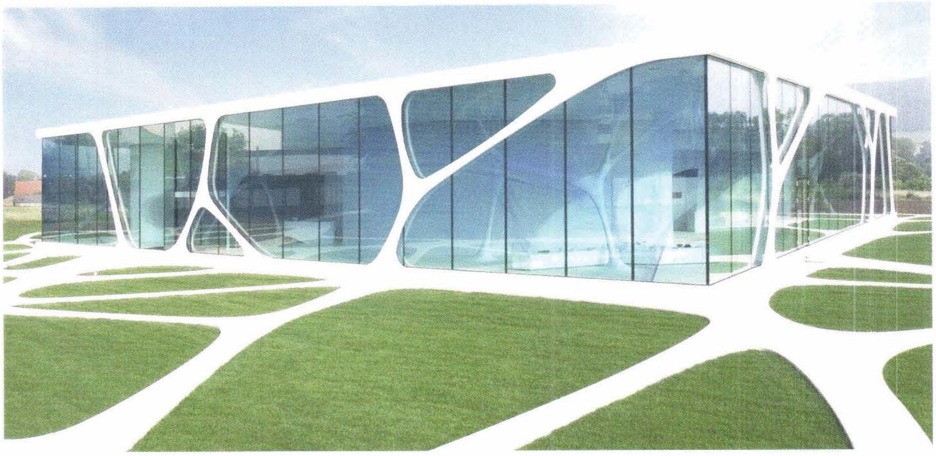
3 Waterproofing around shower tray/bath
  a Waterproofing to surface
  b Sealing gasket
  c Secondary seal
  d Sealant
  e Ceramic tiles in thin-bed adhesive
  f Boarding/lining
4 Example of junction between sanitary fitting and wall-mounted bearing rail
5 Example of junction between shower tray/bath with vertical flange
6,7 Example of wall–shower tray junction

Legend for Figs. 4–7:
  a Boarding/lining
  b Ceramic tiles in thin-bed adhesive
  c Waterproofing to surface
  d Sealing tape
  e Secondary seal
  f Primary seal
  g Shower tray/bath



Case studies for dry construction

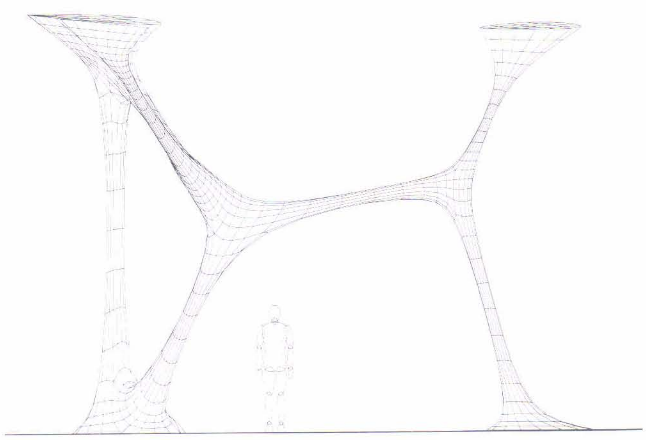
Presentation centre in Bad Driburg



Architects: 3deluxe, Wiesbaden
Contractor: Laackmann Trockenbau, Bad Driburg
Fitting-out system & moulded parts: Lafarge Gips, Oberursel
Construction: 2004–2007

The so-called Glass Cube was conceived as "corporate architecture" for a glass manufacturer. It is the result of an interdisciplinary design process and an integrated architectural concept which attempts to fuse architecture, interior design, graphic design and landscape planning into a single entity. The graphically alienated elements attached to the glass facade of the block are a reference to the architecture and the surrounding landscape. They play a game with the reflections of their real counterparts and form the interface between interior, exterior and a hypernaturalistic, elevated world. The structure consists of two elements with contrasting forms: a geometrically rigorous quadrilateral envelope surrounding a free form in the middle of the building volume. Wave-like, curving, white wall surfaces enclose an introverted exhibition area and on their other side border an extroverted perimeter passageway along the inside of the glass facade.

In the middle of the building, the two floors are linked by a void interspersed by walkways. So upon entering the Glass Cube, the interior opens out not only on the horizontal plane, but upwards and downwards as well. On both levels, the continuous wall rolls inwards to form niches housing thematic product settings and a lounge for meetings. Three sculpted, white structures – so-called Genetics – bring the separate zones of the building together again.
Certain areas of the walls are covered with a gauze material, a lightweight, semitransparent fabric, its fixings concealed in a curving shadowline joint. The fine textile structure of the layer of gauze dissolves the materiality of the white surfaces visually. The incoming daylight creates shimmering moiré effects which are reflected in the glass facade.
A feature of the ceiling is the delicate structure of lines which serve partly as a design element, partly as openings for fresh air. Owing to the intensity of the incoming light, white, pre-primed plasterboard with a smooth face paper were used. In order to guarantee a precise realisation of the three-dimensional computer model, the wall developments were provided with a closely spaced measuring grid. The ceiling and floor junctions consist of flexible, pre-punched UW sections which do not cut into the metal and therefore the structural properties of the supporting framework remain intact. The freely formed surfaces were covered with two layers of flexible 6.5 mm plasterboard finished to quality level Q3.



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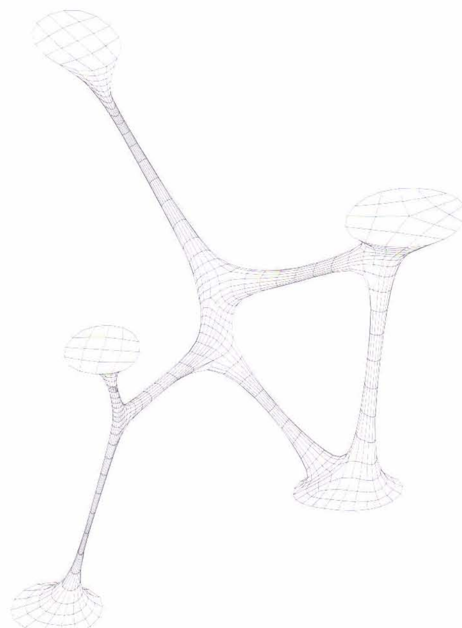

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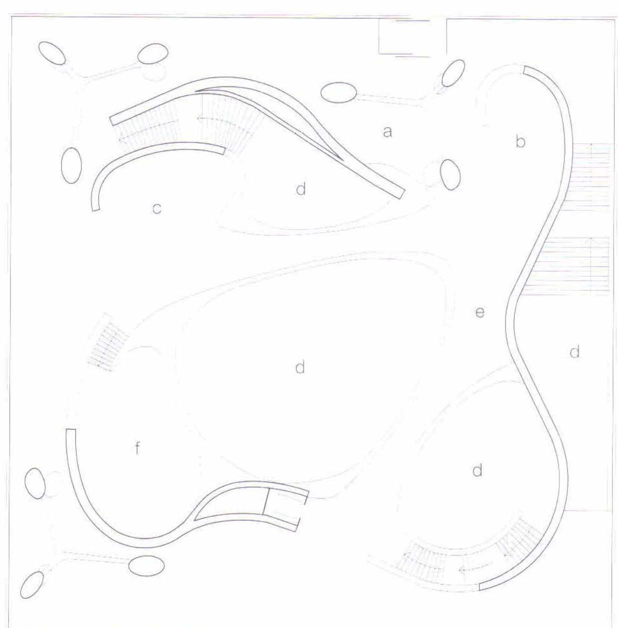


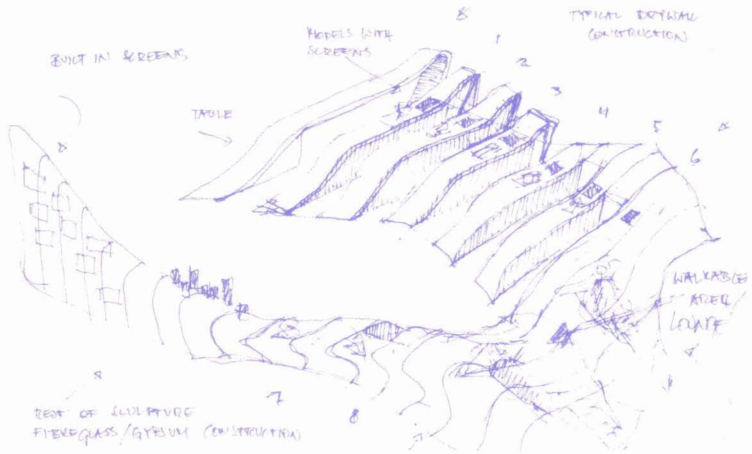
Plan Scale 1:400

a Reception
b Waiting lounge
c Jewellery presentation
d Void
e Gallery
f Lounge

1 Steel circular hollow sections with a supporting framework of timber clad with a deep-drawn shell of acrylic material.
2 Supporting construction to outer ceiling and junction with facade: the ceiling curves towards the facade.
3 (overleaf) The opposing curves of the boards result in a linear design element. The curving wall and ceiling surfaces are made possible by flexible supporting framework systems.

3

Architectural setting and Berlinale Lounge in Berlin

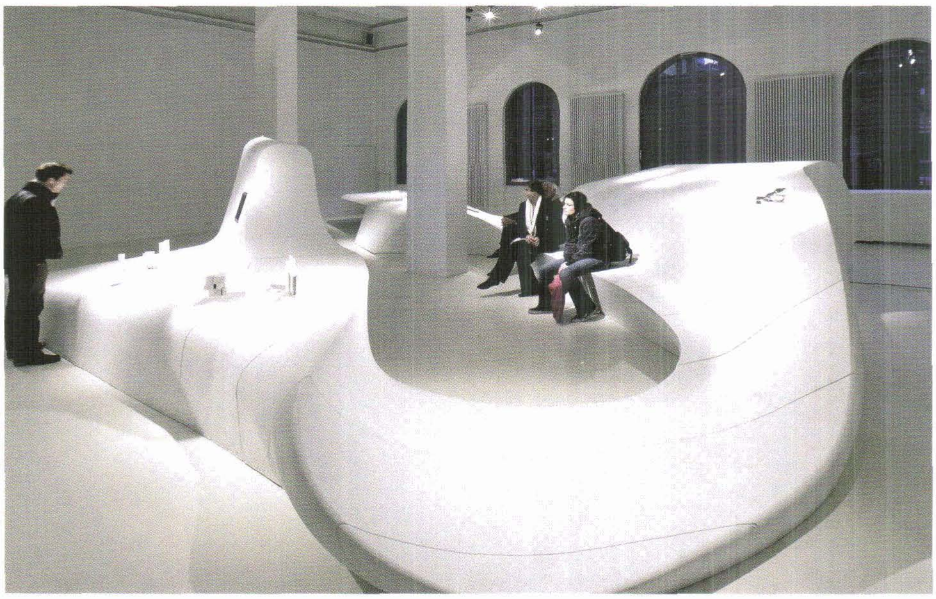


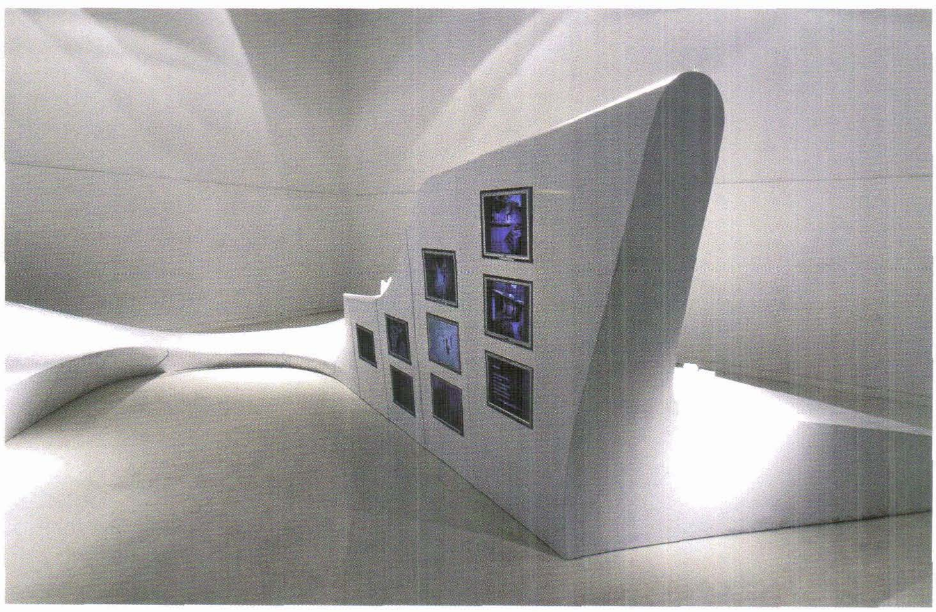
Architects: Graft Architekten, Berlin
Contractor: Mänz & Krauss, Berlin
Fitting-out system & moulded parts: Saint-Gobain Rigips, Düsseldorf
Construction: 2007

The architects have managed to create a walk-in exhibition sculpture – an interactive lounge in which visitors can study projects and relax at the same time. The traditional architectural elements of wall, ceiling and floor have been linked at neuralgic points to form seating, reclining or exhibition elements.
The project illustrates the theme of urban lifestyles and the fusion of living, working and housing: a future trend that is already beginning to take place. To do this, concepts, methods and technologies are not "exhibited" in the classical way, but rather integrated.

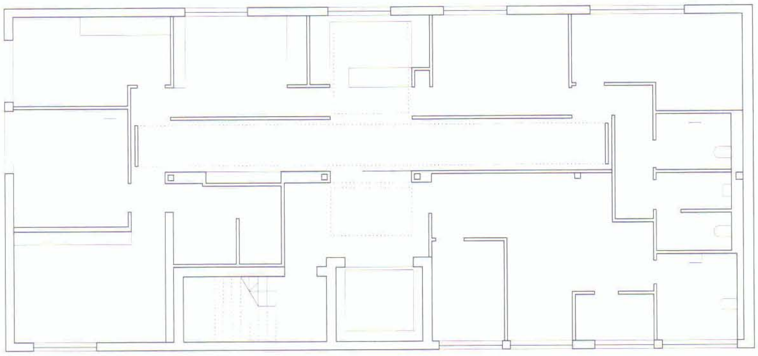
The objective of the architects – the merger of syntactic, semantic and phenomenological aspects – is reflected in the exhibition object. In doing so, narrative elements of film, i.e. "scenographic" thinking, are exploited to the same extent as far-reaching building technology research. The work is an example of the collaboration and interaction of numerous architectural influences, styles and methods, also diverse cultures, which transcend to a new form.

The idea was realised by constructing parallel frames with an enclosing cladding of plasterboard – mainly slotted perforated plasterboard fitted over the supporting framework of wood-based board products and metal sections. The free form of the sculpture was manufactured in segments comprising timber frames and timber ribs. A secondary construction consisting of screw-fixed wood-based board products and 0.6 mm thick C sections serves as a fixing and bearing surface for the plasterboard materials.
Openings and depressions were created in the surfaces for the subsequent installation of flat-screen displays and other exhibition elements.
Both research and realisation demonstrate the diverse methods of tackling projects using the new possibilities offered by the computer modelling of volumes and spaces.





Medical practice in Frankfurt

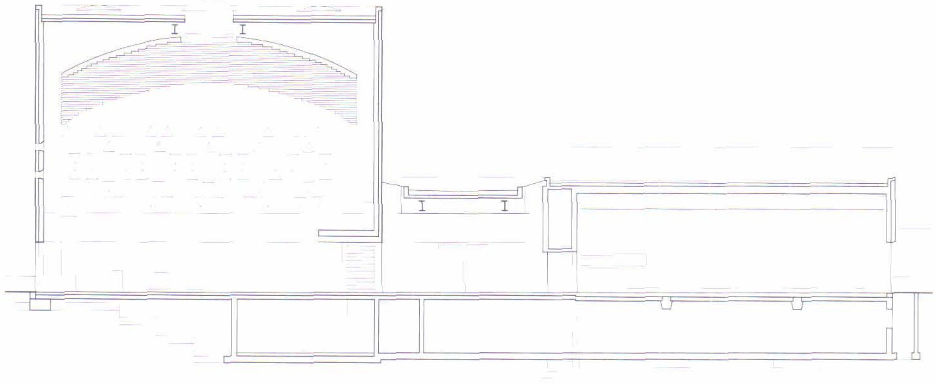


Plan Scale 1:250

Architects: Ian Shaw Architekten, Frankfurt am Main
Technical consultants: Knauf Gips KG, Iphofen
Construction: 2007

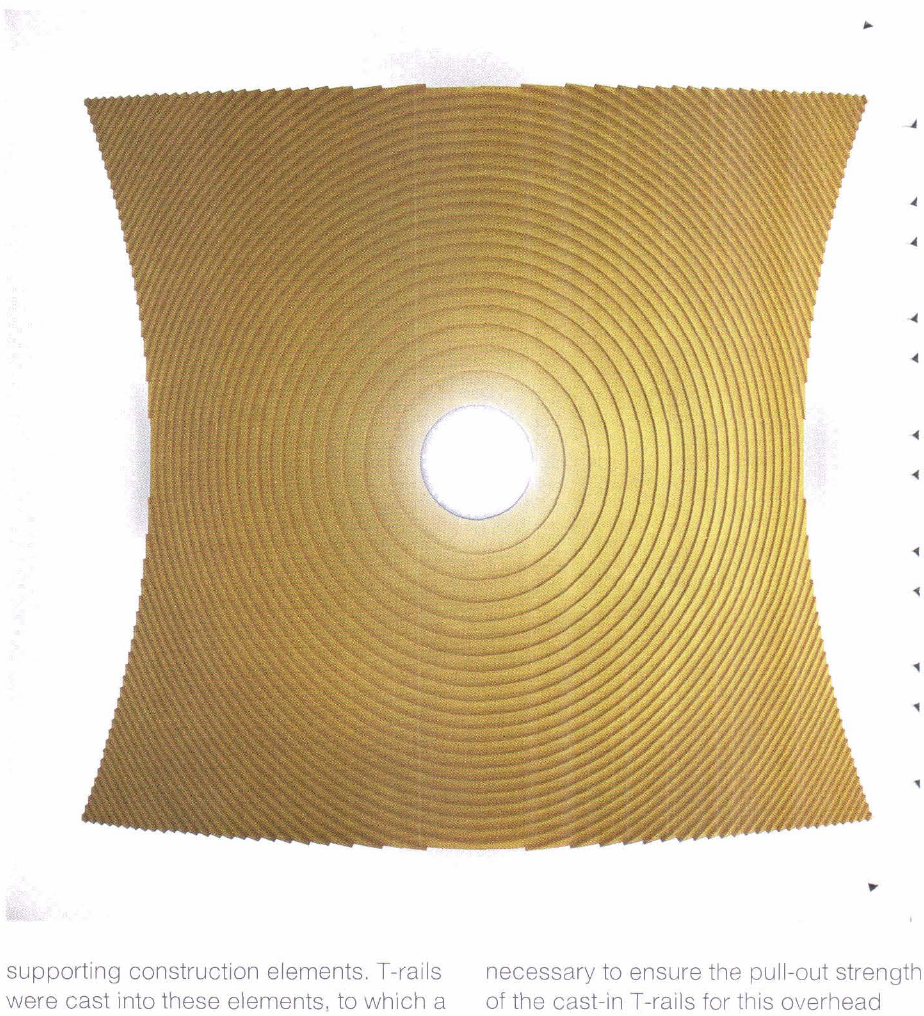
This existing elongated building in a self-contained development presented the architects with a particular challenge. The intention behind the planning of this medical practice in Frankfurt am Main was to create space but at the same time ensure an optimum economic layout. The various functions – reception, waiting room, examination and treatment rooms – are arranged on both sides of the main corridor. The open-plan entrance and reception area interrupts this linear layout, managing to achieve spaciousness. A ceiling with indirect lighting suspended within the room, which at both ends of the corridor turns vertically downwards, almost touching the floor, governs the appearance of the interior.
The distinct, minimal architectural language demands a good standard of workmanship and detailing. The dry construction systems for the walls and ceilings inserted into the existing building enabled the economical realisation of a purist aesthetic, which is based on precise geometry and flat surfaces. The construction of the apparently "floating" ceiling presented a constructional challenge. Together with two other illuminated ceiling elements at right-angles to the main one, the ceiling forms an elongated cross. The construction comprises a framework with transverse ribs clad with two layers of boarding. Upturned edges conceal the "warm-white" fluorescent lamps, which are mounted on the top side of the ceiling. The transition from the horizontal to the vertical involves a very precise detail. The skim coat over the entire surface (quality level Q3) ensures no shadows on the surfaces and hence promotes the reflection of the light within the interior. The indirect lighting, the play of light and shadow and the uniformity of the materials used lend the whole interior a calming, agreeable atmosphere.

Synagogue in Bochum



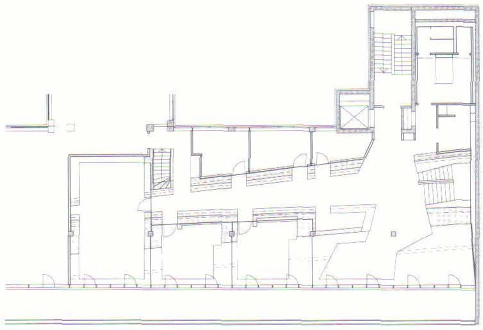
Section Scale 1:400

Architects: Schmitz Architekten, Cologne
Contractor: Mänz & Krauss, Berlin
Design & bldg. technology analyses: Versuchsanstalt für Holz- & Trockenbau (VHT), Darmstadt
Consultant: Lafarge Gips, Oberursel
Construction: 2007

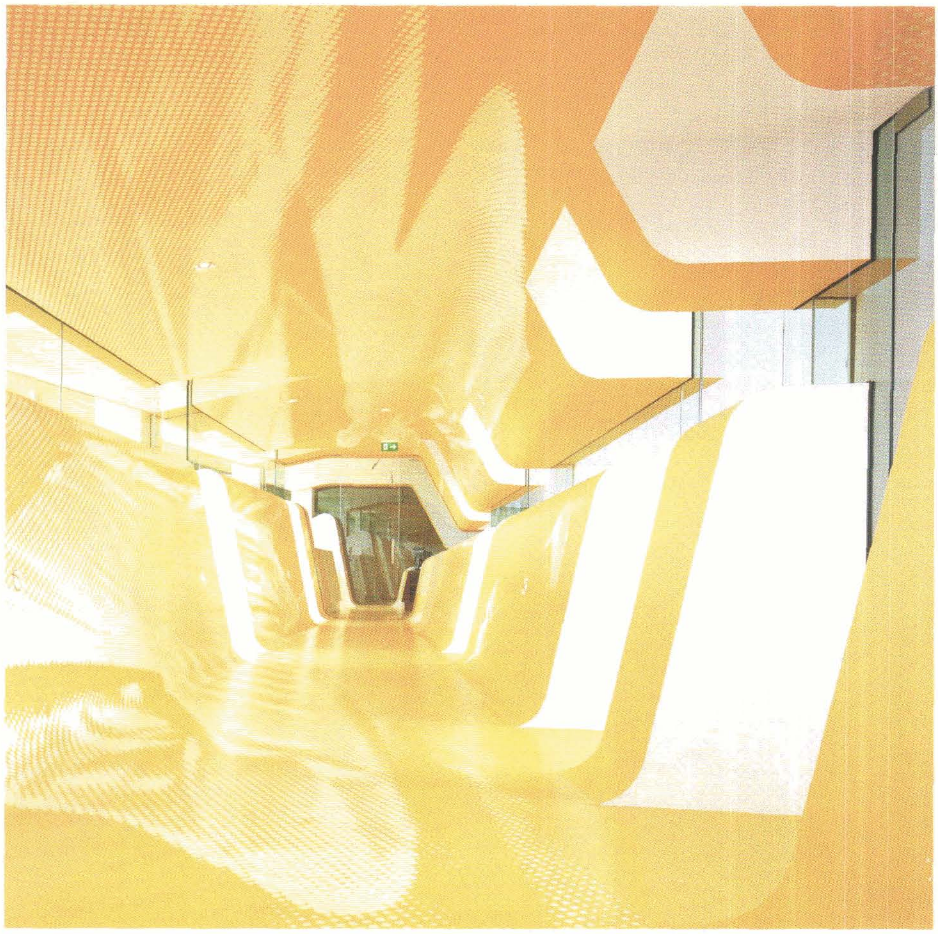


The original Bochum Synagogue, destroyed in the Nazi pogrom of 9–10 November 1938, had not been rebuilt since then. It was not until 2003 that the Jewish community was able to acquire a building plot next to the planetarium on one of the main roads.
The stone block of the synagogue rises off a plateau framed by the clean lines of bush-hammered fair-face concrete walls. This represents a contrast to the shimmering metal dome construction of the neighbouring planetarium.
A Star of David motif is worked into the facade design. Alternating set-back and protruding masonry forms the relief-type ornamentation – a well-known architectural device among the industrial architecture of this region. The ornamented facade gives rise to triangular windows which in the interior form a peripheral frieze on the walls of the synagogue.
In order to give the interior a festive and sublime ambience, a radially stepped dome was developed over a square plan shape which was not used as a construction principle, but rather to emanate the lightness of a floating baldachin. This impression is reinforced by folding the surface into horizontal and vertical steps. In addition, the golden dome is separated from the walls by an illuminated gap. On the whole, the architectural effect is reached through form and colour, based on glass fibre-reinforced gypsum.
The plasterboard dome was prefabricated in 2 m² segments which were assembled on site to form a seamless surface totalling 250 m². The fine radial folds, the minimised self-weight, the short construction time and the high demands placed on the flatness of the surface called for special technology that could not be realised with conventional plasterboard. A new type of technology was therefore employed – individually cast, glass fibre-reinforced polymer-gypsum supporting construction elements. T-rails were cast into these elements, to which a suspension system with threaded rods was attached without the need for any further supporting framework. The glass fibres in the polymer-gypsum matrix render possible board and construction thicknesses of 4–6 mm. The edges of the boards were folded up 75 mm to stiffen the thin gypsum elements, and these vertical pieces also form the butt joints between the individual segments – screwed together to ensure stability.
Tests at the VHT timber and dry construction research centre in Darmstadt were necessary to ensure the pull-out strength of the cast-in T-rails for this overhead application of the moulded gypsum elements. The number of hangers and their maximum spacing were determined as a result of the tests, which also provided the basis for a new type of system that enables the economic design and construction of a stepped dome.

Dental practice in Berlin



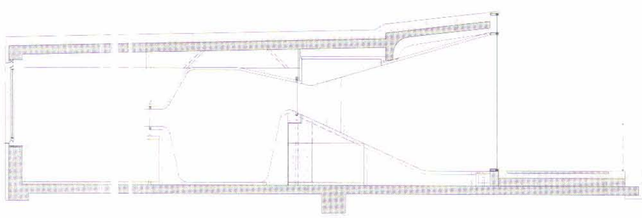
Architects: Graft Architekten, Berlin
Dry construction: Frömmig & Scheffler, Lichtenstein
Technical consultants: Knauf Gips KG, Iphofen
Construction: 2005



The top two floors of an existing building in Berlin provided the home for a new dental practice with a radically new layout and colour concept. The Berlin-based architectural practice used the 900 m² of floor space to create an open sequence of interior spaces in the form of a yellow-and-orange "dune landscape".
Apart from a few special steel assemblies for the framed glass partitions between the treatment rooms on the upper floor, the entire practice was built using dry construction methods. The reception area, corridor and waiting zone are based on a wave idea and have curving floor and ceiling surfaces plus sloping walls, which are clad with different types of factory-bent plasterboard. Prefabricated fillets, which satisfy the high demands regarding scuff and impact resistance, were used to create the seamless transitions between the cambered floor and the sloping walls. High-strength gypsum fibreboard elements were used here up to a height of 300 mm above floor level. The maximum slope of the curving walls is 12°; the tight bending radii and complex curves called for thin, flexible plasterboard elements just 6.5 mm thick. The framing for the dry construction "waves" built off the floor below or suspended from the floor above are supported on steel cross-members. The change of material is in the form of a rebated joint. Glass partitions at eye level permit a view across the entire storey. Even the furniture is incorporated almost seamlessly into the enclosing surfaces.
The ceilings are supported by a typical suspended ceiling framework, based on the idea of barrel vaults with pre-bent CD framing sections. The change from concave to convex bends proved to be a challenge; a high degree of prefabrication proved worthwhile here. All surfaces are finished with printed floor and wall coverings applied to a skim coat over the entire area.
Sloping walls also enclose the stairs down to the lower level with further treatment and consultancy rooms. The wave motif is taken up again in the corridor. With radii of up to 2750 mm, the plasterboard could be bent dry; tighter radii called for the use of flexible boards, which can be bent dry to radii as small as 1000 mm.

Plan Scale 1:500
Sections Not to scale

1 The wall and ceiling constructions are attached to metal cross-members. The boards were cut into segments according to the radii. Precision due to prefabrication: moulded parts were used for very tight radii.
2 The contours are discernible. The glass elements are already in place; fitting-out in dry construction to create interior spaces and in this case the furniture as well.



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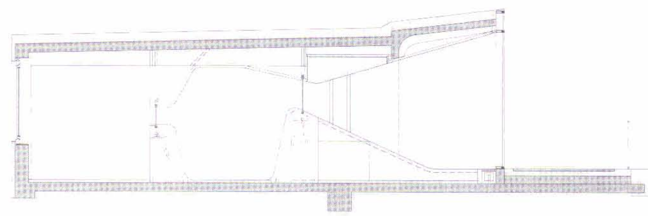

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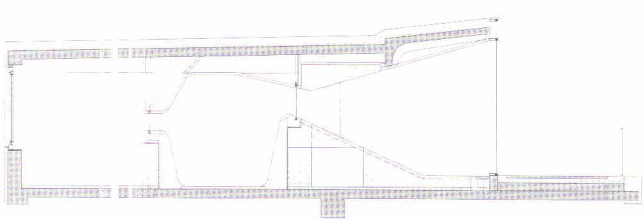

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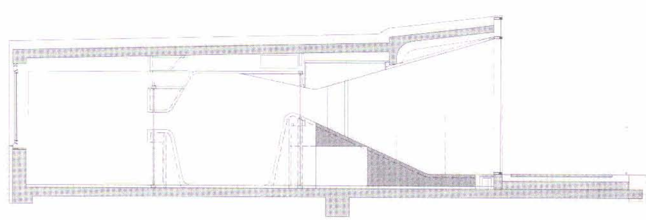

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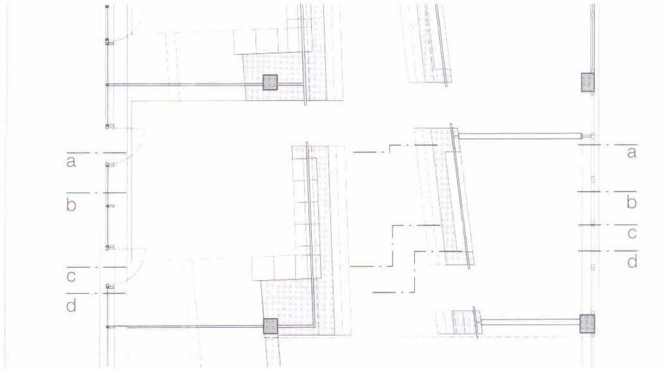
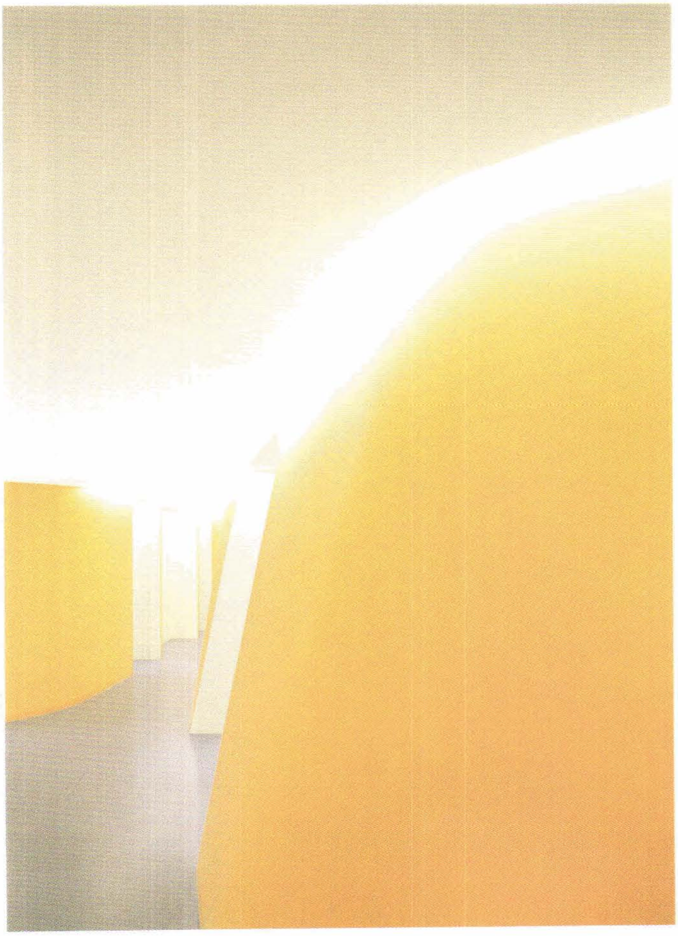


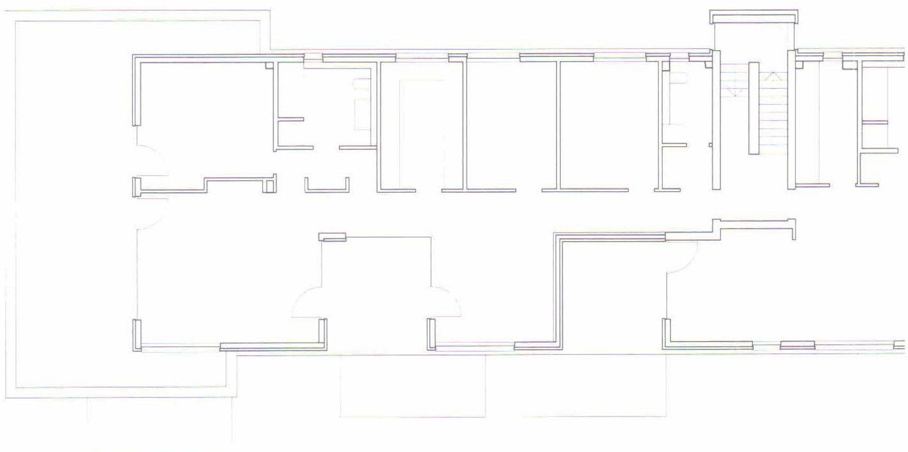
Plan Not to scale



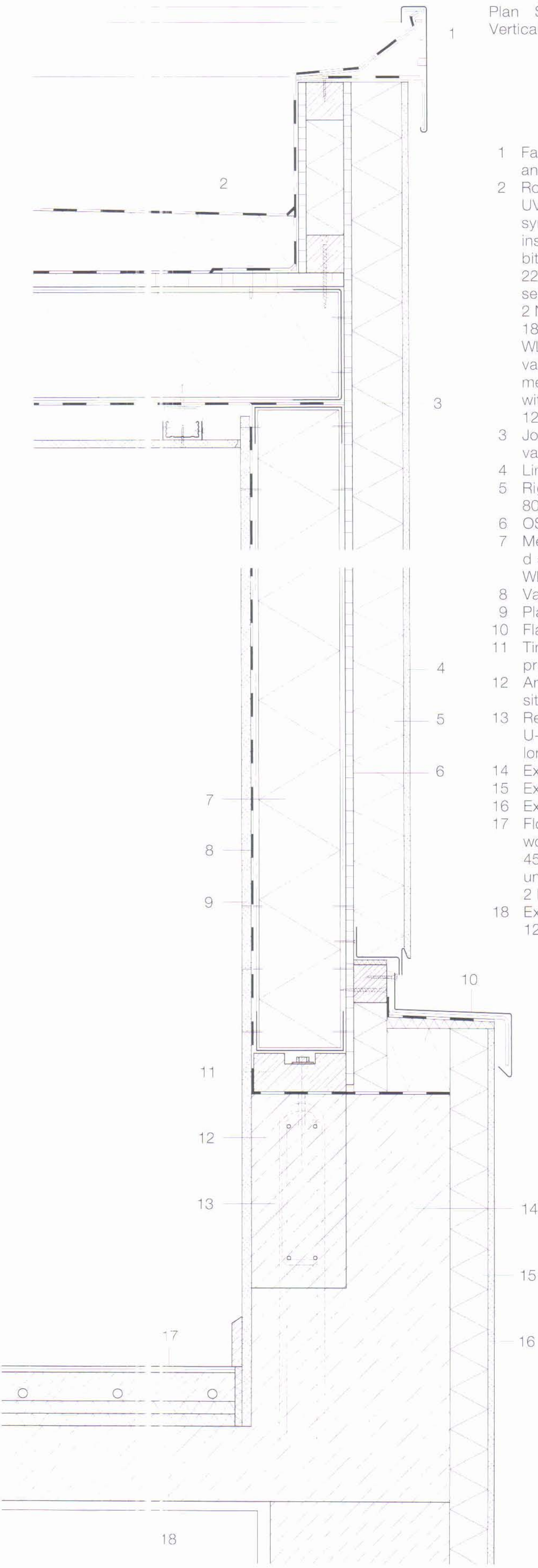
Rooftop extension in Frankfurt am Main

Design: TISIB Ingenieurgesellschaft, Darmstadt
Contractors: Gebrüder Bommhardt Bauunternehmung, Waldkappel-Bischhausen, in collaboration with O. Lux, Roth
Construction: 2007

This existing three-storey block in Praunheim, a district of Frankfurt am Main, can be regarded as a typical residential development of the 1960s. Despite the outdated technical standards and the overdue refurbishment, the good local infrastructure and the large number of trees made this project attractive. The sale of the 12 new apartments built as part of this refurbishment project, in the form of adding another storey in dry construction, provided the finance for the modernisation and upgrading measures necessary for this existing residential development.
All measures had to be carried out rigorously in lightweight construction because the loadbearing capacity of the existing roof surfaces could not accommodate any additional imposed loads. Loadbearing dry construction systems optimised the self-weight. The loadbearing structure of long-span beams made from thin-walled sheet steel sections enabled a flexible plan layout.
As this infill development had to be carried out while the other apartments below were still occupied, a decision was made to use prefabricated wall and roof elements in lightweight steel construction. A typical dry construction was employed in which the thicknesses of the metal studs and roof sections are just 1.5–2.0 mm. The use of shot-fired nails enabled economic jointing of the boarding, which meant that the work could be carried out in a similar way to timber construction. It took less than a week to erect the structure of each group of four apartments with a total floor space of approx. 450 m². The external wall elements were provided with insulation, vapour barrier and boarding to both sides in the factory. After erecting the wall and roof elements, the large areas of glazing were installed, a thermal insulation composite system was applied to the outside of the walls and insulation with integral falls laid on the roof. In contrast to building with masonry or concrete, no construction moisture was introduced and the interior fitting-out could be carried out at the same time as the thermal insulation works directly after completing the erection of the wall and roof elements. By integrating the insulation into the loadbearing construction of the external walls (insulation in the same plane as the studs) and using additional external insulation, U-values in the region of 0.15–0.20 W/m²K were achieved.



a Joining together ceiling channels and studs in the factory
b Filling the wall elements with mineral-fibre insulation
c Erecting the prefabricated elements on the building site
d Wall and roof elements joined together to form semi-prefabricated elements after erection on site



Plan Scale 1:250
Vertical section Scale 1:10

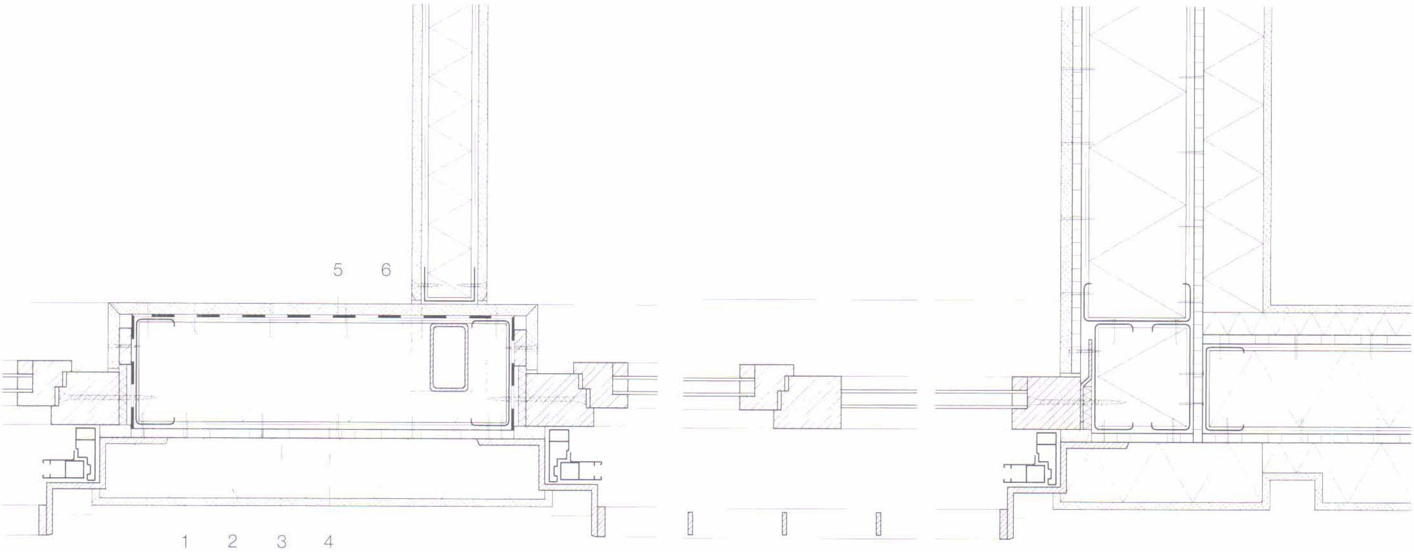
1 Fascia plate to edge of roof, anodised, brushed aluminium, E2/EV1
2 Roof construction:
UV-resistant sheeting
synthetic fleece facing
insulation with integral falls, 80–300 mm
bitumen waterproofing
22 mm OSB
secondary beams S 235,
2 No. 180 × 70 × 2 mm channels
180 mm mineral-fibre insulation, WLG 040
vapour barrier, s_d > 100 m
metal CD section, 60 × 27 mm, with 40 mm hanger brackets
12.5 mm plasterboard
3 Joints in sheeting glued airtight and vapour-tight
4 Lime-cement render
5 Rigid polystyrene foam, WLG 040, 80 mm
6 OSB, 12 mm
7 Metal studs, S 235, 150 × 50 × 10 mm, d = 1.5 mm, with mineral-fibre insulation, WLG 040
8 Vapour barrier
9 Plasterboard with skim coat
10 Flashing, anodised, brushed aluminium
11 Timber plank, 60 × 150 mm, for mounting prefabricated lightweight steel elements
12 Anchors in new parapet section cast in situ, grade C 20/25
13 Reinforcement:
U-bars cast into existing parapet, longitudinal bars and shear links
14 Existing reinforced concrete parapet
15 Existing rigid polystyrene foam, 60 mm
16 Existing lime-cement render, 10 mm
17 Floor construction:
wood-block flooring
45 mm calcium sulphate screed with underfloor heating
2 No. 20 mm impact sound insulation
18 Existing reinforced concrete roof slab, 120 mm


a


b


c


d



Horizontal section
junction between wall element and wall surrounding rooftop terrace
Scale 1:10

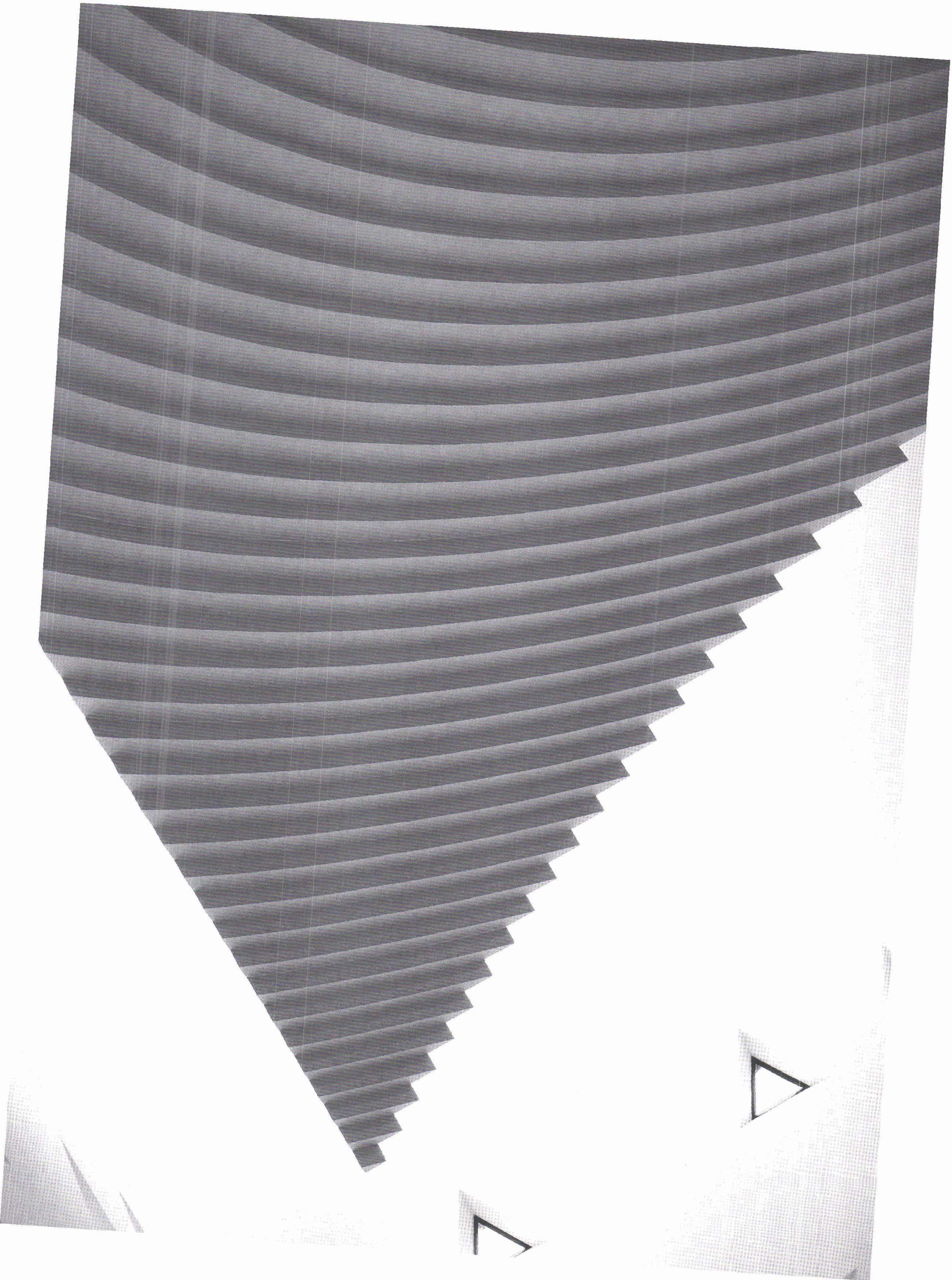
Construction of lightweight steel wall:

1 Lime-cement render
2 Rigid polystyrene foam, WLG 040, 80 mm
3 OSB, 12 mm
4 Metal studs, S 235, 150 × 50 × 10 mm, d = 1.5 mm, with mineral-fibre insulation, WLG 040
5 Vapour barrier
6 Plasterboard lining, skim coat

Museum in Herford

Architects:	Gehry Partners, Los Angeles, with Archimedes Bauplanungsgesellschaft, Herford
Contractor:	Mänz & Krauss, Berlin
Fitting-out system & moulded parts:	Saint-Gobain Rigips, Düsseldorf
Construction:	2005

In the small town of Herford in northern Germany, an 8000 m² plot was acquired to build the "MARTa" museum for contemporary art and design along the winding banks of the River Aa.
The facades, built using the facing bricks so typical of this region, are made up of many convex and concave forms and are topped by the wave-type stainless steel roof. There are no windows on the road side, only lightwells that illuminate the museum's interior naturally and provide changing lighting effects as the sun moves across the sky. The complex is divided into four functional areas: museum, forum, centre and restaurant. The museum demonstrates how dry construction methods can express designs and create structures and space.
The first floor contains a right-angled presentation area, which with its restrained aesthetics and extremely neutral design reminds us of the "White Cube". Contrasting with this, the exhibition rooms on the ground floor represent a dynamic, organic interior layout. This part of the museum has its own sculpted architectural language. It consists of a twisted 22 m high tower, the so-called cathedral, which is surrounded by four further, smaller, organically shaped galleries. All the rooms here follow a single-storey concept so that visitors can also see the whole structure above, right up to the underside of the roof, as well as enjoying the works of art. Rooflights are incorporated into the high ceilings. The way they direct the daylight was determined with the help of simulation models using single- and double-curvature surfaces.
The rooms are almost like walk-in sculptures themselves. The steepest inclined wall in the building is at an angle of 68°. The supporting framework is made up of factory-bent steel members assembled on site. The three-dimensional curves, the tight bending radii and the high demands placed on the surface finishes meant that the possibilities of plasterboard were taken to their limits in this project. Approval by the local building authority was required for the junctions and details of this construction. Plasterboard surfaces are finished to the highest quality level (Q4) in order to prevent strong side-lighting from revealing any joints or blemishes. This solid and hollow sculpted architecture plus the demand for lightness in the architectural language would not have been possible with a monolithic form of construction.



Standards and directives (selection)

DIN 1052
Design of timber structures – General rules and rules for buildings

DIN 4102
Fire behaviour of building materials and building components

DIN 4103-1
Internal non-load bearing partitions; requirements, testing

DIN 4108
Thermal insulation and energy economy in buildings

DIN 4108-7
Thermal insulation and energy economy of buildings – Part 7: Airtightness of building, requirements, recommendations and examples for planning and performance

DIN 4109
Sound insulation in buildings

DIN 4109 Supplement 1
Sound insulation in buildings; construction examples and calculation methods

DIN 18101
Doors; doors for residential buildings; sizes of door leaves, position of hinges and locks, interdependence of dimensions

DIN 18111-1
Door frames – Steel door frames – Part 1: Standard door frames for rebated doors in masonry

DIN 18111-2
Door frames – Steel door frames – Part 2: Standard door frames for metal stud gypsum walls

DIN 18111-3
Door frames – Steel door frames – Part 3: Special door frames for rebated and unrebated door leaves

DIN 18111-4
Door frames – Steel door frames – Part 4: Installation of steel door frames

DIN 18168-1
Ceiling linings and suspended ceilings with gypsum plasterboards – Part 1: Requirements for construction

DIN 18168-2
Ceiling linings and suspended ceilings with gypsum plasterboards – Part 2: Verification of the load-carrying capacity of metal sub-constructions and metal suspending rods

DIN 18180
Gypsum plasterboards – Types and requirements

DIN 18181
Gypsum plasterboards for building construction – Application

DIN 18182-1
Accessories for use with gypsum plasterboards – Part 1: Steel plate sections

DIN 18182-2
Accessories for use with gypsum plasterboards; drywall screws

DIN 18182-3
Accessories for use with gypsum plasterboards; staples

DIN 18182-4
Accessories for use with gypsum plasterboards; nails

DIN 18183
Partitions and wall linings with gypsum boards on metal framing

DIN 18184
Gypsum plaster boards with polystyrene or polyurethane rigid foam as insulating material

DIN 18340
German construction contract procedures – Part C: General technical specifications for building works – Dry construction works

DIN 55928-8
Protection of steel structures from corrosion by organic and metallic coatings – Part 8: protection of supporting thin-walled building components from corrosion

OENORM DIN 55928-9
Protection of steel structures from corrosion by organic and metallic coatings – Coating materials – Composition of binders and pigments

DIN 68127
Acoustic boards

DIN 68706-1
Interior doors made from wood and wood-based panels – Part 1: Door leaves; concepts, sizes, requirements

DIN 68706-2
Interior doors made from wood and wood-based panels – Part 2: Door frames; concepts, sizes, installation

DIN 68740-2
Panels – Part 2: Veneer outer layers on wood-based panels

DIN 68762
Chipboard for special purposes in building construction; concepts, requirements, testing

DIN 68800-1
Protection of timber used in buildings; general specifications

DIN 68800-2
Protection of timber – Part 2: Preventive constructional measures in buildings

DIN 68800-3
Protection of timber; preventive chemical protection

DIN 68800-4
Wood preservation; measures for the eradication of fungi and insects

DIN 68800-5
Protection of timber used in buildings; preventive chemical protection for wood-based materials

DIN EN 438-1
High-pressure decorative laminates (HPL) – Sheets based on thermosetting resins (usually called laminates) – Part 1: Introduction and general information

DIN EN 438-2
High-pressure decorative laminates (HPL) – Sheets based on thermosetting resins (usually called laminates) – Part 2: Determination of properties

DIN EN 438-3
High-pressure decorative laminates (HPL) – Sheets based on thermosetting resins (usually called laminates) – Part 3: Classification and specifications for laminates less than 2 mm thick intended for bonding to supporting substrates

DIN EN 12431
Thermal insulating products for building applications – Determination of thickness for floating floor insulating products

DIN EN 12524
Building materials and products – Hygrothermal properties – Tabulated design values

DIN EN 12825
Raised access floors

DIN EN 13162
Thermal insulation products for buildings – Factory-made mineral wool (MW) products – Specification

DIN EN 13163
Thermal insulation products for buildings – Factory-made products of expanded polystyrene (EPS) – Specification

DIN EN 13164
Thermal insulation products for buildings – Factory-made products of extruded polystyrene foam (XPS) – Specification

DIN EN 13165
Thermal insulation products for buildings – Factory-made rigid polyurethane foam (PUR) products – Specification

DIN EN 13166
Thermal insulation products for buildings – Factory-made products of phenolic foam (PF) – Specification

DIN EN 13167
Thermal insulation products for buildings – Factory-made cellular glass (CG) products – Specification

DIN EN 13168
Thermal insulation products for buildings – Factory-made wood wool (WW) products – Specification

DIN EN 13169
Thermal insulation products for buildings – Factory-made products of expanded perlite (EPB) – Specification

DIN EN 13170
Thermal insulation products for buildings – Factory-made products of expanded cork (ICB) – Specification

DIN EN 13170 Corrigenda 1

DIN EN 13171
Thermal insulation products for buildings – Factory-made wood fibre (WF) products – Specification

DIN EN 13213
Hollow floors

DIN EN 13964
Suspended ceilings – Requirements and test methods

DIN EN 13986
Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking

DIN EN 14195
Metal framing components for gypsum plasterboard systems – Definitions, requirements and test methods

DIN EN 14322
Wood-based panels – Melamine faced boards for interior uses – Definitions, requirements and classification

DIN EN 14566
Mechanical fasteners for gypsum plasterboard systems – Definitions, requirements and test methods

Institutes and trade associations (selection)

Institutes

Bundesweite Interessengemeinschaft Trockenbau e.V.
www.big-trockenbau.de

RAL-Gütegemeinschaft Trockenbau e.V.
www.trockenbau-ral.de

IGG – Industriegruppe Gipsplatten (part of Bundesverband der Gipsindustrie e.V.)
www.gips.de

BVS Bundesverband Systemböden e.V.
www.systemboden.de

TAIM e.V. – Federation of Industrial Metal Ceiling Manufacturers
www.taim-ev.org

GPDA – Gypsum Products Development Association
www.gpda.com

Gypsum Association (USA)
www.gypsum.org

Manufacturers (selection)

AMF Deckensysteme
(Knauf AMF GmbH & Co. KG)
www.amf-grafenau.de

Armstrong World Industries
www.armstrong.com

BER Deckensysteme GmbH
www.ber-deckenkonzepte.com

Bohle Innenausbau GmbH & Co. KG
www.bohle-gruppe.de

British Gypsum Ltd
www.british-gypsum.com

Burgess Architectural Products Ltd
www.burgessceilings.co.uk

Calsitherm Silikatbaustoffe GmbH
www.calsitherm.de

Chicago Metallic Corporation
www.chicago-metallic.com

Danogips GmbH & Co. KG
www.danogips.de

Deutsche Heraklith GmbH
www.heraklith.com

Eternit AG
www.eternit.de

Franz Habisreutinger GmbH & Co. KG
www.habisreutinger.de

Haubold Befestigungstechnik GmbH
www.haubold-deutschland.com

Hunter Douglas Components
www.hunterdouglas.com

Isorast GmbH
www.isorast.de

Kiefer Luft- & Klimatechnik
www.kieferklima.de

Knauf Drywall UK
www.knaufdrywall.co.uk

Knauf Perlite GmbH
www.perlite.de

König GmbH & Co. KG
www.koenig-produkte.de

Lafarge Cement UK
www.lafarge.co.uk

Liapor GmbH & Co. KG
www.liapor.com

Lignokustik AG
www.lignokustik.ch

Lindner AG
www.lindner-holding.de

Lindner Reinraumtechnik
www.lindner-reinraumtechnik.com

Mänz & Krauss Ausbau GmbH
www.maenz-berlin.com

Mero – TSK International GmbH & Co. KG
www.mero.de

Miprotec Brandschutzprodukte
(part of Techno-Physik Engineering GmbH)
www.techno-physik.com

NE Paneel Decken
(Nagelstutz & Eichler GmbH & Co. KG)
www.nagelstutzundeichler.de

Okel GmbH & Co. KG
www.okel.de

OWA – Odenwald Faserplattenwerk GmbH
www.owa.de

pinta acoustic GmbH
www.pinta-acoustic.de

Promat GmbH
www.promat.de

Protektorwerk Florenz Maisch GmbH & Co. KG
www.protektor.com

Richter System GmbH & Co. KG
www.richtersystem.com

Rockwool Ltd
www.rockwool.co.uk

Röhr GmbH
www.europlac.de

Saint-Gobain Rigips GmbH
www.rigips.de

Saint-Gobain Isover
www.isover.com

Suckow & Fischer Systeme GmbH & Co. KG
www.suckow-fischer.de

Topakustik Promotion GmbH & Co. KG
www.topakustik.de

Tremco illbruck GmbH & Co. KG
www.tremco-illbruck.com

URSA Deutschland GmbH
www.ursa.de

USG Deutschland GmbH
www.usgeurope.com

Vogl Deckensysteme GmbH
www.vogl-deckensysteme.de

WeGo Systembaustoffe GmbH & Co. oHG
www.wego-vti.de

Xella International GmbH
www.xella.de

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Document 591, Bauen im Bestand – Lösungen in Stahlleichtbauweise, Stahl-Informationszentrum, Düsseldorf, 2007

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IGG data sheet 1:
Baustellenbedingungen, Bundesverband der Gipsindustrie, Darmstadt, 2007

IGG data sheet 2:
Verspachtelung von Gipsplatten – Oberflächengüten, Bundesverband der Gipsindustrie, Darmstadt, 2007

IGG data sheet 3:
Gipsplattenkonstruktionen Fugen und Anschlüsse, Bundesverband der Gipsindustrie, Darmstadt, 2004

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Regeldetails zum Wärmeschutz, Modernisierung mit Trockenbausystemen, Bundesverband der Gipsindustrie, Darmstadt, 2006

IGG data sheet 5:
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IGG data sheet 6:
Trockenbauflächen aus Gipsplatten zur weitergehenden Oberflächenbeschichtung bzw. -bekleidung, Bundesverband der Gipsindustrie, Darmstadt, 2006

IGG data sheet 7:
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ISBN 978-3-7643-8808-9