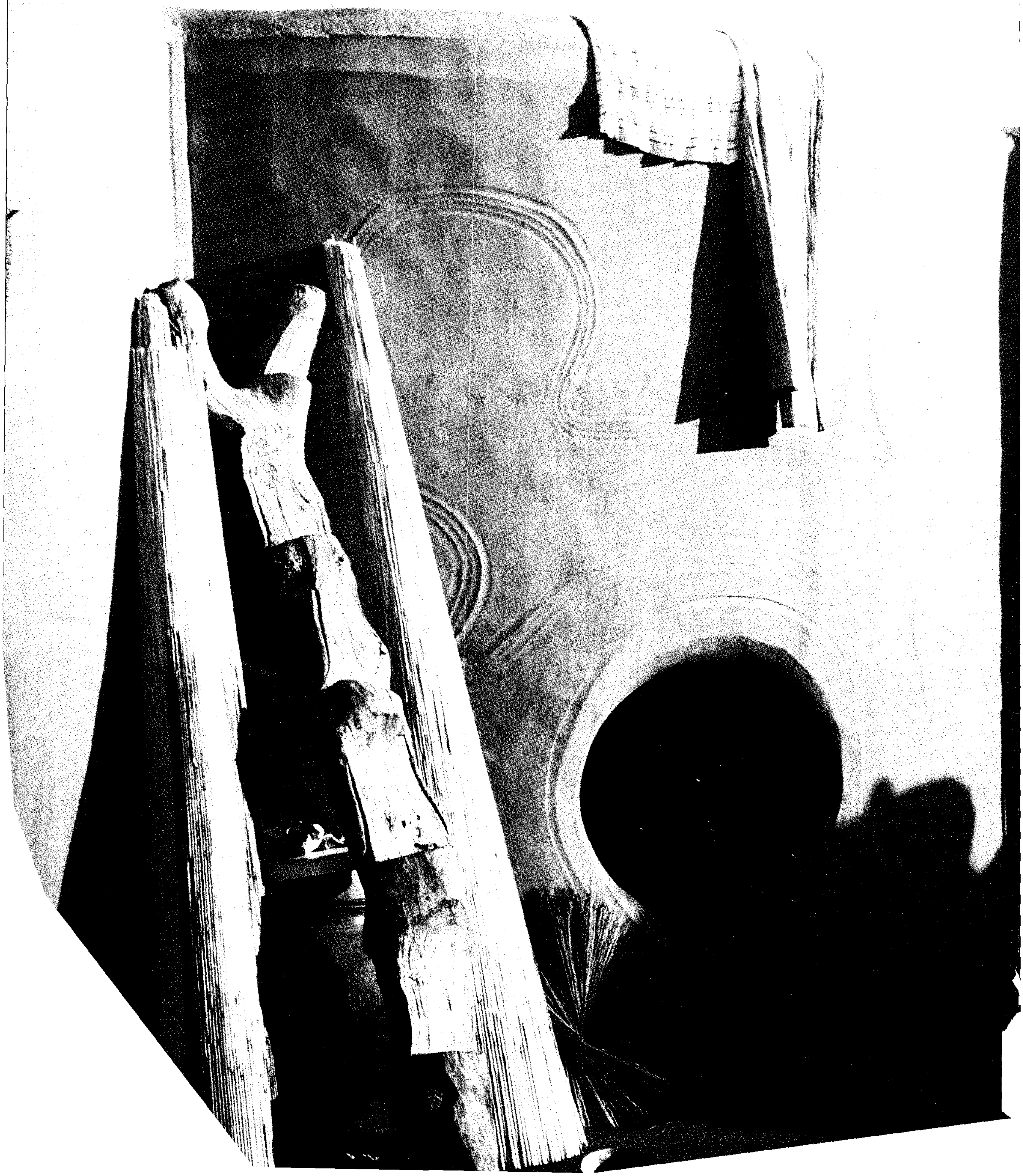
CONSTRUCTION TECHNOLOGY FOR A TROPICAL DEVELOPING COUNTRY



CONSTRUCTION TECHNOLOGY

FOR A TROPICAL DEVELOPING COUNTRY

HANNAH SCHRECKENBACH

WITH THE ASSISTANCE OF
JACKSON G.K. ABANKWA

DEUTSCHE GESELLSCHAFT FÜR TECHNISCHE ZUSAMMENARBEIT (GTZ) GMBH
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Opposite Title pagé: In the Chief's compound at Sandema, Northern Ghana (1968).

Dipl. Ing. Hannah Schreckenbach, a German, has worked as archtitect (for development) in Ghana in the Public Works Department of the Ministry of Works and Housing since September 1960. During this time she was, for different periods, in charge of the Housing, General and Special Duties Section as Senior Architect and has designed and supervised the construction of a large number of projects (houses for different income groups, offices, colleges, laboratories, workshops, post offices and the extensions to the Parliament House in Accra). She joined the Faculty of Architecture of the University of Science and Technology in Kumasi as Senior Lecturer in 1975 for "Construction Technology", "Building Services for Architects" and "Introduction into Structures". She is Fellow of the Ghana Institute of Architects. In April 1981 she was awarded the "Order of Merit" by the President of the Federal Republic of Germany.

She started with the preparation of this textbook as the project leader of a GTZ-project in October 1980.

Jackson G.K. Abankwa, a Ghanaian, joined Hannah Schreckenbach as a Teaching Assistant, attached to the GTZ-project during the period of his National Service, in August 1981. He completed his Postgraduate Diploma Course in July 1981 with the Diploma in Architecture and took an early interest in construction methods applicable for a tropical developing country.

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– Fig. 146: Walls in Cuzco, from "The Incredible Incas and Their Timeless Land" by Loren McIntyre, National Geographic Society, U.S.A.;

– Fig. 161: Spread of bamboo throughout the world; Fig. 163: Growth and structure of clump bamboo; Fig. 174: Bamboo scaffolding in Hongkong, from "Bamboo, the Giant Grass" by L. Marden, National Geographic, Vol. 158, No 4, October 1980;

– Fig. 164 and 165: Preservation of Bamboo by Boucherie process and by dipping, from "Bamboo" by J. Jansen, University of Technology, Eindhoven, The Netherlands;

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– Fig. 214: Schematical detail of the Oxford solar heated kiln, from "A Solar Heated Dryer for Timber" by A.D.K. Hardie, "Appropriate Technology", Vol. 6, No 1, May 1979;

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– Fig. 240: Structural systems and span; Fig. 242: Compression and tension structures, from "Bauwerk, Tragwerk, Tragstruktur" by O. Büttner and E. Hampe, VEB-Verlag für Bauwesen, Berlin;

– Fig. 241: The state of equilibrium, from "Structures" by H.W. Rosenthal; Fig. 247: Uneven loading; Fig. 248: Shear failure of foundations; Fig. 249: Bending failure; Fig. 250: Overturning due to lateral forces; Fig. 252: Strip

foundation; Fig. 253: Pad foundation; Fig. 254: Raft foundation; Detail 5.3.3: Retaining walls and revetments,

FOREWORD

The architecture of every age has often reflected, among other factors, sociological, economic and technological expression of that period. This accounts for similarity in appearance of buildings of similar function in a given period of time, such similarity being achieved through the application of certain design features and forms.
But every often students and practising architects in tropical countries tend to accept the use of many design features without pausing to assess their suitability in terms of environmental conformity or of economic and climatic considerations. They also specify materials and constructions techniques that are inappropriate and consequently result in failure.

Since many of the "Third World" countries fall within the tropical climatic zone, their students of architecture cannot afford extensive travel and so tend to accept the buildings around them as their only practical and tangible examples of synthesis of design and construction theory. There is need therefore for practising architects to approach their design and construction problems with caution and from first principles. In this regard, interpretation of client's brief must be backed by a thorough knowledge of the social, historical and technological setting of the environment, even though very often this knowledge cannot be found in the required form in any existing literature. Our students in Kumasi have acquired it through a carefully regulated curriculum the requirements of which have produced an impressive collection of data and documentation which have proved immensely useful in the preparation of this book.

As most of the schools of architecture in the Tropical Developing Countries were founded on British or American systems their original curriculums were imported and, being unrelated to local experience, often produced disastrous consequences. Many of these schools have, of course, modified their original syllabuses with good results but the Kumasi experience which has been well acknowledged is of significant interest.

It started with a modified syllabus of the Royal Institute of British Architects which did not go far enough to achieve the objective stated above. Consequentlyl a new syllabus was devised in the early sixties which had as its basis studio programmes designed around integrated studios of communities as experienced by students at the end of the 2nd and 3rd years in given areas where they are obliged to stay for a two week period during the long vacation. The documentation that followed gives the students a comprehensive background to the following year's programme. While the junior year covers rural development the senior year deals with urban problems, but it is essential that both give the student the opportunity to design for the two main climatic belts of Ghana – the hot dry climate of the northern savannah and the warm humid forest belt.

Through this approach, a majority of students experience, for the first time, traditional methods of construction and the range of options in materials and construction which will help them face the challenge of using local materials to save foreign exchange on certain imported building materials.

Modern materials and techniques have been applied increasingly in the tropics but often the results have been poor in quality and durability for both technical and social reasons, as well as being expensive. Traditional materials and techniques have depended, by their nature, upon locally available materials. Without any urge to try alternative solutions such construction has, perforce, been socially acceptable. The problem of durability has not always been of importance, as with materials to hand, seasonal repairs such as re-thatching has become part of the traditions.

However, with the growth of population and which external influences affecting people's lives, societies are changing. Also some traditional materials, such as timber are now being exported in increasing quantities for the much needed foreign exchange, and are therefore getting scarce in the savannah belt or expensive generally. The need for increased durability therefore has become important.

Although many books have been published on Building Construction, few are specifically concerned with the tropical environment. Lots of publications are also available on other aspects of the tropical environment, but it is rare to come across literature which not only describes the technology, but also puts it in the social and historical setting for which it is intended.

Hannah Schreckenbach had been practising architecture for 15 years in Ghana before joining the Department of Architecture at the University of Science and Technology, Kumasi in 1975 as well as discovering at first hand the day-to-day problems encountered when putting up buildings in Ghana, she has, through extensive travel in West Africa acquired significant insight into the social needs of various problems. She has built upon this knowledge by extensive research.

"Construction Technology for a Tropical Developing Country" presents information essential to the building designer, through a comprehensive text and exquisite drawings, and puts it in context. It makes clear the variations in climate and hence in the living habits of the people in the tropical zone. Id describes traditional solutions to construction problems, and illustrates the positive and negative aspects of these techniques. It also provides a comprehensive range of alternative solutions, covering modern traditional materials where appropriate.

The emphasis on traditional construction materials and techniques underscores the importance of the need for architects and builders in the tropics to search for local substitutes for expensive imported materials which account for a substantial proportion of scarce foreign exchange resources in most of these countries. The student of Architecture and the practitioner will find this work to be an invaluable design tool.

"Construction Technology for a Tropical Developing Country" which had a small beginning as a Departmental Research programme under the leadership of Hannah has developed into a textbook, the outcome of International Technical Co-operation between the GTZ and the University of Science and Technology, Kumasi.

PROF. J. OWUSU-ADDO
Dean, Faculty of Architecture,
U.S.T., Kumasi

1 INTRODUCTION

"I have no doubt that it is possible to give a new direction to technological development, a direction that shall lead it back to the real needs of man, and that also means: **To the actual size of man.** Man is small and, therefore, small is beautiful". (DR. E. F. Schumacher in his book "Small is beautiful" – A Study of Economics as if People Mattered – 1973).

Food is one basic need of man, shelter is another. Developing countries throughout the world are trying hard to satisfy the first need by attaching highest priority in their different government programmes to the promotion of agriculture in order to achieve self-sufficiency in this sector with varying levels of success. They are trying equally hard to satisfy the basic need of shelter for their people. And this has, since achievement of independence for most of the developing countries turned out to be an uphill struggle with little success.
Technologies for construction of houses in tropical developing countries depend to a large extent on imported building materials. When local industries are set up to produce some of these materials, this process of "industrialisation" (already expensive initially involving a large amount of foreign currency) relies on the imported raw materials for the manufacture of their products. It also relies on a regular supply of spare parts for the machines in the respective factories. It is also based on imported technologies for the production process.
Most of the developing countries have to cope with varying degrees of economic crisis caused by the fluctuations of world market prices for their main export goods (from cocoa, coffee, minerals to timber, etc.) Moreover, many of these countries have been very adversely affected by the oil crisis of 1973.

Ghana, for example, is now spending over 40% of her export earning for the importation of crude oil. The result is that there is not enough foreign currency available for importing raw materials for the industries producing building materials or for the importation of such materials. The steadily rising demand for cement, for example, cannot be satisfied. "Black market" prices cannot be paid by the middle and low-income earner or by the small farmer for cement or for corrugated aluminium or asbestos-cement roofing sheets or for window glass (louvres) or for plywood flush doors etc. And it is this group of people, the workers, clerks, artisans, civil servants, young professionals, teachers, etc. who cannot afford to build a house or flat for themselves and who rent a room or rooms at exorbitant prices in already overcrowded, unhealthy surroundings (*see* Plate "Introduction") of uncontrolled growth suburban areas in the large towns, because the authorities are also not in a position to put up sufficient and cheap rental units due to the same constraints.

Opposite: Anloga, a Kumasi Zongo, taken from the air (1976).

Attempts have been made by some developing countries to fully utilize locally available building materials, to process others from own resources with technologies which do not depend on a large foreign currency component and to improve their own known traditional building methods with these materials, in order to achieve a better durability of the buildings put up with these methods and at the same time to improve the quality of the traditional materials used.

This is a good beginning. What is now needed is an educational process to convince the authorities in these countries and the designers that "intermediate or appropriate technology" does not mean an inferior, outdated technology. It very simply means, in the context of this book, a new understanding and precise knowledge of traditional methods of construction with the full use of all locally available materials for construction and how this knowledge can be applied in different ways in a "labour surplus" (*from* "Small is beautiful" by Dr. E.R. Schumacher) society.

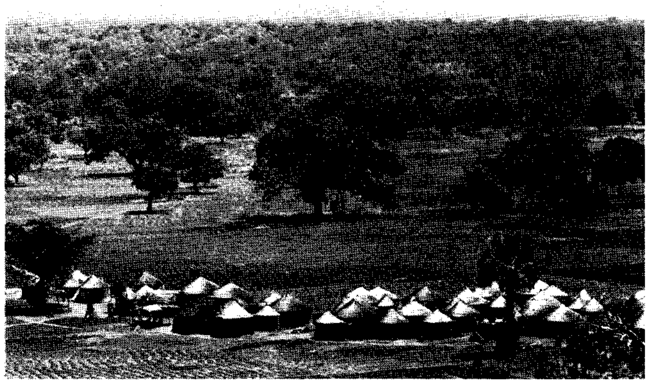
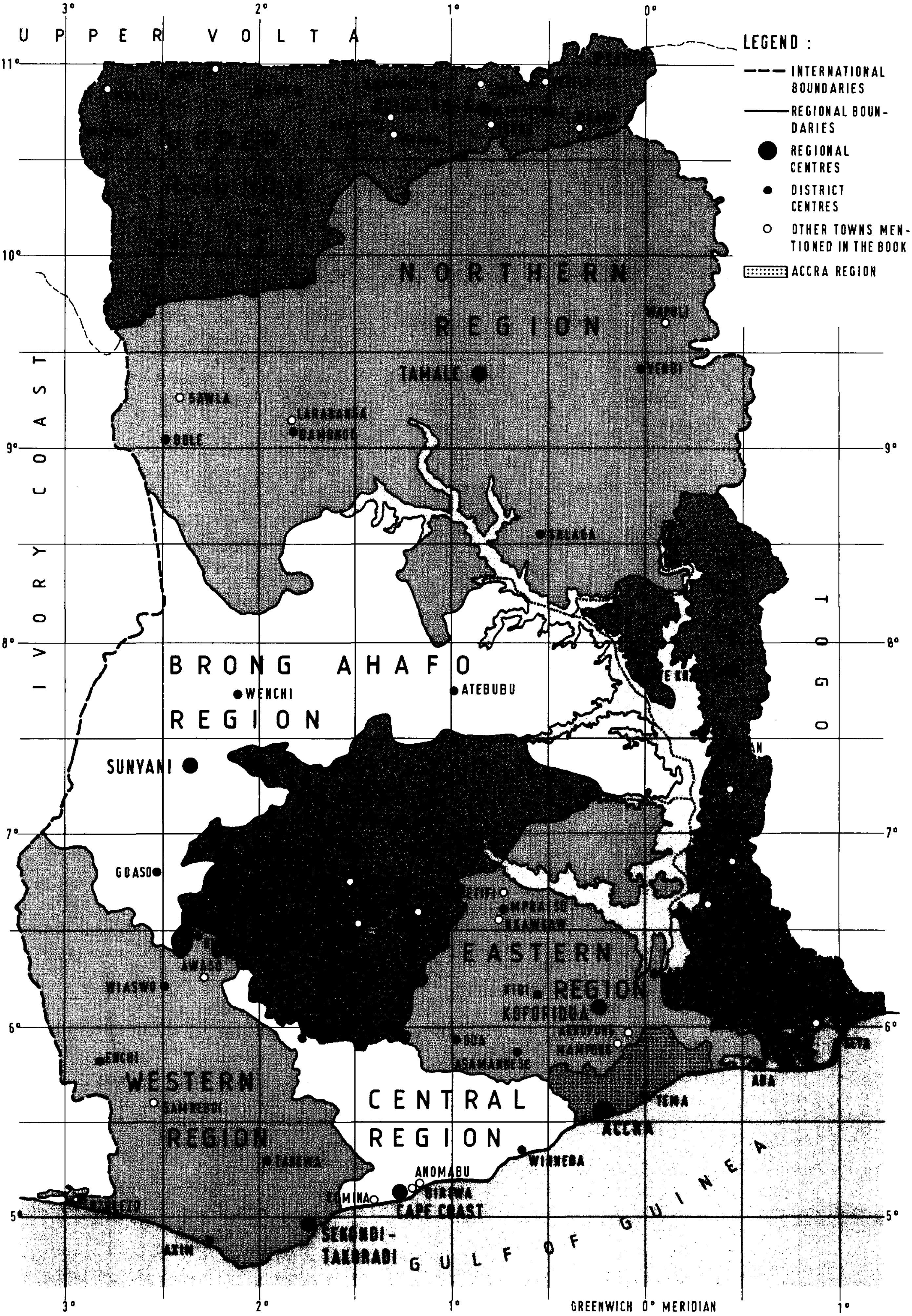


Fig. 2: A Mamprusi compound in the Guinea savannah woodland, south of Bolgatanga, Upper Region (1962).

Fig. 3: An old Ashanti village within the municipal area of Kumasi, taken from the air (1976).

Fig. 1: The Chief's compound at Tenzugu in the Tongo Hills, Upper Region of Ghana (1978).



MAP N°1 : GHANA-ADMINISTRATIVE

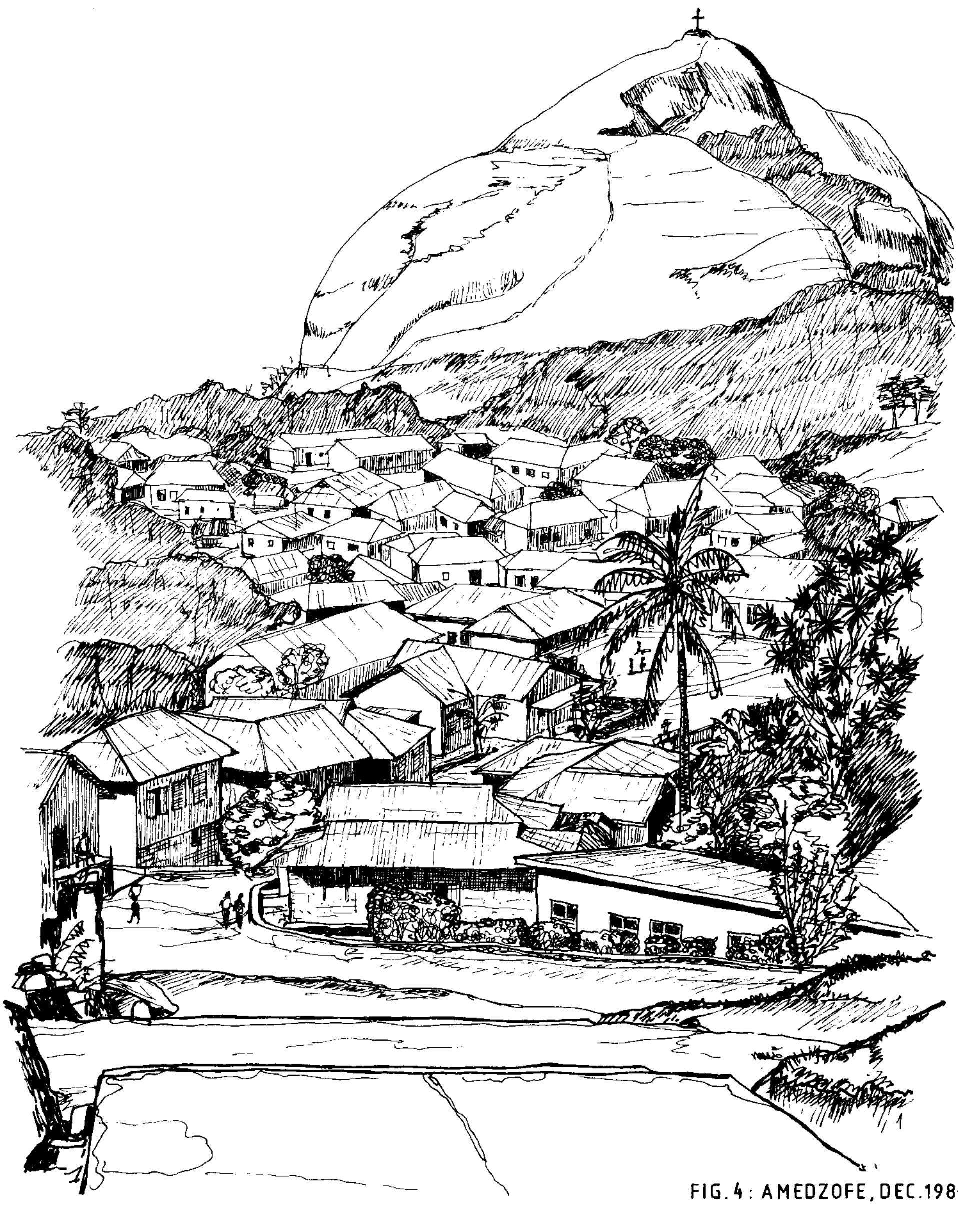
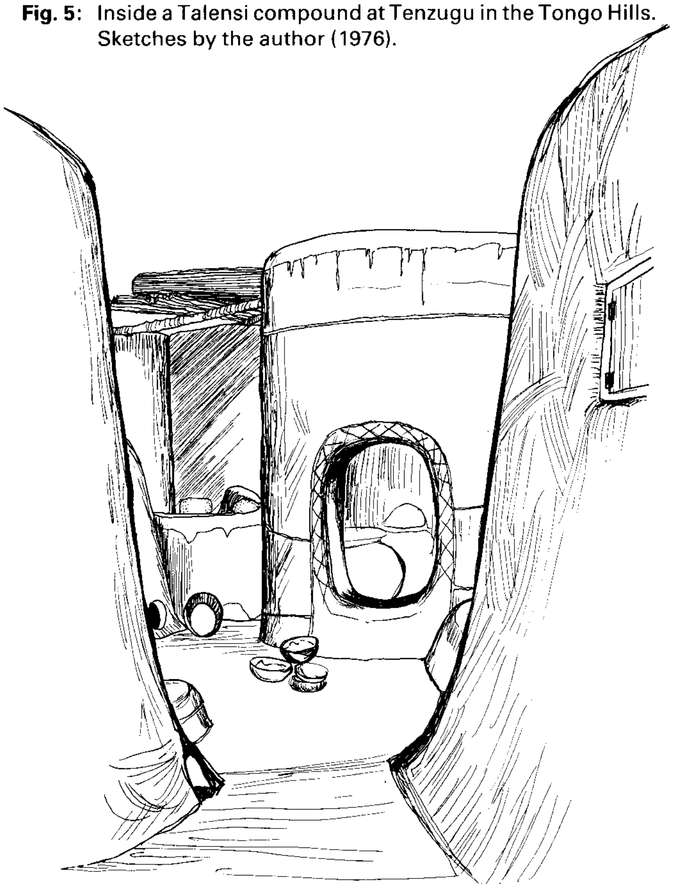


FIG. 4: AMEDZOFE, DEC. 1980

Fig. 5: Inside a Talensi compound at Tenzugu in the Tongo Hills. Sketches by the author (1976).



The first part of this book records the indigenous building methods in Ghana in detail (Fig. 1 *to* 5). The study of these methods will show that the "traditional builder" utilized to his full advantage available materials from his natural environment – forest, savannah, soil, river banks, etc. and built houses which were developed from simple huts to solid buildings and which were suitable for the tropical conditions of the different climatic zones in the country in which he lived.

The second part lists and describes possible uses of Ghana's locally available natural and processed building materials and other conventional materials, as well as production of building materials from wastes. Examples of uses will also be listed from other tropical developing countries with similar conditions to Ghana's.

Another section deals with Ghana's timber. It contains a catalogue listing over 100 timber species and their uses or possible uses in construction, carpentry, joinery, etc. Timber framework details are also included.

The main part of the book explains appropriate construction technologies from soil investigations, setting-out, excavations, foundations to roofs and all finishes for a two-storey building. A section on **basic services** follows separately.

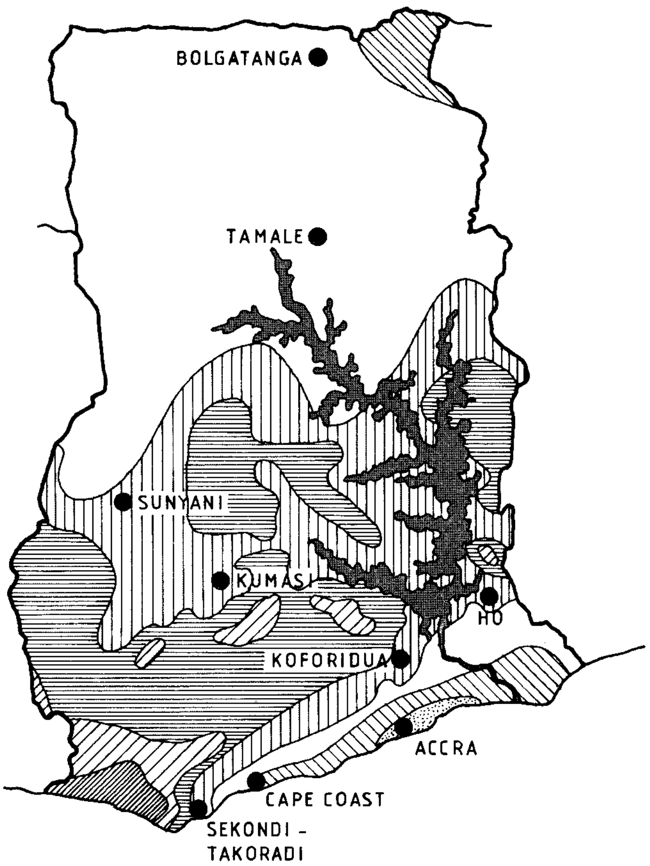
1.1 GHANA

Ghana (Map. No. 1) is situated almost centrally among the countries strung along the Guinea Coast of West Africa, between latitudes 4°30′ N and 11°10′ N and longitudes 1°12′ E and 3°15′ W. It is bounded on the west by the Republic of Ivory Coast, on the east by the Republic of Togo and on the north by Upper Volta. It is not far away from the Equator. The country extends about 750km from south to north and 480km at the widest part from east to west. The Greenwich Meridian runs through Ghana (at Tema).

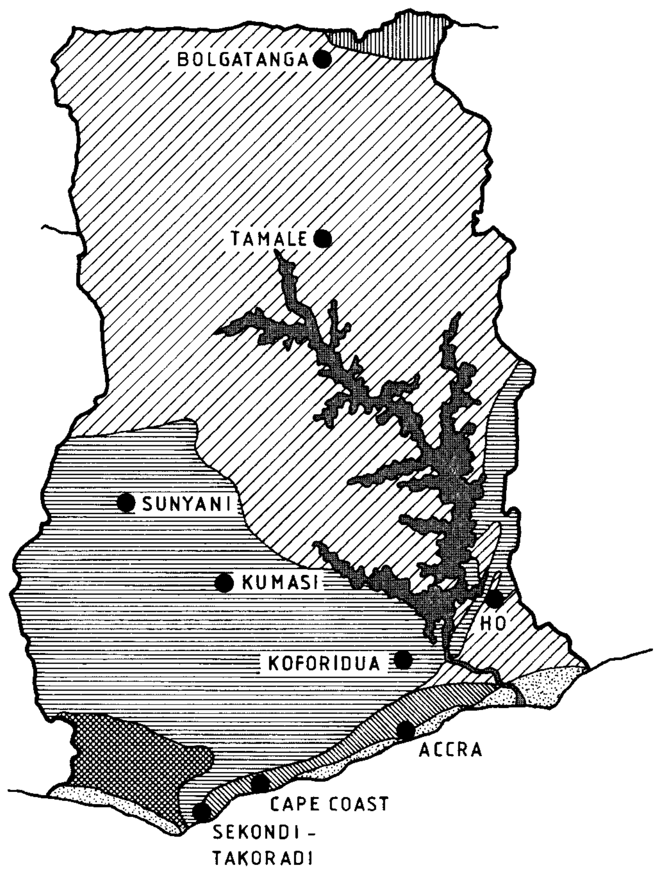
The country lies in the tropics and is exposed to the south-west winds, blowing from the South Atlantic towards the Guinea Coast, as well as to the north-east trade winds blowing from the Sahara towards the Guinea Coast. The first are comparatively cool and moist, the latter hot and dry. Annual mean temperatures range from 26°C to 29°C, with the lowest near the coast and the highest in the north of the country. In the north the lowest humidity is recorded from December to February with the lowest night temperatures (as low as 11°C during January), whilst the highest temperatures are recorded in March, April (up to 40°C). The annual mean rainfall is shown on Map No. 2. Map No. 3 shows the vegetation in the country.

When considering construction technologies appropriate for a tropical developing country like Ghana it is important to "design for the climate" and to utilize the materials to this effect as well. The designer will also consider solar radiation in Ghana with the maximum solar angle of elevation with a value between 55° and 90°. The daily pass of the sun goes through south in the months September to March and through the north in the period from April to August. Details like windows, doors and roofs will reflect this, as well as the materials proposed for these details.

Ghana has at present a population of about 12 million of which the largest numbers are concentrated in the Accra, Eastern, Ashanti and Volta Regions. It has the most extensive man-made lake in the world with the lake formed above the Akosombo Dam by damming the river Volta (Fig. 6).



MAP N° 2 : AVERAGE ANNUAL RAINFALL



MAP N° 3 : VEGETATION

Fig. 6: The Akosombo Dam during spilling in August, 1968.

Fig. 7: High-rise flats in Westberlin, Maerkisches Viertel (from: BERLINER FORUM, BERLIN, 1/71, Das Maerkische Viertel).

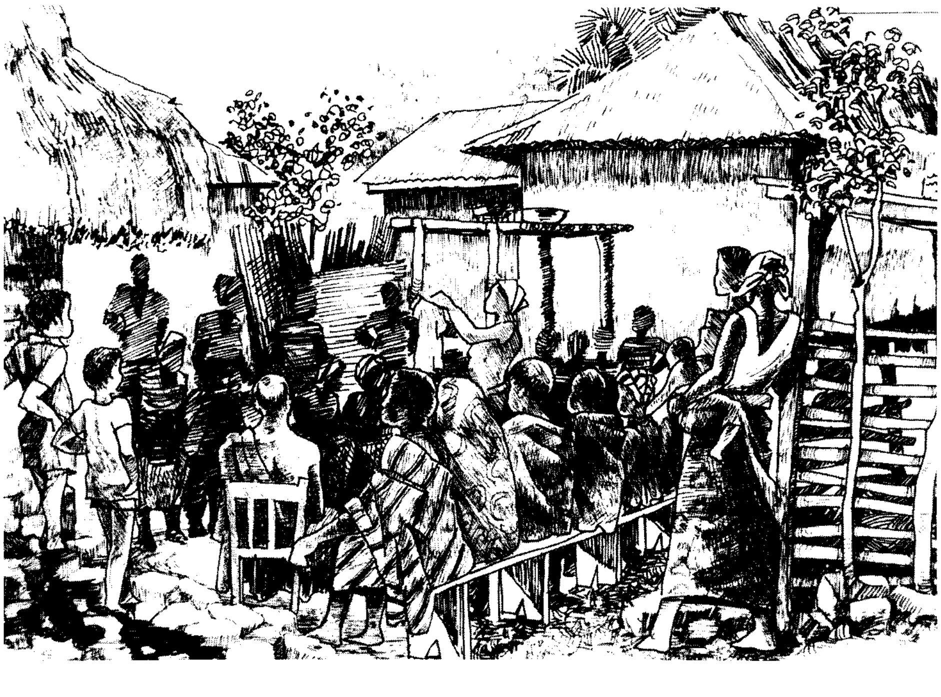


Fig. 8: Family gathering in Aviefe, Volta Region (from the Ho-Taviefe Survey, Department of Architecture U.S.T., August, 1980, sketch by M. BORTEI-DOKU).

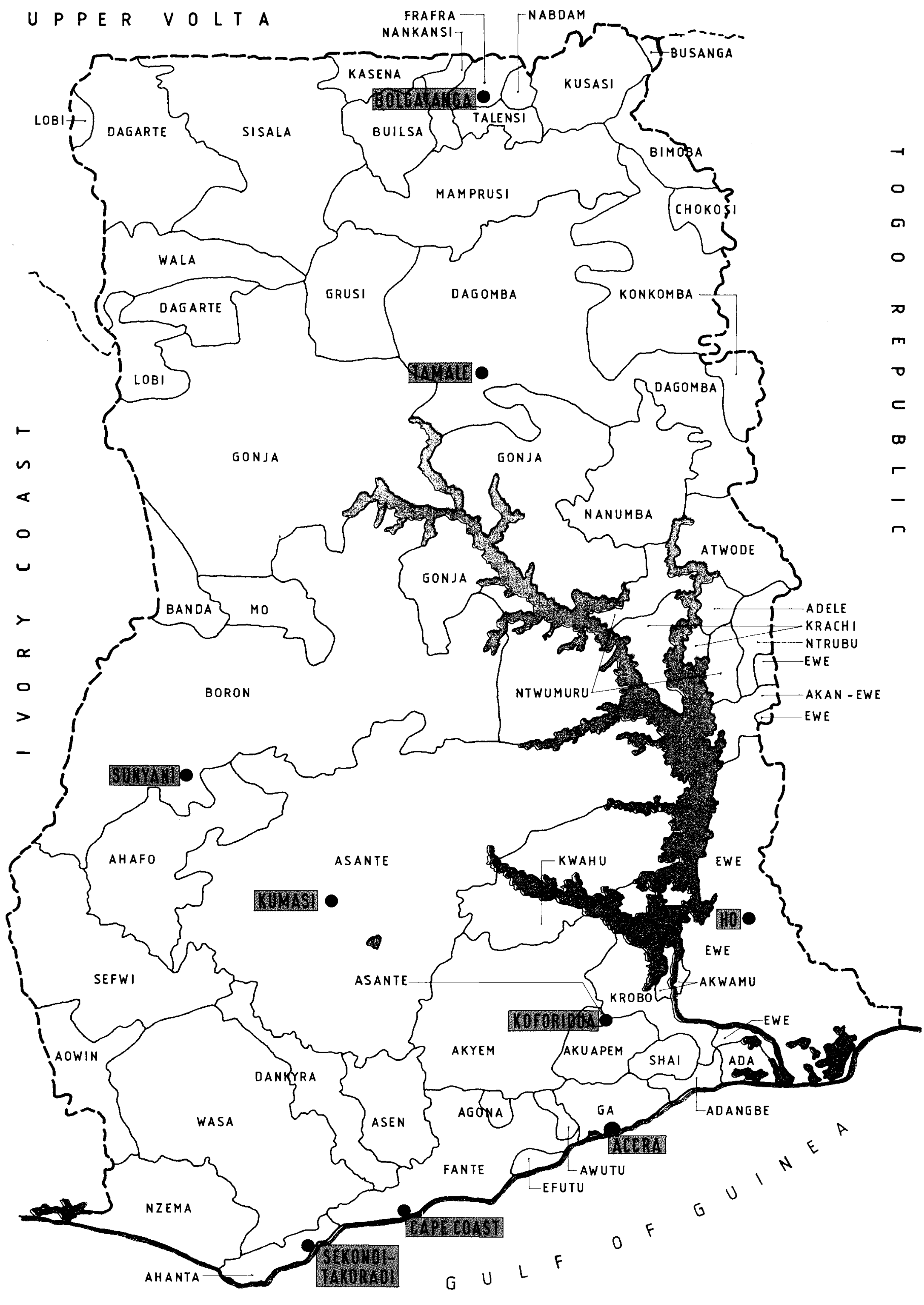
Fig. 9: The "Roman Hill" area, a part of the City of Kumasi, 1979.

With the establishment of new industries following the completion of the Volta Project and availability of hydro-electric energy in the mid-sixties attempts were made to introduce prefabricated concrete panel systems in the building industry in Ghana. These attempts have so far proved unsuccessful, not only due to the steady economic decline of the country. Designs for "mass-produced" high-rise flats (Fig. 7) are foreign to an African society which is based on the extended family system with strong interaction between communities (Fig. 8 *and* 9). The social problems caused by these high-rise residential units especially in European towns have resulted in a new approach to design in the industrialised countries.

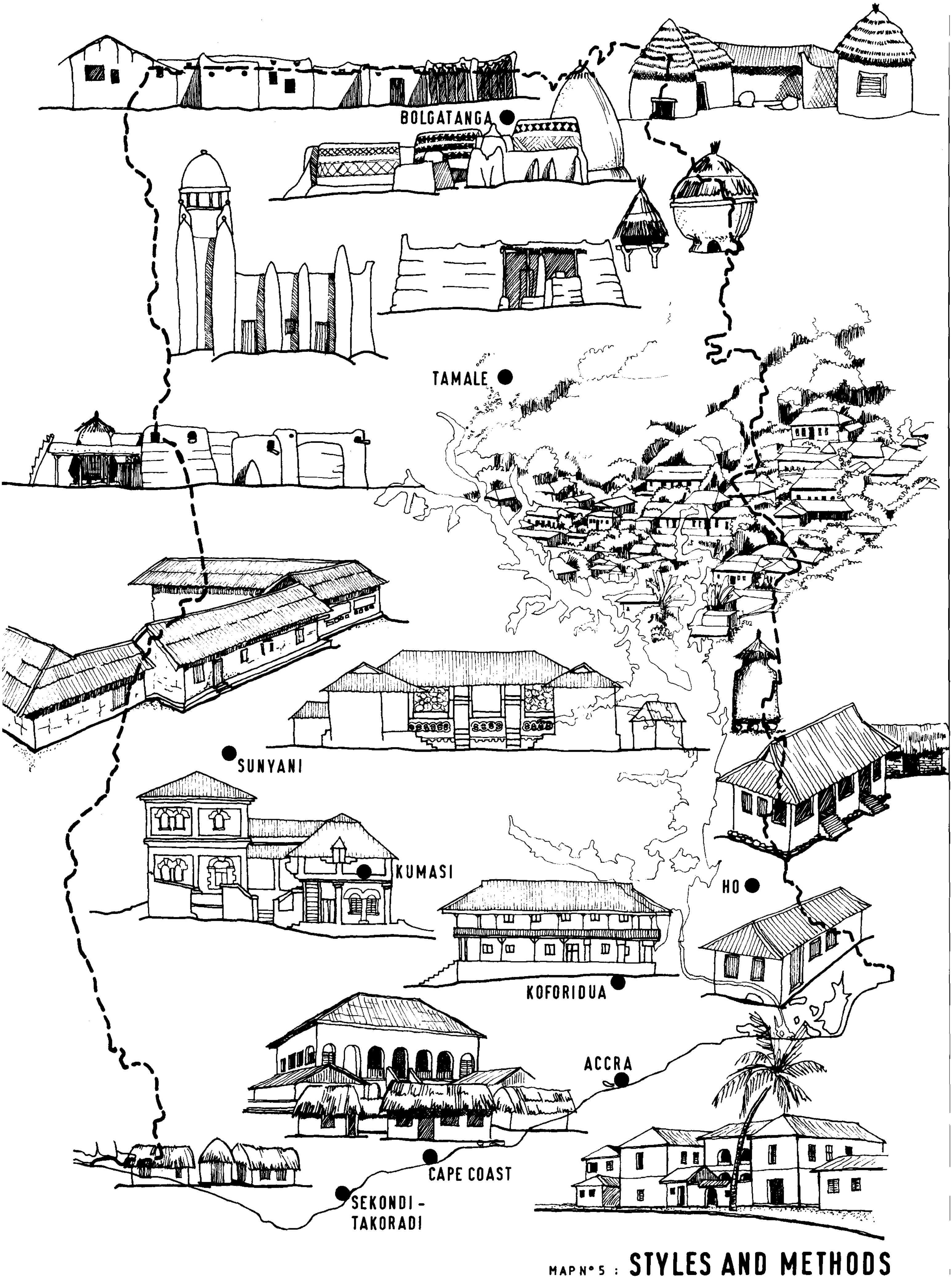
System building and industrialised building methods for a tropical developing country could form part of another study at the appropriate time.

1 INTRODUCTION – References:

1. E.A. BOATENG – A Geography of Ghana (Cambridge University Press, Second Edition, 1970).
2. W. MANSHARD – Afrika – Suedlich der Sahara. (Fischer Laenderkunde, 1970).
3. E.F. SCHUMACHER – Small is Beautiful – A Study of Economics as If People Mattered. (ABACUS, London, 1974).



MAP N°4 : **MAIN ETHNIC GROUPS IN GHANA**



MAP N° 5 : **STYLES AND METHODS**

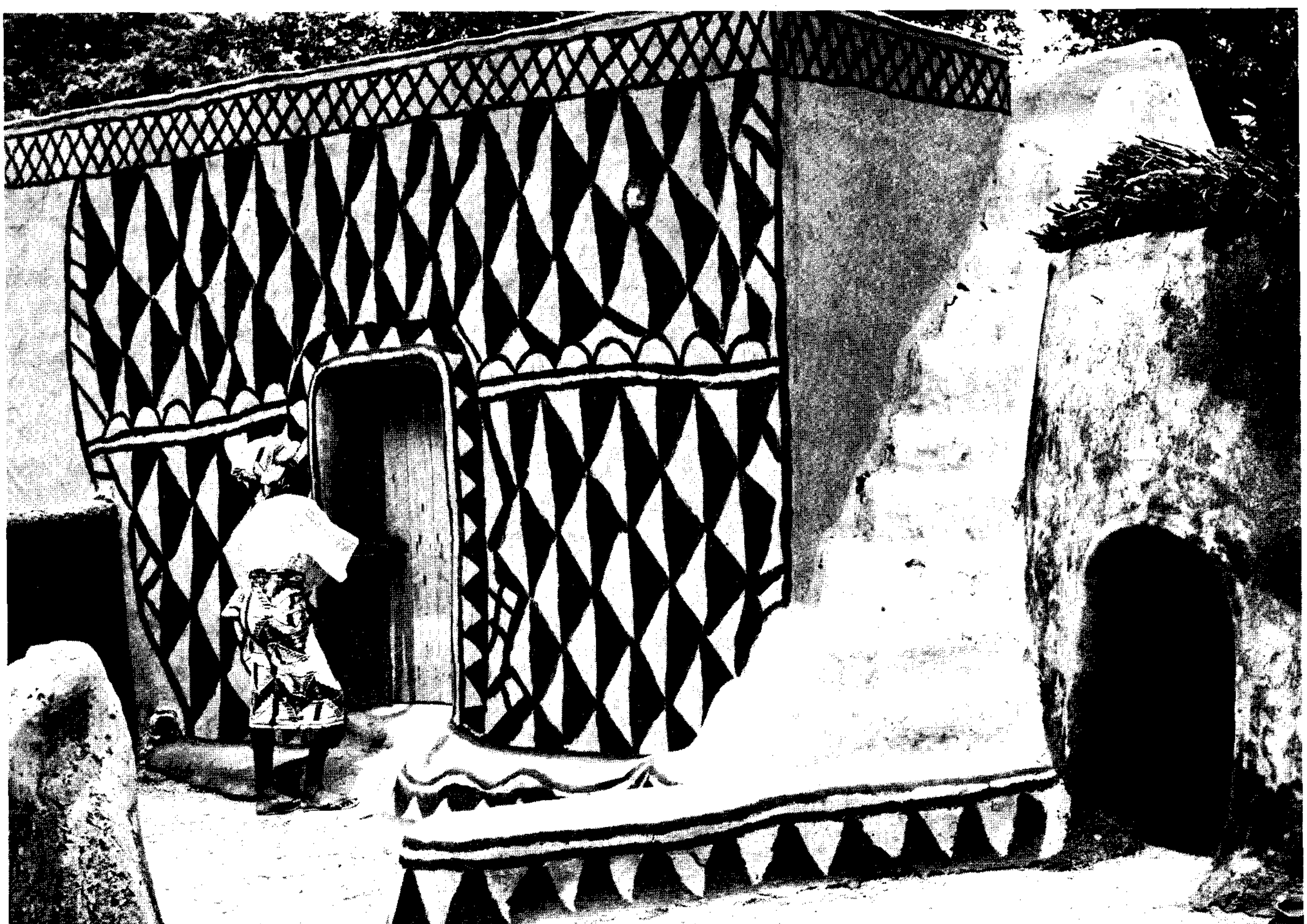
2 TRADITIONAL BUILDING METHODS

To enable an architect to design and detail good but cheap houses in tropical developing countries he or she must have a complete understanding of the methods with which the traditional builder has built his structures. Ghana, for example, has four main climatic zones which, as will be shown further on, influenced the indigenous building methods through different vegetation, soils, stones etc. in these areas. They are: The coastal plain, the rain forest, the transitional forest, the savannah.

The traditional building methods in this part are explained for Northern and Southern Ghana.

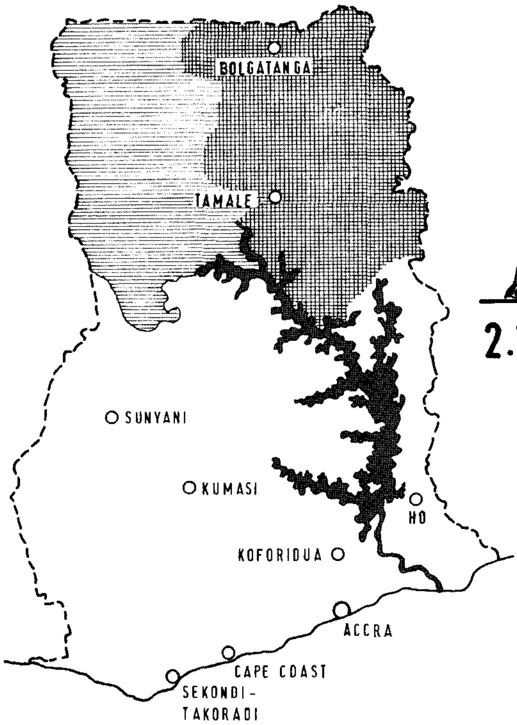
2.1 INDIGENOUS BUILDING METHODS IN NORTHERN GHANA

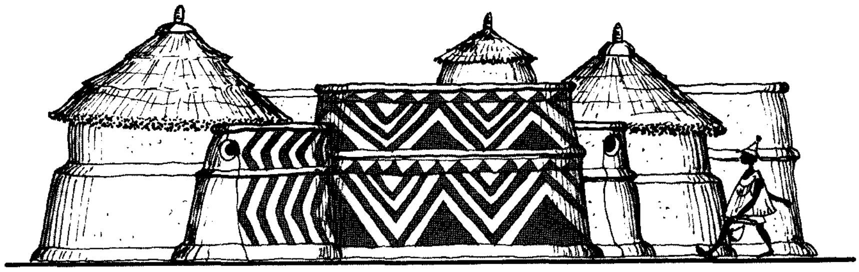
In the dry and northern half of Ghana the traditional building methods in mud are still followed throughout the region, mainly in the rural areas. In the north-eastern half of this area the buildings are circular and arranged as cells around an inner yard. The maximum compressive strength of mud as a homogenous material is achieved through the circular shape of the load-bearing walls. Roofs are built conical and thatched over rafters or as flat mud roofs with a mud parapet. In the western, predominantly Moslem half of the region, rectilinear structures of interconnected cellular spaces are built with flat mud roofs. In the Lobi area (Map No. 4) these roofs are supported by posts, beams and rafters. The mud walls are not load-bearing like in the other areas of the region. In the remaining areas of the region one finds a combination of the two main layouts. There are also Fulani settlements in places with circular huts constructed from grass-woven mats tied to posts with conical thatched roofs from the same materials. In the district and regional centres of the area most of the buildings are built with cement-sand blocks, reinforced concrete structural framework, floor slabs, ceilings and corrugated iron, aluminium or asbestos-cement roofing sheets over a timber substructure. The plans of the buildings are rectangular. The rectangular layout for buildings has also been introduced in those rural areas where the traditional layout was circular. Yet the traditional building method with wet mud walls moulded into layers achieves its best structural strength through the circular form. In the rectangular shape erosion with resulting disintegration starts at the corners of such structures.



Opposite: Inside a Builsa compound at Wiaga, Upper Region, 1978.

Fig. 10: House decorations in a Kassena compound near Navrongo, Upper Region, 1964.





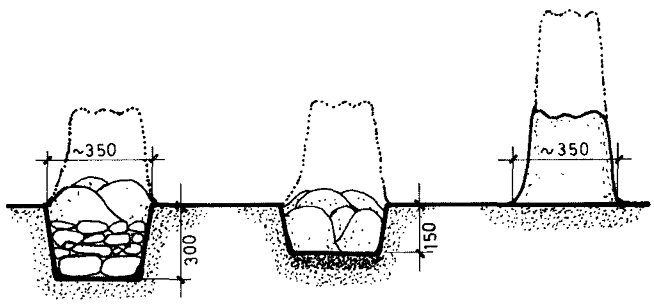
2.1.1 TRADITIONAL BUILDING METHODS IN THE NORTHEAST OF GHANA - FIG.11

2.1.1.1 HOUSE CONSTRUCTION

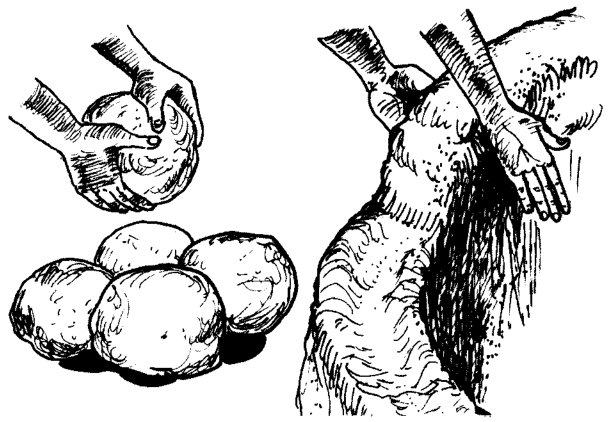
The materials used and the resulting form of the traditional buildings point to different socio-economic organisations, activities and religious beliefs of the people in this region. This is also reflected in the time for building activities. In the case of the Dagombas (and also Mamprusis and Konkombas) where most of the yam in this region is grown, the months of March and April are "building months". In the other areas building activity may commence on the on-set of the dry season in November and last until March, especially in places where extensive decorations are applied to the freshly plastered walls (Fig. 10).

The men are the builders. They build the walls and roofs of the buildings. Women begin the building activity, after the Tindana (the Earth's custodian) has performed the appropriate ritual on the chosen site (in the non-Christian and non-Moslem areas), by weeding and sweeping the space marked out by the compound owner for the building. The swept site is then watered thoroughly. After the men have completed the wall construction and built the roof (a co-operative effort by the clans), the women plaster the in- and outside of the buildings, lay and beat the floor and apply decorative finishes to the walls. The Dagombas and Gonjas do not plaster their buildings, decorations are applied only around door openings. Their structures have a much shorter life span (about 4 years, unless annually maintained). A plastered and therefore protected mud structure will last a long time. Plaster is repaired and decorations are normally renewed every 4 to 5 years. Roofs have to be annually maintained in all structures.

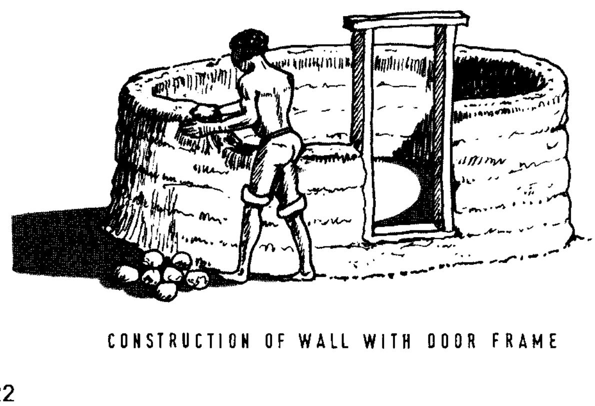
The following parts will describe traditional construction methods in this region in detail.



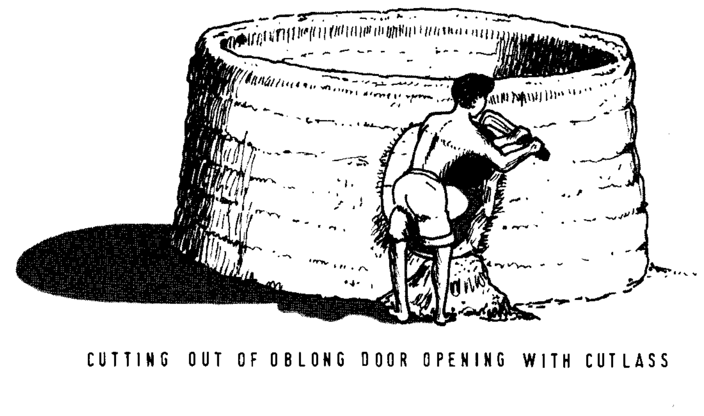
FOUNDATION TRENCH FILLED WITH RAMMED FOOTING OF BOULDERS AND SMALL STONES OR SHALLOW DUG, WELL RAMMED TRENCH WITH FIRST LAYER OF MUD BALLS OR BASE OF WALL STARTED ON SWEPT AND WETTED GROUND



KNEADING OF MUD BALLS AND MOULDING OF WALL LAYER



CONSTRUCTION OF WALL WITH DOOR FRAME

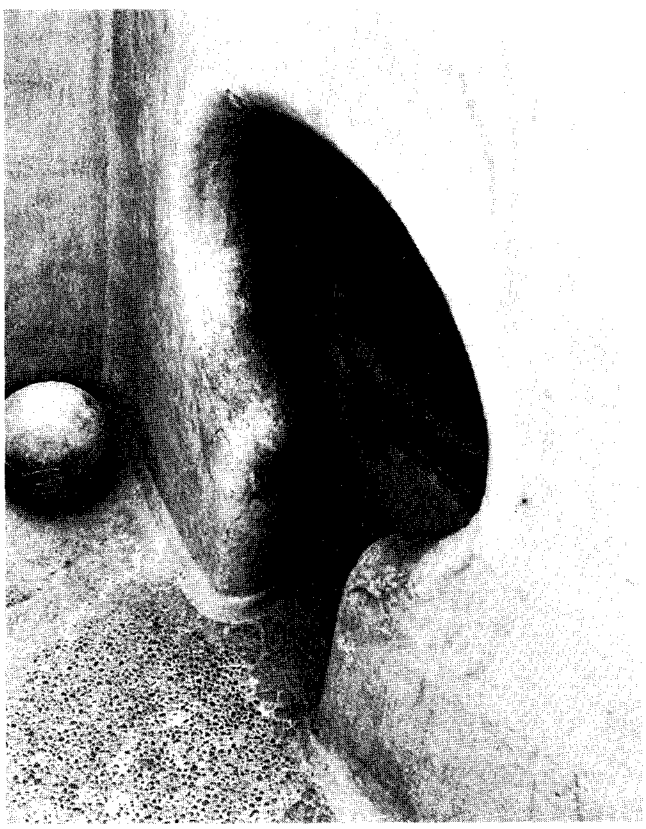


CUTTING OUT OF OBLONG DOOR OPENING WITH CUTLASS

Fig. 12: A Talensi farmer moulding mud balls for house construction. In the background is part of a completed wall, 1976.

Fig. 13: A Talensi elder finishing one course of the wall of a new house in his compound, 1976.

Fig. 14: Entrance to a house in a Builsa compound at Wiaga. Note the small low screen wall just inside the entrance opening and the carefully finished floor of in-laid calabash and pot shards at the entrance, 1978.



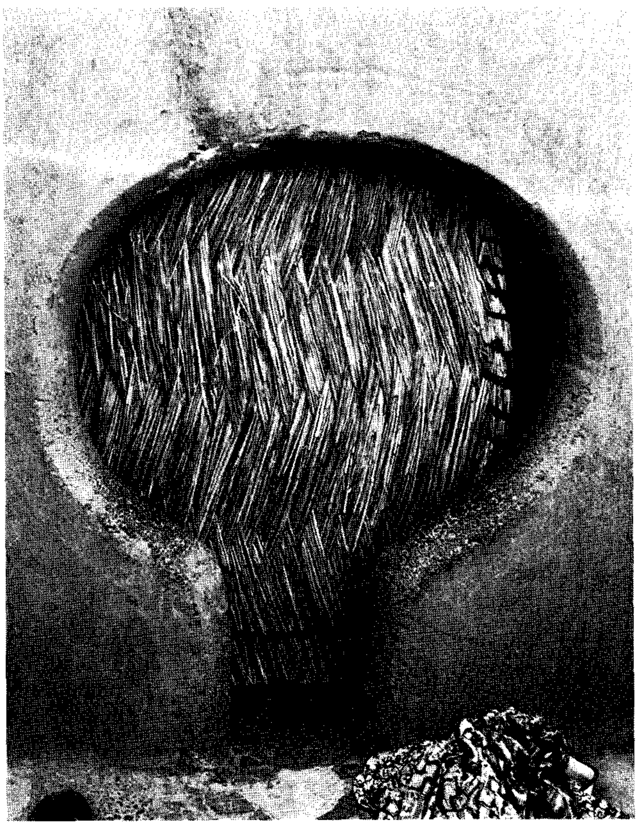
WALLS

Laterite or soils containing clay (dug from pits near the building site) or alluvial soil from riverbanks are used as material. Organic matter and stones are removed. The material is then mixed with water, kneaded (with feet) until it is smooth (Fig. 11). Fine, sharp riversand or gravel may be added as a form of aggregate. The material is then rolled and formed into balls (Fig. 12). In some areas the wall will have a small foundation, dug about 150 to 300mm deep, rammed and filled with stones or a first layer of mud balls. In other places the wall is started on the swept and wetted ground. It is constructed in layers, each approximately 300 to 400mm high from a thickness of about 350mm at the foot of the wall to 200mm at the top. The mud balls are worked and moulded by hand and after one layer is completed, grooved with the thumbs at the top for bonding with the next layer (Fig. 13), normally laid the next day after the first layer has been allowed to settle and dry.

DOORS

The traditional circular house has no door. The entrance into the house is an opening, cut into the wall with a cutlass by the builder after the construction of the wall has been completed. The ethnic groups have different sizes and shapes of openings as can be seen from the illustrations (Fig. 14, 15). In some cases already timber door frames are fitted into the wall during construction to receive door stops and an inward opening boarded door of about 1.50m height (Fig. 16).

Fig. 15: A Zana-mat door put against the entrance opening from the inside of a house in the same compound.



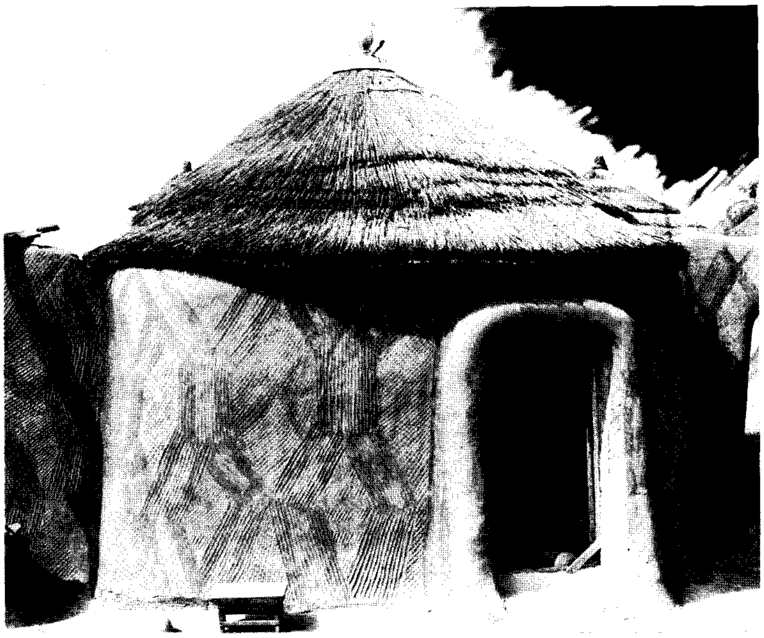


Fig. 16: Door opening with an inward opening boarded door to a house in a Kusasi compound at Binaba, Upper Region, 1964.

Fig. 17: Ventilation opening under the thatched roof of a kitchen in a Kusasi compound at Zebila, 1968.

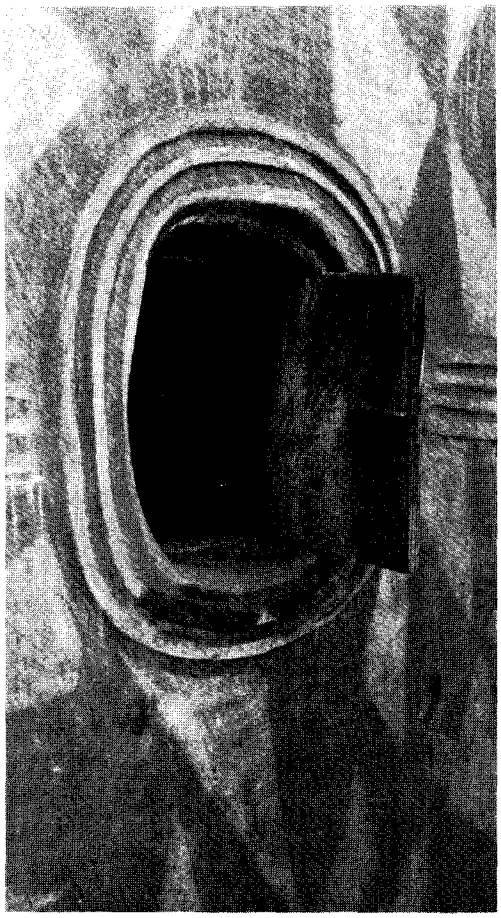


Fig. 18: Window opening in a Nankansi compound near Sirigu, 1978.

Fig. 19: Window opening in a Kassena compound near Navrongo, 1964.

WINDOWS

The traditional round house has no windows. Ventilation is achieved by lifting the "roof skin" with a bent wooden piece in form of a knee which is inserted under the roof on top of the mud wall opposite or above the entrance opening (Fig. 17). In the case of a flat mud roof a clay pot without bottom is inserted into the mud layer during construction of the roof, also at a position opposite or above the entrance opening. The top of the pot can be covered with a calabash or another pot during rain. Both "openings" admit light and achieve vertical ventilation through the stack effect. In rectilinear structures in some areas small wooden framed and boarded windows have been introduced (Fig. 18 *and* 19).

ROOFS

1. THE THATCH ROOF

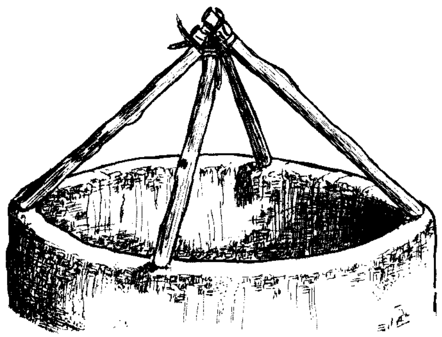
This refers in most cases to the conical thatch roof over a round house, but in some places of the region (especially in the Nabdam and Kusasi ethnic areas along the Bolgatanga-Bawku road) to a thatch roof with ridge over a rectangular house.

Due to the limited structural properties of the materials used roof spans are rather short; buildings normally have a width or diameter of around 3 metres. This can be extended by introducing different methods of support.

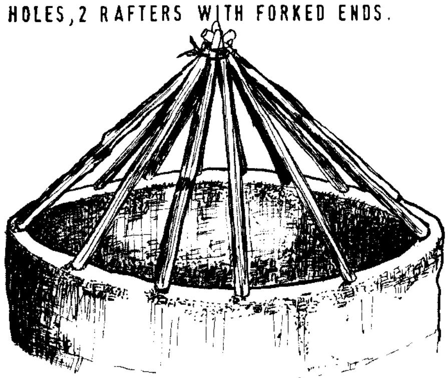
The traditional conical thatch roof (Fig. 20) has a substructure of four main bush pole rafters (normally from the **Shea-butter tree** – *Butyrospermum Parkii* – a heavy termite-proof timber) about 2.5m long and 75mm in diameter bedded into the top of the wall, forked and tied at the top ends with **Kenaf** fibres. These rafters form a radial frame together with smaller rafters (of 45mm diameter). They are stabilized by a number of 50mm diameter grass-rope purlins or purlins roped similarly from young **Nim tree** branches *(Azadirachta Indica)* tied together and to the rafters with kenaf fibres. The lower third of the roof is then covered with a **Zana**-mat (Fig. 21) which is woven from grass (*Andropogon Gayanus*) a grass growing up to 3.5m in length in the coastal and interior savannahs and used in the North for weaving rough mat walls, screens for openings and protection against wind etc.). On top of the Zana-mat the roof thatch (from dried spear grass – *Heteropogon Contortus,* or another common savannah grass – *Imperata Cylindrica*) is laid in layers, "sewn" with Kenaf fibres through the Zana-mat to purlin ropes and rafters. The thatch is tied together at the apex, sometimes kept fixed into place with a bowl without bottom or an overturned pot or grass ropes and sticks (Fig. 22). The upper layer of the thatch near the apex is in some areas again a Zana-mat.

The largest safe span of a conical roof constructed in this fashion is 4–5 metres, with an additional centre support in form of a post which is placed beneath the junction of the rafters. Large rooms are rare, however, since it would already be difficult to find the necessary longer rafters for such span.

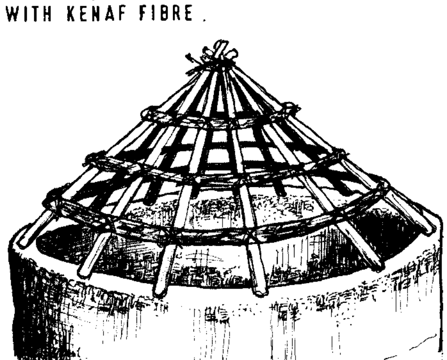
FIG. 20 : **BUILDING OF THE SUB-STRUCTURE OF A CONICAL THATCH ROOF**



PLACING OF 4 MAIN RAFTERS ON MUD WALLS, 2,5m LONG, ⌀75mm, TO REST IN PREPARED HOLES, 2 RAFTERS WITH FORKED ENDS.



SMALLER RAFTERS OF ⌀50mm ADDED AS FILL-IN, ALL TIED TOGETHER AT TOP END WITH KENAF FIBRE.



PURLINS OF YOUNG NIM TREE BRANCHES OR GRASS ROPE PURLINS BOUND WITH KENAF FIBRE AND TIED TO RAFTERS.

Fig. 21: A thatch roof in a Kusasi compound from the inside. Note the arrangement of the Zana-mat on the lower section of the roof and the grass purlins tied to the rafters, 1974.

2. THE FLAT MUD ROOF

This type of roof is built by the Talensis (Fig. 23), Frafras, Nankansis (Fig. 24 *and* 25), Kasenas and Builsas, as well as by the people living in the north-western part of the region (described separately). The walls are load-bearing, they fully support the roof beams, except in places like the roofed-over wet season kitchen of the Nankansis which is built against another house.

Timber used for construction is from the Shea-butter tree, which is termite-proof. One layer of beam-poles is supported on the walls, thinner rafters are laid across these about 100 mm apart. On top of this layer small pieces of split poles or twigs are laid in a cross-wise direction, very close together. The next layer is about 250 mm thick from well-kneaded mud or clay. The finish is a screed of a mixture of mud or clay, fine sand, cow-dung and the residual meal from the Shea-butter-nut during extraction. The surface is finished off with a varnish which is produced by boiling the empty pods of the **Dawa-Dawa** tree (West African Locust Bean tree, *Parkia Clappertoniana*). The mud layer of the roof is given a fall, so that the roof sheds rainwater easily through spouts (from metal sheets, wood or openings left in the wall). A parapet wall from mud is built around the roof. The roof is, in many areas, used for storage as well as for sleeping during the hot months at the end of the dry season (March, April).

Fig. 22: A fresh roof cover on a Kusasi house at Zebila, 1976.

Fig. 24: A portion of a flat mud roof in a Nankansi compound near Sirigu showing two built-in pots without bottom acting as ventilation and light opening, 1972.

Fig. 23: Roofscape of the Chief's compound at Tenzugu in the Tongo Hills, 1972.

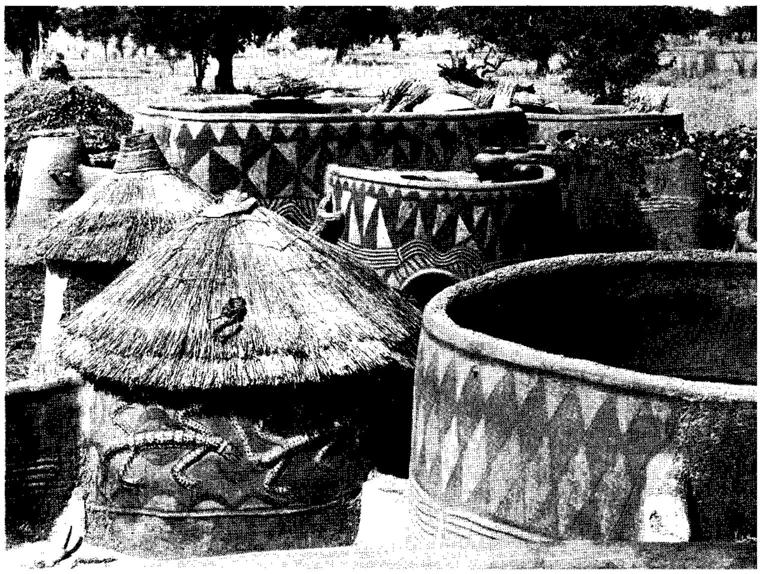


Fig. 25: Roofs of the same compound with ancestor's shrine in the foreground covered with a thatch roof, 1972.

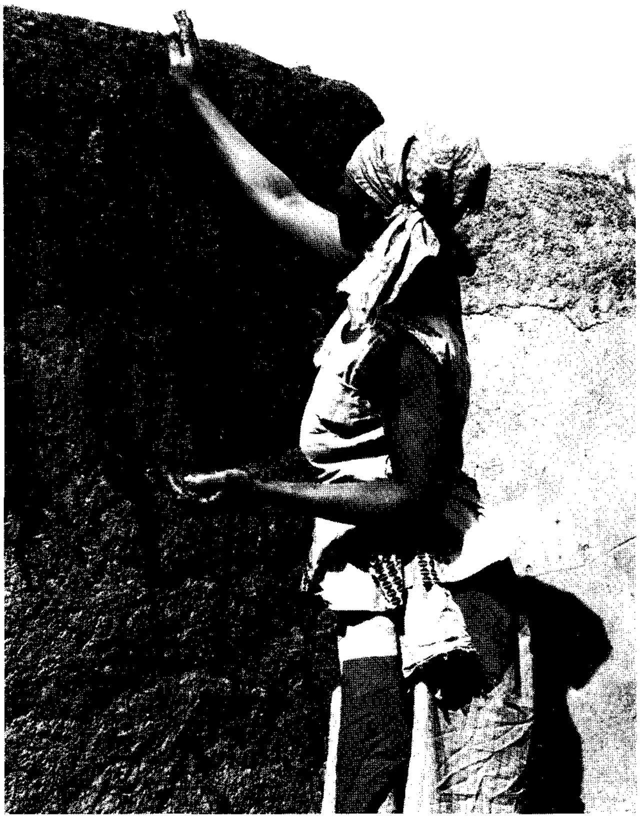


Fig. 26: A talensi woman preparing a wall for plastering in Tenzugu, 1978.

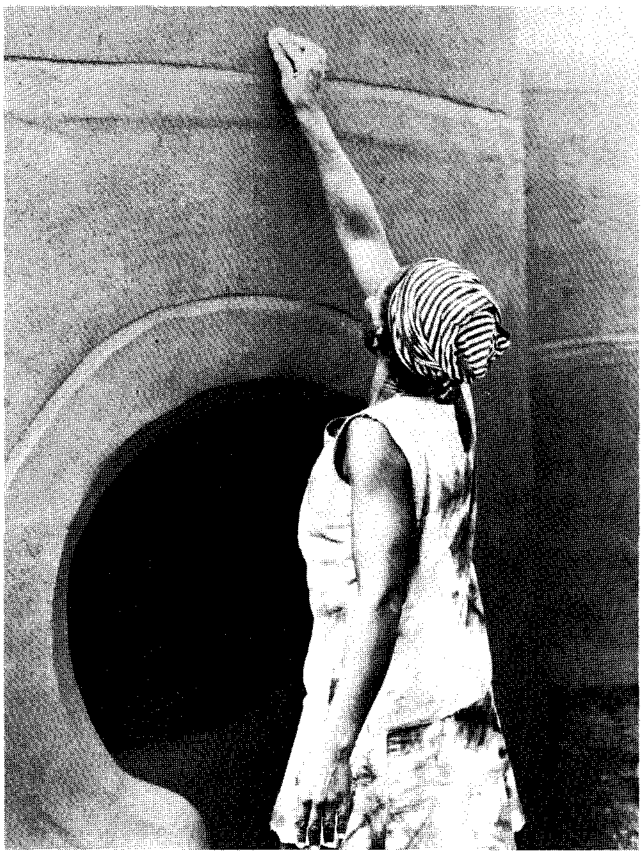


Fig. 28: A Builsa woman in polishing the dried plaster with a flat pebble (Wiaga, 1978).

WALL FINISHES

Walls are plastered in-and outside with a mixture of cow-dung, mud and the juice from the boiled, empty Locust Bean tree pods (Fig. 26, 27, 28, 29). This extract (sometimes the bark is also boiled in addition) acts as a plaster hardener and stabilizer, and forms a firm waterproof layer on the external surface, when it is sprayed on with a brush after plastering. The wall finish, as mentioned before, is the work of women, who have, in the different ethnic groups, developed high artistic skills in decorating the finished walls. These decorations are incised patterns (applied with flat or pointed pebbles or fingers), moulded, painted or a combination of different techniques (Fig. 30). Dagombas and Konkombas have no surface decoration, but embed cowrie-shells or broken china (or whole plates) into the mud above the entrance opening to the round houses or embellish the complete openings. In Dagombaland this decoration symbolizes the house owner's wealth. Openings which are to receive such decorative treatment are first plastered (mixture of mud and cow-dung, Fig. 31 *and* 32). Another method of finishing a wall is used by the Konkombas. They grind shells collected from the banks of the river Oti (which passes through their area) and mix the obtained lime with cow-dung. This "limewash" hardens the surface of the walls, makes it impervious to rain and gives the Konkomba houses their characteristic white, rather concrete-like appearance.

In the Nankansi area the women decorators polish the painted surface of the wall with flat stones (granite or pebbles) until the appearance is that of a wall painted with glossy oil paint (Fig. 33 *and* 34).

Fig. 27: After the plaster has been applied another woman smoothens the surface with a flat stone.

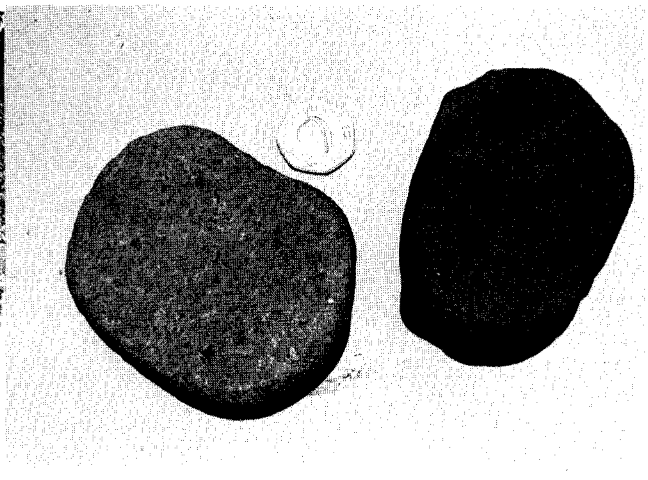


Fig. 29: Granite and Basalt stones from the Tongo Hills, used for the plastering and polishing, 1982.

FIG. 30 : DECORATIONS IN THE FRAFRA CHIEF'S COMPOUND AT ZUARUNGU - SKETCH BY THE AUTHOR, 1976.

Fig. 31: Broken china and whole plates embedded in the plaster around a door opening of a Dagomba compound near Tamale, 1981.

Fig. 32: Dooropening decoration of a Dagomba compound near Tamale, 1981. Note the change of decoration from Fig. 31 due to the inability of the farmers to get china and cowry shells.

Fig. 34: A Nankansi woman brushes a newly decorated wall in her compound with the decoction of the Locust Bean tree pods before she will polish the wall with a flat pebble, which can be seen on the stool in front of her (Sirigu, 1978).

Opposite: Fig. 33: A freshly decorated Nankansi house in a compound near Sirigu. The walls are also polished. Note that the decoration is applied also to the roof upstand of the kitchen next to the house, 1978.

FLOOR FINISH

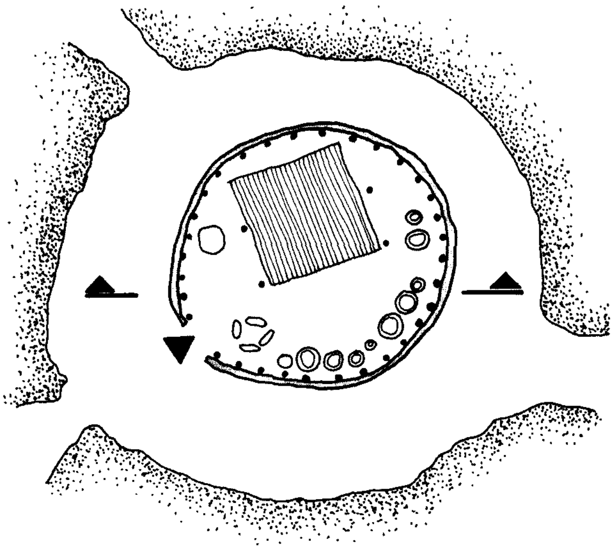
The last job is the laying and finishing of the floor. This work is again done by the women of the compound and it extends to laying the floor not only in the rooms but also in the actual compound yard outside the houses up to the walls which encircle the inner yard of the compound in which the granaries are placed and sheep, goats, cows and poultry stay during the night. Mud or laterite is mixed with fine sand collected from riversides. Cow-dung solution or in some places a mixture of sand and cement is sprinkled over this layer of mud or laterite (average screed thickness about 20 to 40mm) which is laid straight on the swept and wetted ground. The cow-dung solution has been left to soak in water for about three days. A group of women then beat the floor with special wooden implements or flat stones in unison amidst singing, for about two to three hours (Fig. 35). The resulting floor finish is a smooth, hardwearing surface. The extract from the boiled empty pods or bark of the Locust Bean tree is sprinkled daily on to the finished floor for two weeks. This hardens the surface further, makes it waterproof and at the same time gives it a pleasant, rustic, reddish appearance. The outside floor is laid to fall to enable surface water to drain off easily, usually through an opening at the base of a bathroom wall to the outside of the compound.

2.1.1.2 FULANI COMPOUNDS

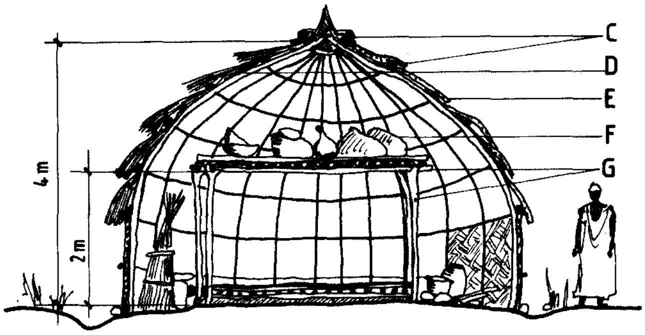
In some areas of the north Fulanis (who are nomads) have settled; they still pursue their traditional profession as cattle herders. One can find their settlements in Zongo-sections of Bolgatanga, Tamale, Bawku or in villages in which cattle are raised.

Their house structures are different from those of the host villages or towns in which they live. The structures reflect their life style. Although they may have settled permanently in the chosen area, their houses appear like large tents. Wooden poles are anchored into the ground, arched over to meet and be fixed at the apex (the layout is more or less circular). This structural framework is covered on the out- and inside with rough woven grass mats (Zana-mats) held in place with branches and mud. Towards the apex layers of thatch are added on top of the mats similar to the indigenous conical thatch roof finish. From the outside such a house resembles the traditional circular building but its structural system is completely different; it reflects a lightweight shelter which can easily be removed and assembled elsewhere (Fig. 36). The arrangement of individual compound units placed around an internal courtyard is similar to the compound arrangements in the northern part of the region; their linking walls are also made from woven grass mats.

FIG.35 : FLOOR POUNDING IN NORTH GHANA



PLAN : DIAMETER OF HOUSE APPROXIMATELY 5 m



SECTION

A — WOODEN POLES BENT AND FIXED AT APEX

B — WOVEN GRASS MATS FIXED TO STRUCTURAL FRAMEWORK FROM THE OUTSIDE (AND SOMETIMES INSIDE) UP TO DOOR LEVEL.

C — WOVEN GRASS PURLIN ROPES TIED TO POLES. AT THE APEX AN ADDITIONAL PURLIN IS FIXED INSIDE TO HOLD THE TOPS OF THE BENT POLES INTO PLACE.

D — THATCH LAYERS TIED TO PURLINS

E — HIDES ARE ALSO USED AS ROOF COVERING

F — TOP OF BED USED FOR STORAGE

G — POST AND BEAM STRUCTURE OF BED AND CANOPY

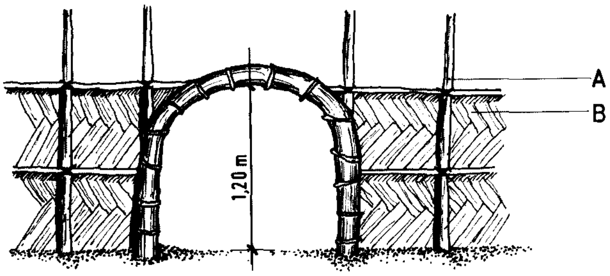


FIG. 36 : PLAN, SECTION AND ENTRANCE DETAIL OF A FULANI HOUSE NEAR GWOLLU, UPPER REGION

FIG. 37 : A KUSASI GRANARY OUTSIDE A COMPOUND AT BINABA - SKETCH BY THE AUTHOR, 1976.

2.1.1.3 GRANARIES

The importance attached to the place in which the basic food items are stored which the northern farmer harvests from his farm can be seen from the high level of proficiency in the indigenous construction methods used for the construction of granaries (silos, barns). Maize, millet, guinea corn and rice are stored in these structures. In areas where the animistic tradition is still followed the main granary of the compound is the place in which the soul of the compound owner lives during his lifetime. It is the location of this granary which is fixed by the Tindana (or Earth's custodian) first and all the other buildings of

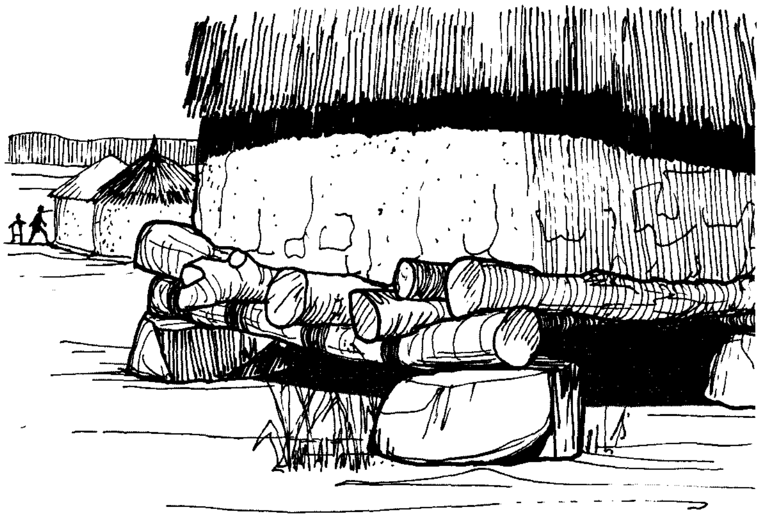


FIG. 38 : FOUNDATION OF A KUSASI GRANARY SHOWING THE CROSS-LAYER OF SHEA-NUT TREE POLES SUPPORTED ON LARGE GRANITE BOULDERS - SKETCH BY THE AUTHOR, 1976.

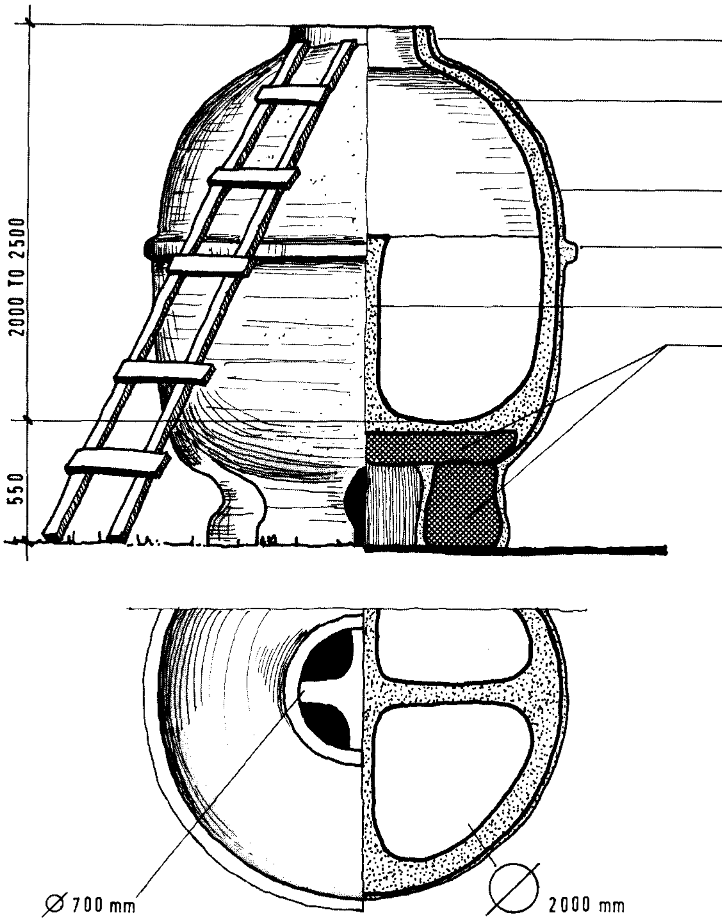
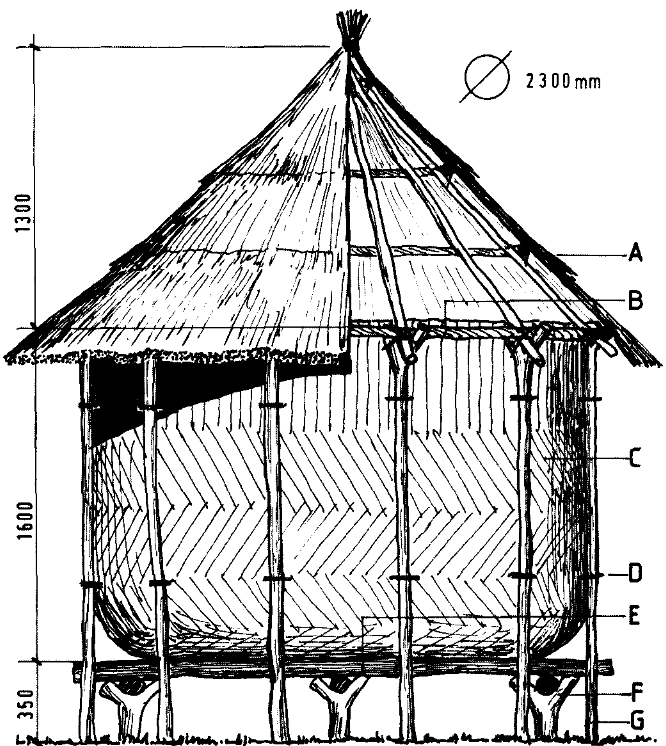


FIG. 39 : **PART PLAN, SECTION AND ELEVATION OF A KONKOMBA GRANARY AT WAPULI**

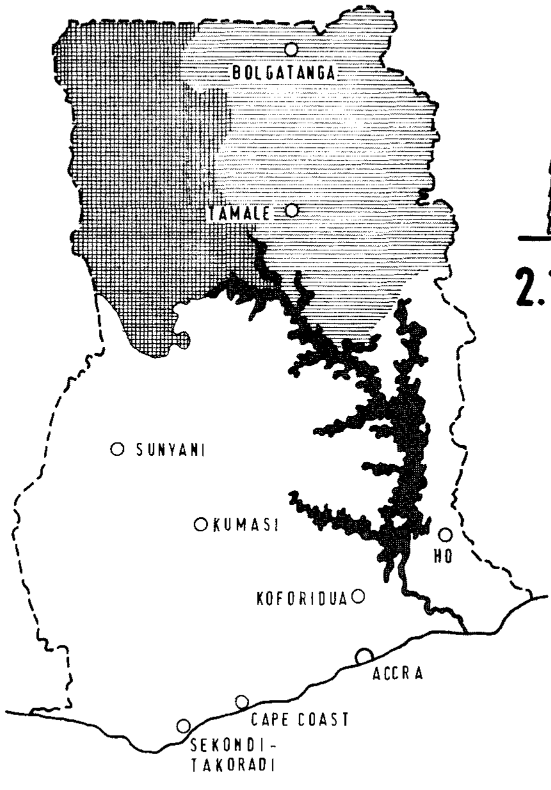
the compound are laid out in relation to it. This tradition is still followed, as investigations in the field revealed, even in areas where Christianity has penetrated.

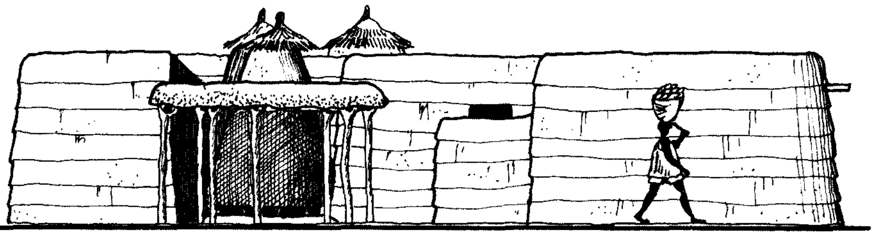
The granaries are built from wet mud in the same way as the circular houses are built, on top of a well designed foundation from large stones (solid) or stones together with a system of cross beams from the Shea butter tree on top (to allow ventilation to pass under the silo). The walls taper off towards the opening at the top which is covered with a woven thatch "lid" (Fig. 37 *and* 38). The average capacity of the mud silos is 1½ to 2 tons – the Frafras, Kusasis and Builsas have built silos with larger capacities. The Konkomba silos (for threshed and unthreshed grains) are distinctive structures (Fig. 39). They are built in large pot form from coarse woven basket work which is thickly covered with a mixture of soft mud and cow-dung on both sides. They are supported on three or four large granite blocks with a flat stone as base laid over. The externally applied thick solution of mud and cow-dung is also smeared over the base stones. The outside of the granary is finished with limewash (the lime is obtained from grinding rivershells). In the interior of the silo divider walls of mud (about 100mm thick) are built for stabilization of the structure. The Konkomba silos are larger than the similarly constructed Mamprusi basket granaries. The circular barns of the Mamprusis and Dagombas (as well as those of the Gonjas) are built for the storage of unshelled late-millet, guinea corn, bambara beans, yam and sweet potatoes. The grain is not stored for very long in these barns (Fig. 40). It is removed as the threshing proceeds and then transferred to the permanent granary. Normally four large granite stones (placed to form a square inside a marked circle) carry a wooden platform from bush poles. About 12 poles with forked top ends are dug into the ground around the platform. At the top they are tied to a thick grass rope (which acts as "wall plate"). The inside (floor and wall) is covered with coarse woven grass mats which are fixed to the poles. An additional thick woven grass mat is laid on the floor. The thatch roof is built in the same way as has already been described.



A THATCH ROOF FIXED TO POLE RAFTERS AND GRASS ROPE PURLINS
B GRASS ROPE PURLIN FIXED TO FORKED COLUMNS TO HOLD TOP END OF BARN TOGETHER
C GRASS MAT WALL OF BARN
D FASTENING ROPES
E TIMBER PLATFORM
F PLATFORM COLUMNS
G MAIN COLUMNS OF BARN

FIG. 40 : **DAGOMBA CIRCULAR BARN AT KAMBONAYILI NEAR TAMALE** (FIG. 39 AND 40 FROM "TRADITIONAL AND MODERN GRAIN STORAGE STRUCTURES" BY THE AUTHOR)





2.1.2 TRADITIONAL BUILDING METHODS IN THE NORTH-WEST OF GHANA - FIG.41

Fig. 43: Entrance to the same house.

Fig. 42: External walls of a Lobi compound near Sawla, Northern Region, 1962.

WALLS

In this area of the country floor plans of buildings are more or less rectangular. In the Lobi-house with its covered internal courtyard, walls are laid out rectilinear to enclose interconnecting spaces. They are built in the same way as the circular house walls in the North-east of Ghana, that is: moulded in layers with wet mud balls or with sun-dried mud bricks or in some cases also with dried mud clods from old, broken down buildings. The walls are, however, thicker (average 400mm). The separate layers, if built with mud balls, are clearly recognizable, since the next layer overlaps the previous layer so that the external appearance (the inside walls are plastered and finished smoothly) is that of an exaggerated horizontal feather-edge boarding (Fig. 42 *and* 43). The Lobis support the flat mud roof entirely with a post and beam arrangement (which will be explained later). The walls are therefore not load bearing. Room widths do not exceed 2.5 to 3 metres. Each room is in itself an independent structural entity, as can be seen from the part-plan of a Lobi house (Fig. 44). It is easy to understand the internal layout of such a house when one stands on the flat roof. The non-load bearing walls project in the form of parapets (about 250 to 300mm high) beyond the roof surface (Fig. 45). The Lobi house walls are exposed to fewer stresses compared to the load-bearing walls of the other ethnic groups in the area, where the flat mud roof is supported on these walls with its beams and rafters bedded into the mud of the wall. Corners of such build-

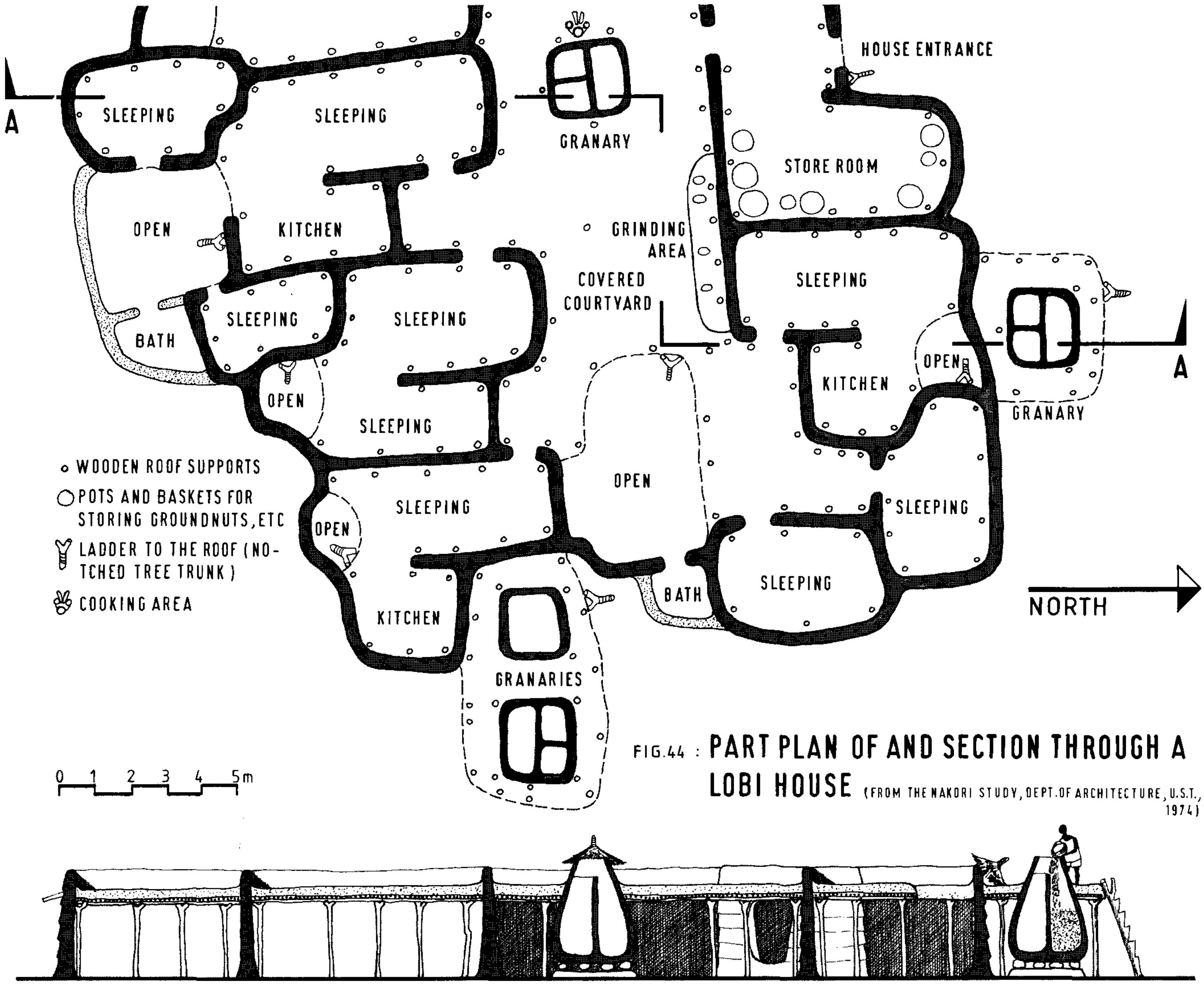
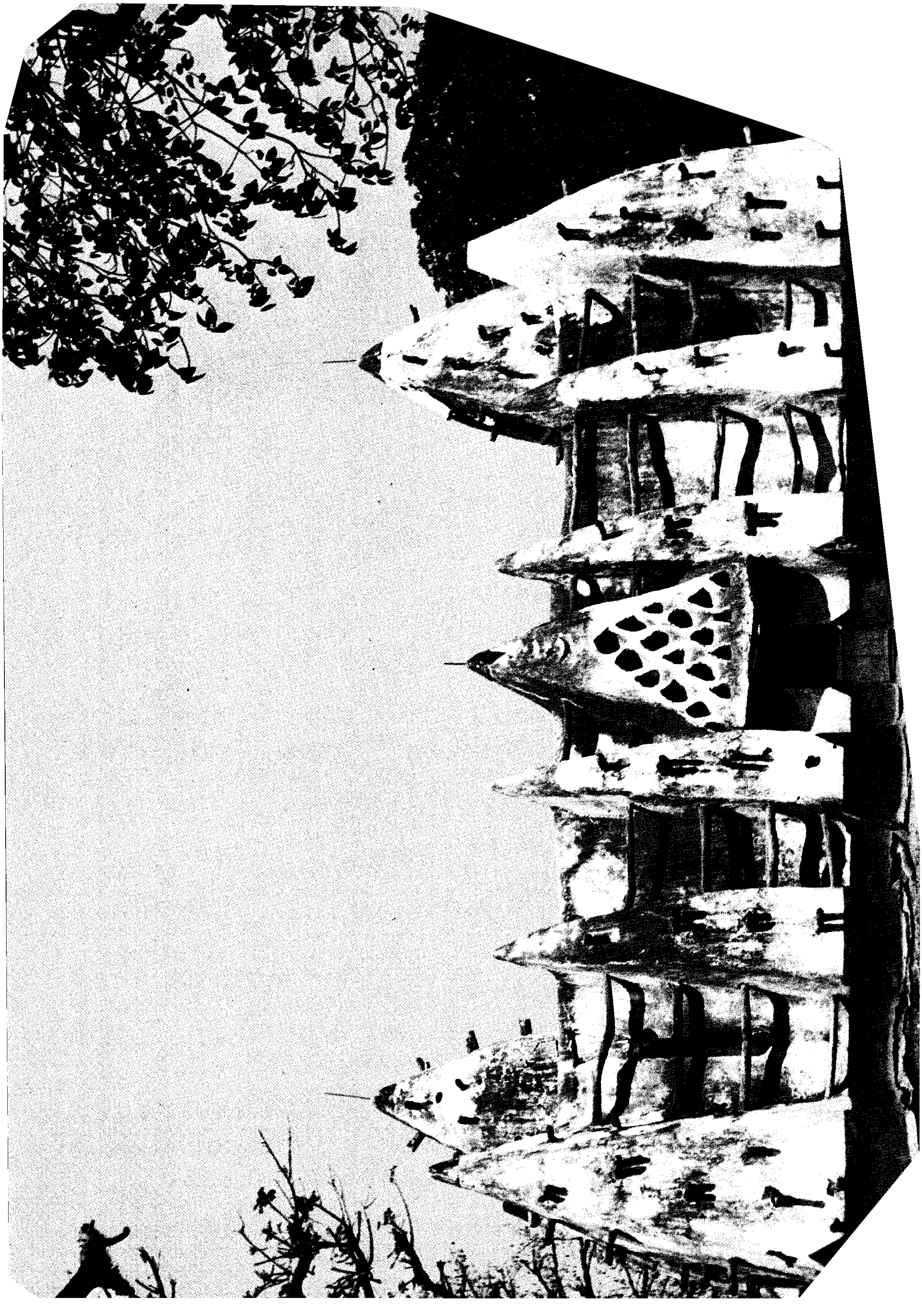


FIG.44 : **PART PLAN OF AND SECTION THROUGH A LOBI HOUSE** (FROM THE NAKORI STUDY, DEPT. OF ARCHITECTURE, U.S.T., 1974)

ings, unless reinforced, cannot transmit the forces to which the walls are subjected. Early deterioration is the result. From the 16th century onwards when Islam was introduced in West Africa and also in the present Northwest region of Ghana through traders and migrants from North Africa and the Sahel area the method of constructing heavy buttresses to reinforce wall corners and walls found its way into this area with the mosque buildings (Fig. 46) and was also adopted by most of the people along the present Lawra-Wa-Bole-Bamboi road, part of the historic north-south trade route, with exception of the Lobis (Fig. 47). From this it can be seen that "foreign influence" in the North is restricted to a comparatively small area. A combination of both construction methods has developed at the same time and can be found in the buildings of the Gonjas, Dagartis, Walas and others.

Fig. 45: Roof of the same compound. Note the grain silos protruding through the flat mud roof, and the low parapet around the roof.

Opposite: Fig. 46: The Friday mosque at Larabanga, Northern Region, 1962.



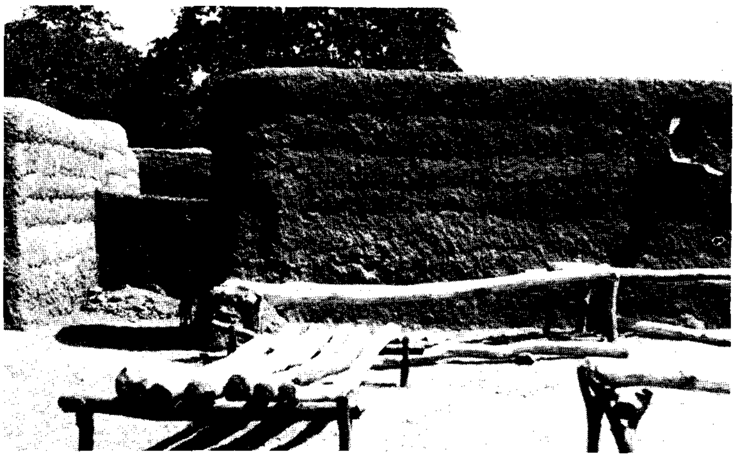


Fig. 47: Gonja houses at Bole, 1962.

DOORS AND WINDOWS

Due to the rectilinear layout of the buildings in this part of Ghana entrance openings to rooms (or to the house in the case of the Lobis) are more or less rectangular. They are covered or closed with thick mats woven from grass (similar to the Zana-mats), or have already a doorframe with an inward opening boarded door (Fig. 48). Windows were not normally part of the traditional house or compound. They have been introduced during the last 25 years. Own field studies undertaken in the area in 1961 showed very small window openings (boarded casement windows in a timber frame) in some houses of the Gonjas, Walas, Dagartis and Lobis. During the documentation survey which the Department of Architecture students undertook in 1975 in Gwollu in the Northwest of Ghana close to the border with Upper Volta, it was found that nearly all buildings in this rural community had small windows.

ROOFS

As already described under **"Walls"** the flat mud roofs (the conical thatch roof, which is quite alien to this region, is found occasionally in Lobi compounds) are built with a supporting bush pole substructure of posts and beams or beams and rafters from the Shea butter tree bedded into the mud wall. The posts have forked ends at the top and

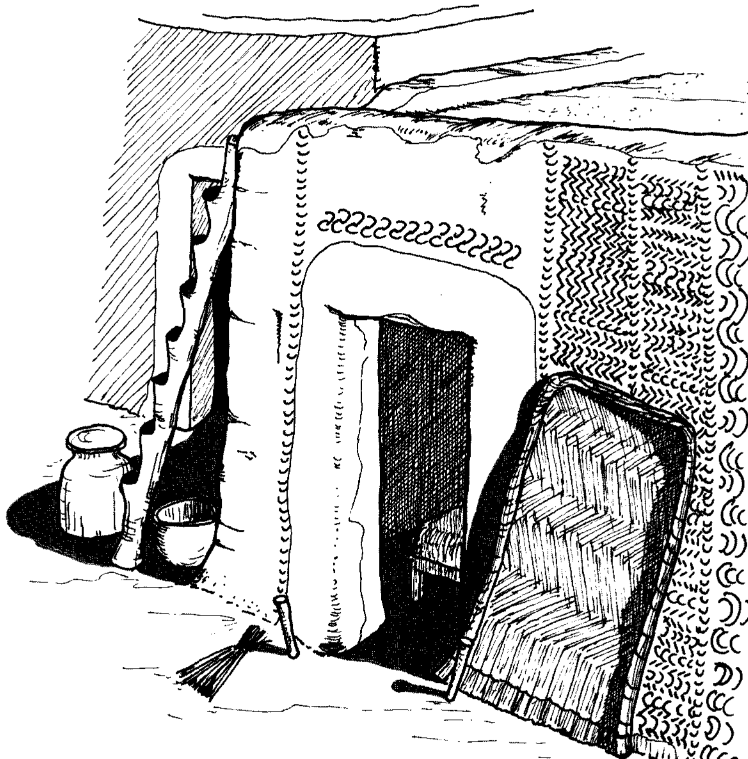


FIG.48 : DOOR AND WALL DECORATIONS IN A GONJA HOUSE AT LARABANGA - SKETCH BY THE AUTHOR, 1962.

carry the beams. Across these are laid smaller poles (rafters) at a distance of 100 mm apart in two layers. Over these follows a layer of crosswise arranged, closely laid twigs or small split poles. A layer of about 200 mm thick well kneaded mud or clayey soil is put on top of this. A finish of a mixture of mud, cow-dung, sand and the residue from shea butter during extraction is applied to the mud layer and brushed with the liquid obtained from boiling the Locust Bean tree pods. A pot without bottom is inserted into the mud roof in places to let in light or for extraction of smoke. It can be covered with a calabash or bowl during rain. The mud roofs are laid such that they drain off rainwater easily through spouts let into the small parapet wall which normally surrounds the roof (Fig. 49).

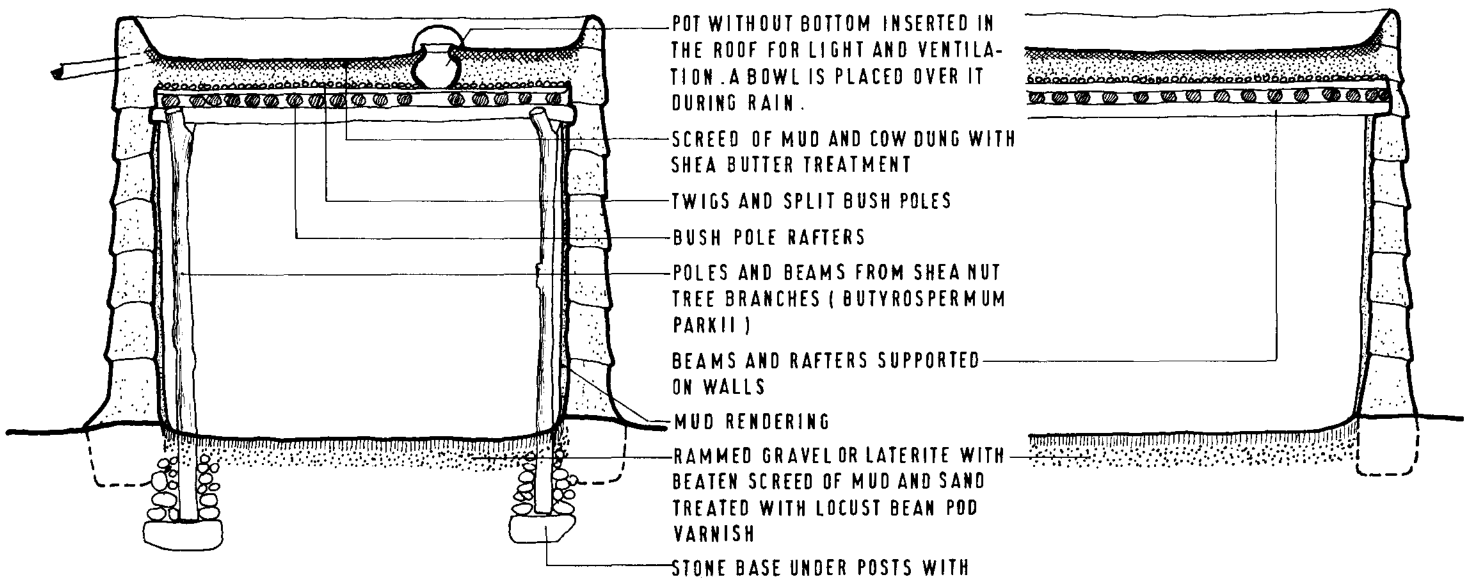
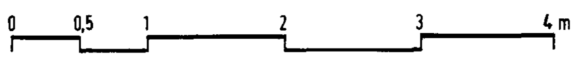


FIG.49: SECTION THROUGH A MUD ROOF SUPPORTED ON A POST AND BEAM SYSTEM OR ON THE MUD WALLS OF THE HOUSE



WALL FINISHES

Only in areas where cattle are raised is cow-dung available as the smooth cohesive agent for the traditional mud plaster, and this applies only to a part of the region. For example the Gonjas, who do not have cattle, will only apply an additional mud coat to the completed walls. The Lobis finish their external walls smoothly during building in the described overlapping fashion. Due to the absence of proper plastering buildings tend to deteriorate quicker than in the Northeast of Ghana and need very regular maintenance. The only decorative treatment of wall surfaces in form of "herring-bone" or round patterns is applied with fingers by the Gonja women into the rendered walls, especially around door openings (Fig. 50). The Sisalas and Walas use decorations over door lintels or in the roof parapet by arranging sun-dried mud bricks in such a way that they form triangles (which can also be found over the entrances into the mosques in this area) which give the appearance of a „perforated" wall.

FLOOR FINISH

The floor finish is applied quite similar to that in the northeastern part of the country, and also beaten with wooden implements or with wooden rams by the women of the compound builder's family.

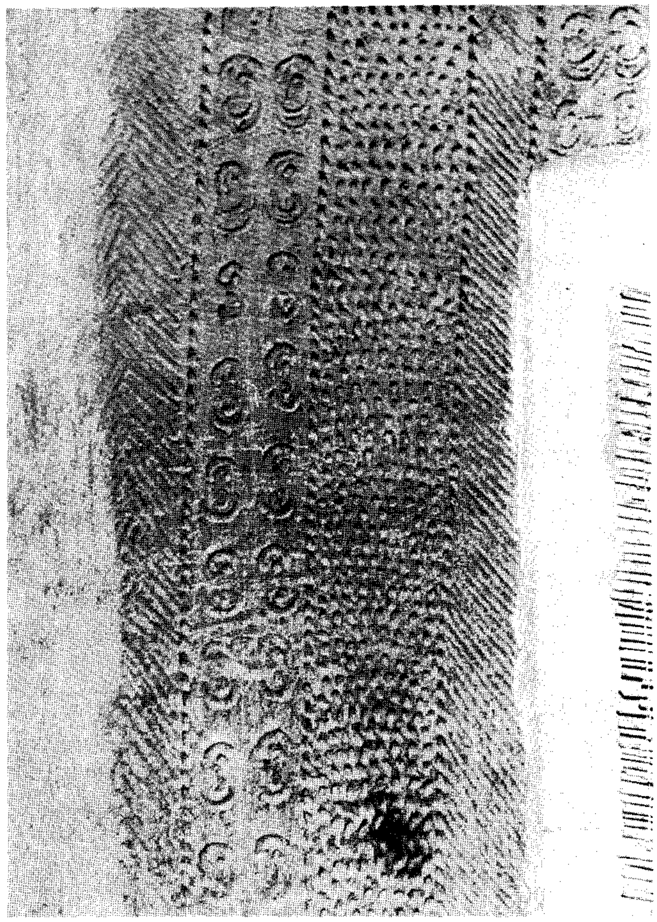


Fig. 50: Decorations around a bedroom door in a Gonja compound at Larabanga, 1962.

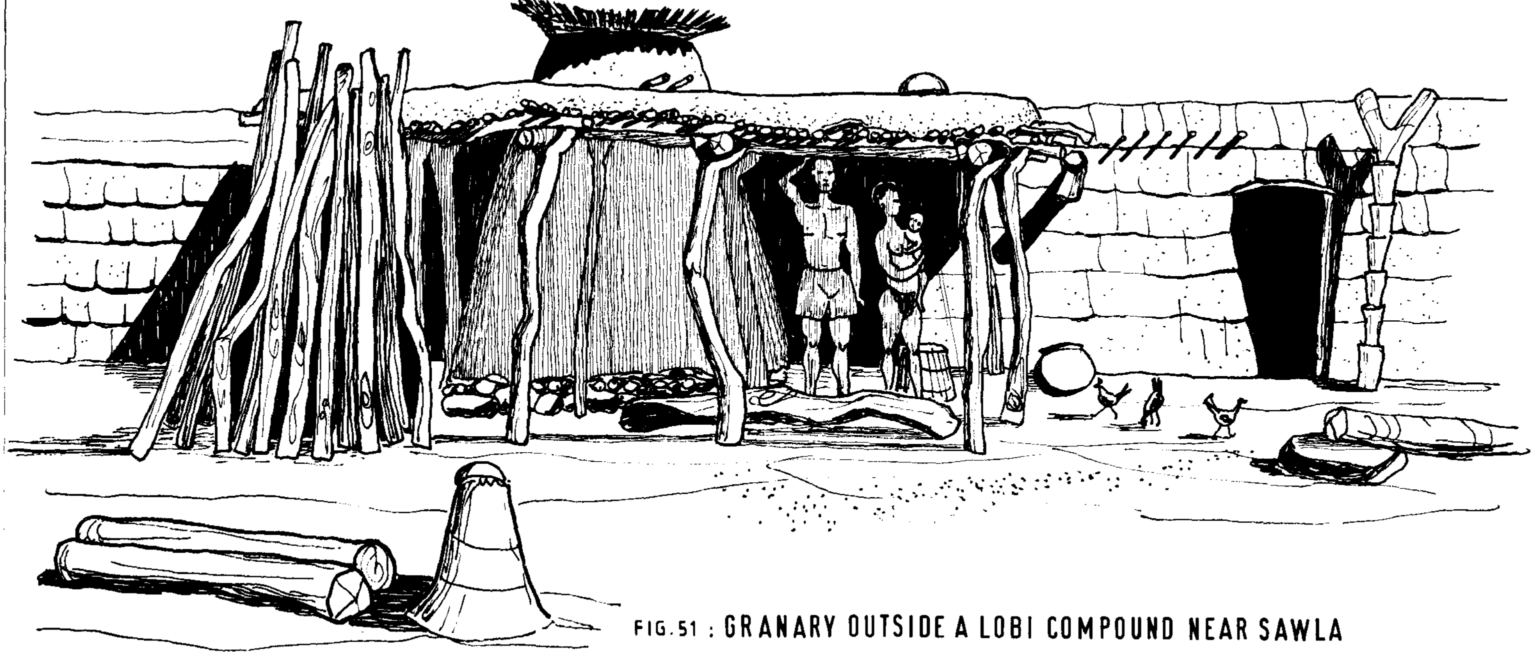
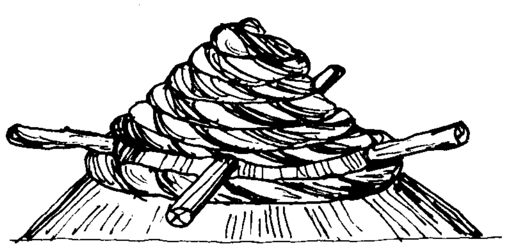


FIG. 51 : GRANARY OUTSIDE A LOBI COMPOUND NEAR SAWLA



APEX DETAIL OF GRANARY :

CROSS STICKS THROUGH THATCH TIED DOWN TOGETHER WITH TOP OF THATCH WITH ROPES MADE FROM BUNDLES OF GRASS

FIG. 52 SQUARE LOBI GRANARY WITH CONICAL THATCH ROOF

2.1.2.1 GRANARIES

With the exception of the Lobi silos the granaries in this area are not of such striking features as those of the Frafras, Konkombas or Kusasis in the Northeast of the country. The Gonja farmer grows mainly guinea corn and groundnuts. The large circular barns for storing the unthreshed corn are placed near the farm and built from grass mats similar to the Dagomba barns. In the compound the threshed corn is stored in large baskets inside a store and the groundnuts in small baskets, smeared in- and outside with mud and covered with thatch, which are placed on wooden platforms inside the compound yard. The Lobis build cylindrical granaries over a square base tapering off towards the top, from a thick mixture of mud, cow-dung and crushed straw (from dried guinea corn or millet stalks). The neck is covered with a thatch "hat". They locate the granary outside the external compound wall. A roof is built around the neck of the granary (threshed grain is stored and taken out from the top). Like this the granary is incorporated into the house when new rooms are added to it (Fig. 51). Similar to the Konkomba granaries divider walls which at the same time act as reinforcement of the granary are built inside. For the unthreshed corn square mud silos covered with a thatch roof are built near the farm (Fig. 52).

2.1.3 SUMMARY

In the Savannah mud has always been a universal building material, its plastic form and moulded application resulting in a unique architecture. In addition the circular mud wall is a structure which consequently achieves the fundamental principle of building construction: **The stability of the structure.**

Since building is a co-operative effort of the whole family or clan in this area, the technology with which this is achieved is known to everybody. A farmer does not engage skilled or specialized craftsmen to build his house. He and his brothers and sons are skilled themselves. And to what high level can be seen from the optimum use of mud as structural material in the building of his granaries, especially among the Konkombas, Frafras, Kusasis, Builsas, Mamprusis and Lobis.

Opposite: Fig. 53: Part of old Accra in James Town, 1969.

2.2 TRADITIONAL BUILDING METHODS IN SOUTHERN GHANA

From the map of Ghana it can be seen that the Northern part of the country, described in the foregoing chapter as dry, hot and arid, begins north of the Volta River and Volta Lake.

The Southern part of Ghana, with different climatic zones, predominantly hot and humid (the coastal savannah, the mountain area of the Volta Region, the moist semi-deciduous forest zone, the transitional forest area, the rain forest and Guinea Savannah), begins roughly to the south of the Volta River and Volta Lake. This conforms also with the chart of the average annual rainfall, which to the north of the Volta River and Lake is about 1.15 to 1.20m. To the south of this line the rainfall increases rapidly to the highest amount of above 2.00m in the rain forest area. It decreases again drastically to less than 0.75m in the Accra area – to 0.90m and up to 1.75m in the coastal plain and coastal savannah from Sekondi to Ho (see Map 2).

Agriculture, from subsistence level to larger scale farming, dominates life in the North. The South is an area of very different activities. The early trade with gold, diamonds, timber, later cocoa, different types of minerals, as well as agriculture, brought in foreign influence from other Continents into the country. There were two main directions and factors of influence – the already mentioned spread of Islam and with it Moslem penetration from the North with the islamized Dyula traders from Djenne (city state on the Niger) and the Western Sudan in the 15th century who established the Gonja state, and the European penetration from the South which started with the foundation of Elmina in 1482 by the Portuguese.

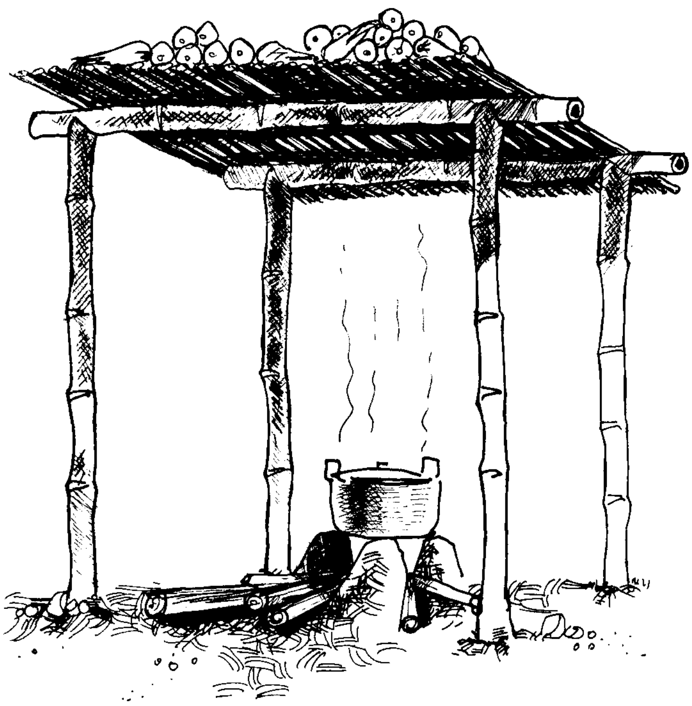


FIG.54 : COVERED COOKING AREA FROM BAMBOO IN AVIEFE-TAVIEFE, VOLTA REGION

The influence from the fortified trade posts to the settlements and towns around them along the coast (Fig. 53) and from there to the interior, and later the Christian missionary influence, brought certain elements and details into the traditional building methods, like the timber verandah, louvered timber shutters, stone wall construction and walls from sun-dried mud bricks or later burnt bricks. These "imported" styles and methods were fully assimilated into the indigenous forms and ways of building.

In the Southern area of Ghana the traditional timber framework can be found with wattle and daub construction, as well as houses built with the Atakpame method or walls of stones, sun-dried bricks from lateritic soils and burnt bricks. Traditional roofing is thatch from different materials or in a few fishing villages flat mud roofs or roofs from split bamboo. The house plan is rectangular, roofs are quite steeply pitched (except when flat mud roofs) and gable-ended. With increasing outside influence which brought in imported materials and technologies one can trace certain stages of development in the building methods. A shelter of bamboo posts and beams roofed over with thatch or palm leaf fronds is built and used for a covered cooking area and serves at the same time as general storage and for drying corn cobs (Fig. 54 *and* 55). Built as a "lean-to" against the house it serves as an animal shelter. The method of construction with split palm fronds is used for bathrooms (Volta Region) and kitchens. The bathrooms are open shelters, the kitchens timber framework structures with a thatched roof (Fig. 56 *and* 57). Palm leaf fronds as well as bamboo are also used as fencing material. The Ewe fishermen settled along the Coast use cocos-nut palm fronds, leaves and trunks for their buildings. The next stage is the wattle and daub construction (Fig. 58), spread throughout the area, followed by the Atakpame building – from wet mud balls moulded in layers similarly to the wet mud wall construction of the North (Fig. 59). This method was chosen in many areas after it was found that the wattle and daub method was more tedious, required more skills and that termites were moreover attacking the timber framework and reinforcement of the wattle and daub

Fig. 55: Bamboo shelter in Kuntanase, Ashanti Region, over an outdoor cooking area, serving also as corn storage, 1979.

FIG.56 : **BATHROOM SHELTER FROM SPLIT PALM FRONDS** - TAFIEVE, VOLTA REGION

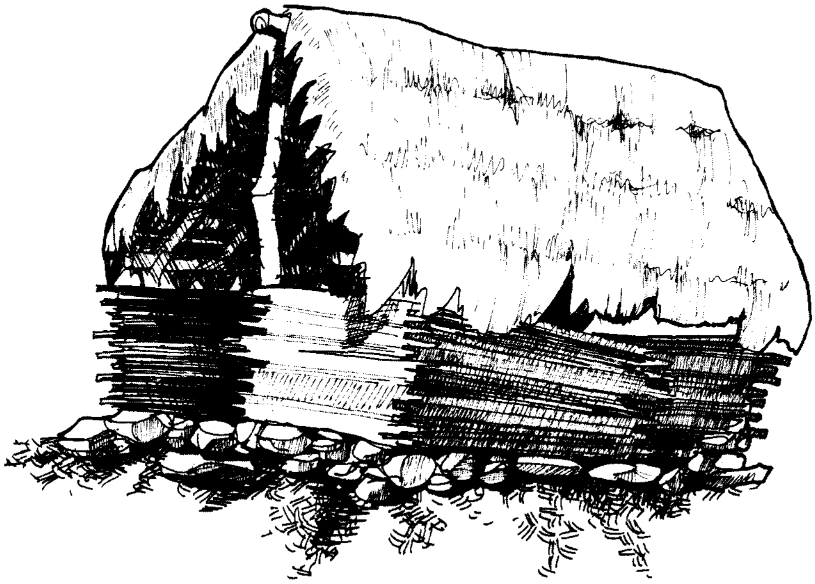


FIG.57 : **KITCHEN BUILDING WITH PALM FROND WALLS IN AVIEFE, VOLTA REGION**

wall, causing early deterioration and collapse. Whilst the house built from wattle and daub still has a thatch or shingle roof, the Atakpame house is covered with corrugated iron sheets on a timber sub-structure. Following this method was the construction with sun-dried mud bricks bonded with mud mortar or already cement-sand mortar, and roofed with iron sheets (Fig. 60). Stone wall construction has not been common, but can be found in the Akwapim area, the Western Region, Accra and Cape Coast. The last stage is the construction with blocks (from sand and cement). With the introduction of corrugated aluminium and asbestos-cement as roofing sheets this stage is the beginning of a new technology in building construction (Fig. 61).

In the rural areas where the farmer or fisherman or craftsman is his own builder (with exception of some areas in the Ashanti and Brong-Ahafo regions) the traditional methods are still used, at the same time modern methods are becoming familiar. The house owner may have one next to the other type of building (from palm fronds, wattle and daub, Atakpame and sun-dried mud bricks) in his compound. The view from above a typical Volta Region village or the "roofscape" of it reveals the types of building methods being used (Fig. 62).

The following parts show in detail the traditional ways of construction in some typical areas of this part of the country.

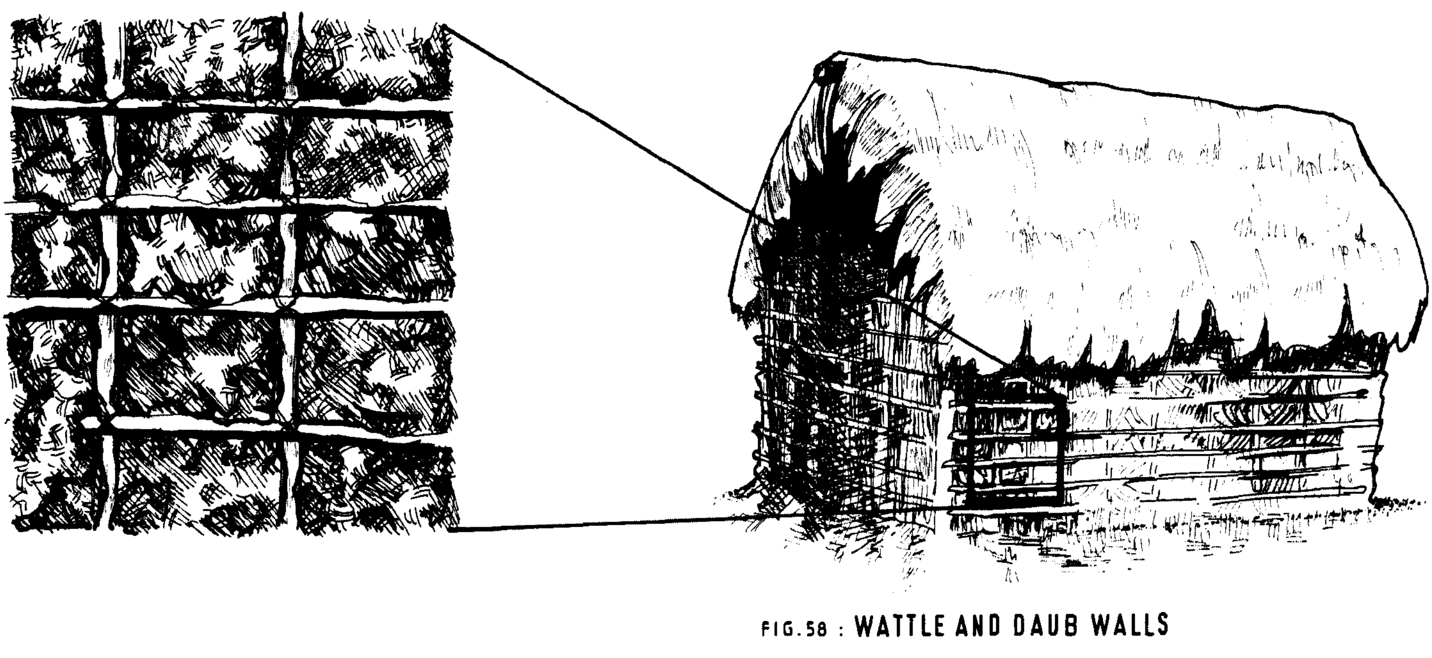


FIG.58 : **WATTLE AND DAUB WALLS**

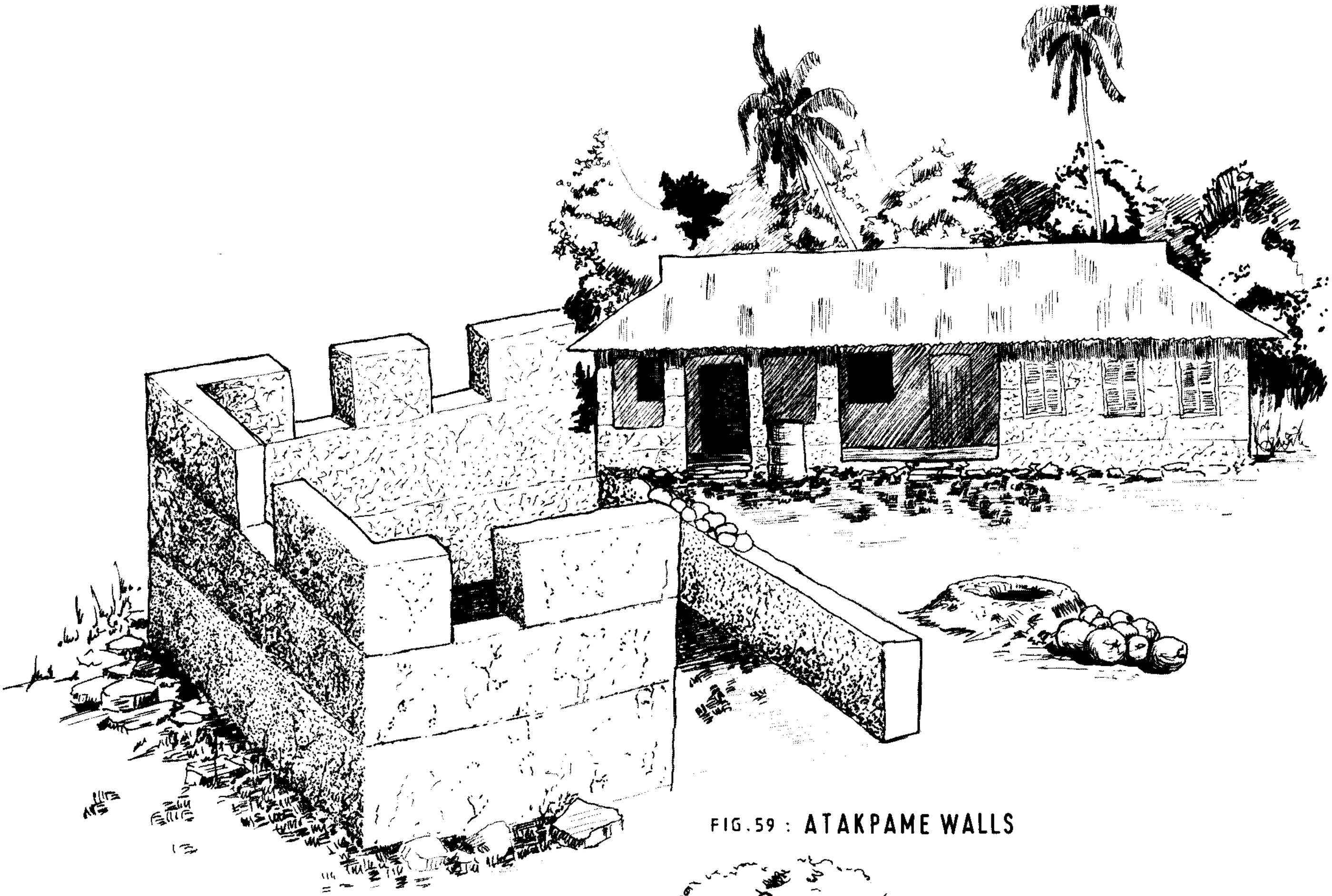


FIG.59 : **ATAKPAME WALLS**

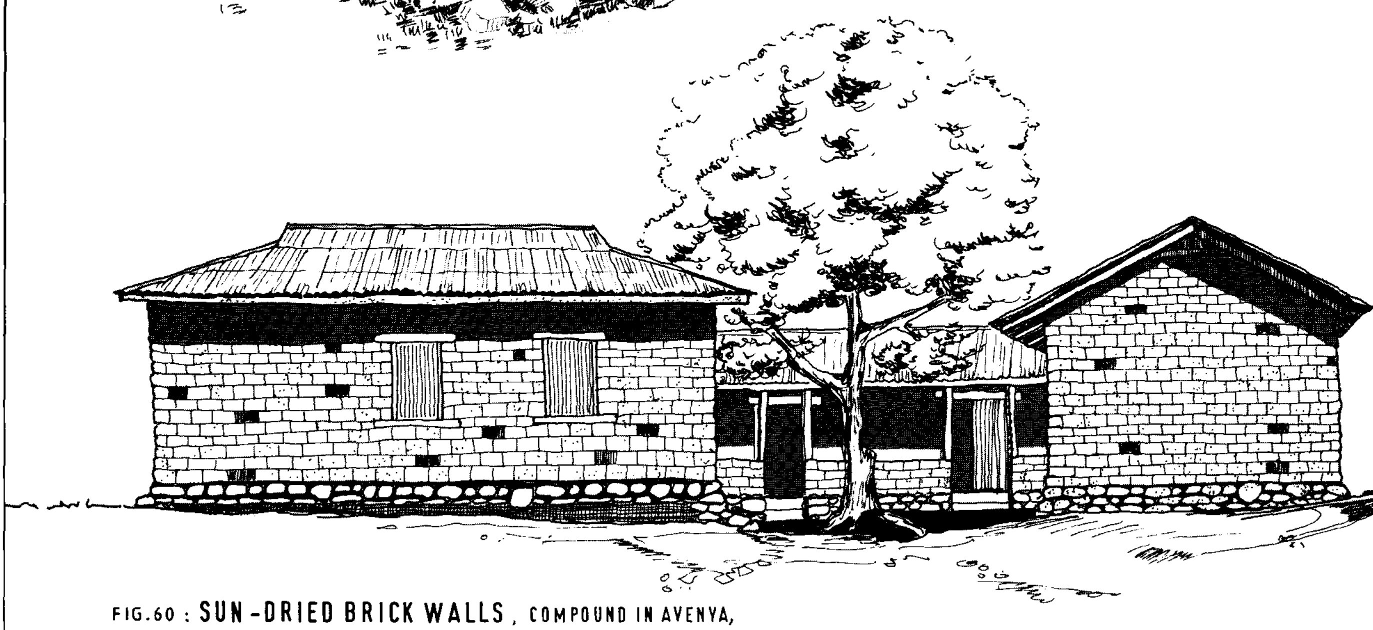


FIG.60 : **SUN-DRIED BRICK WALLS**, COMPOUND IN AVENYA, VOLTA REGION

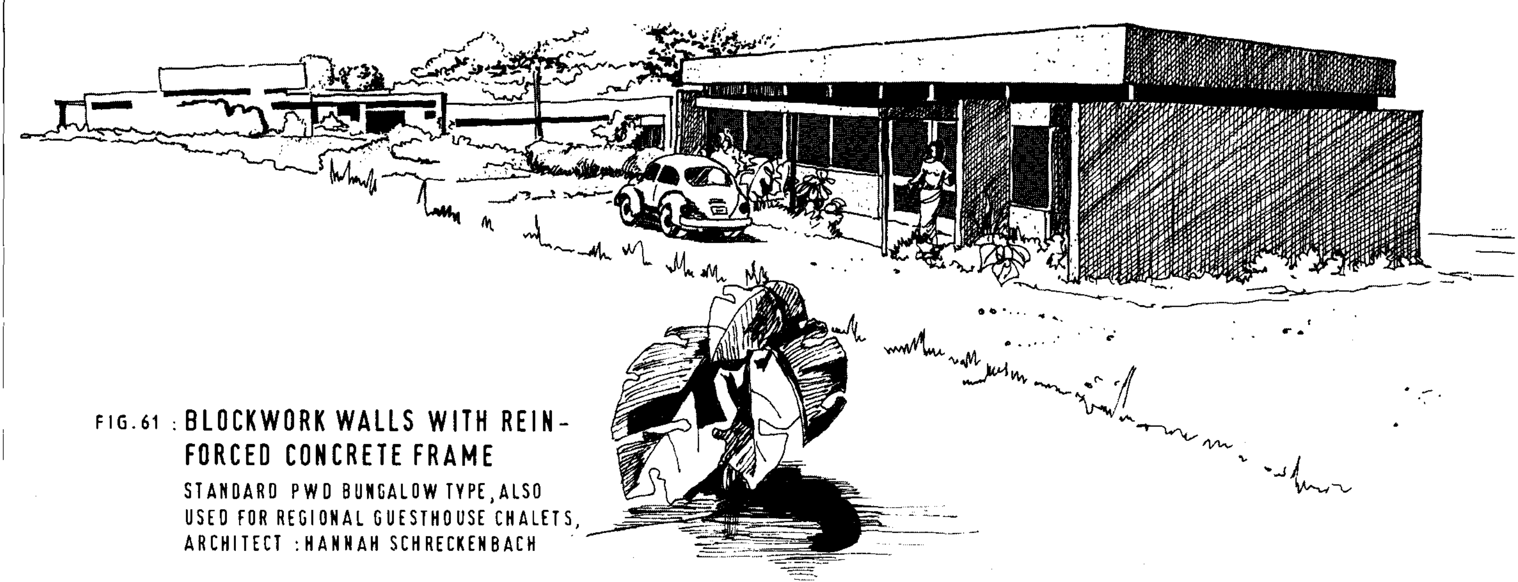


FIG.61 : **BLOCKWORK WALLS WITH REIN- FORCED CONCRETE FRAME**
STANDARD PWD BUNGALOW TYPE, ALSO USED FOR REGIONAL GUESTHOUSE CHALETS, ARCHITECT : HANNAH SCHRECKENBACH

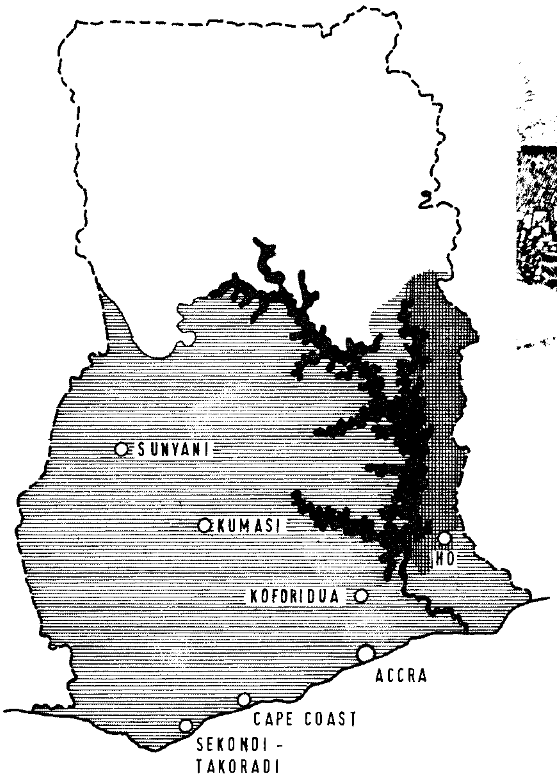


Fig. 63: The mountain villages in the Volta Region (from the Ho – Taviefe Survey, Department of Architecture U.S.T., August, 1980, sketch by B. K. ACHEAMPONG).

Overleaf: Fig. 62: Biakpa in the Volta Region, as seen from Amedzofe, 1981.

2.2.1 THE MOUNTAIN VILLAGES IN THE VOLTA REGION

As did so many people across the vast African continent the Ewes also migrated from other areas to their present homeland. It is believed that the Akans, the Dahomeyans, the Adas, the Gas and the Ewes settled long ago together on the river bank of the river Niger near Timbuktu. When the great ancient empire of Songhai broke up about 1594 a large migration began.

The Ewes, after various "intermittent stations", finally settled in Notsie, a walled city in the present Republic of Togo on the road between Lome and Atakpame. To escape the tyranny of the oppressive ruler Agokoli another migration took place in 1670 in different directions towards the West, resulting finally in the settlement of the Ewes in their present areas of Ghana in the Volta Region.

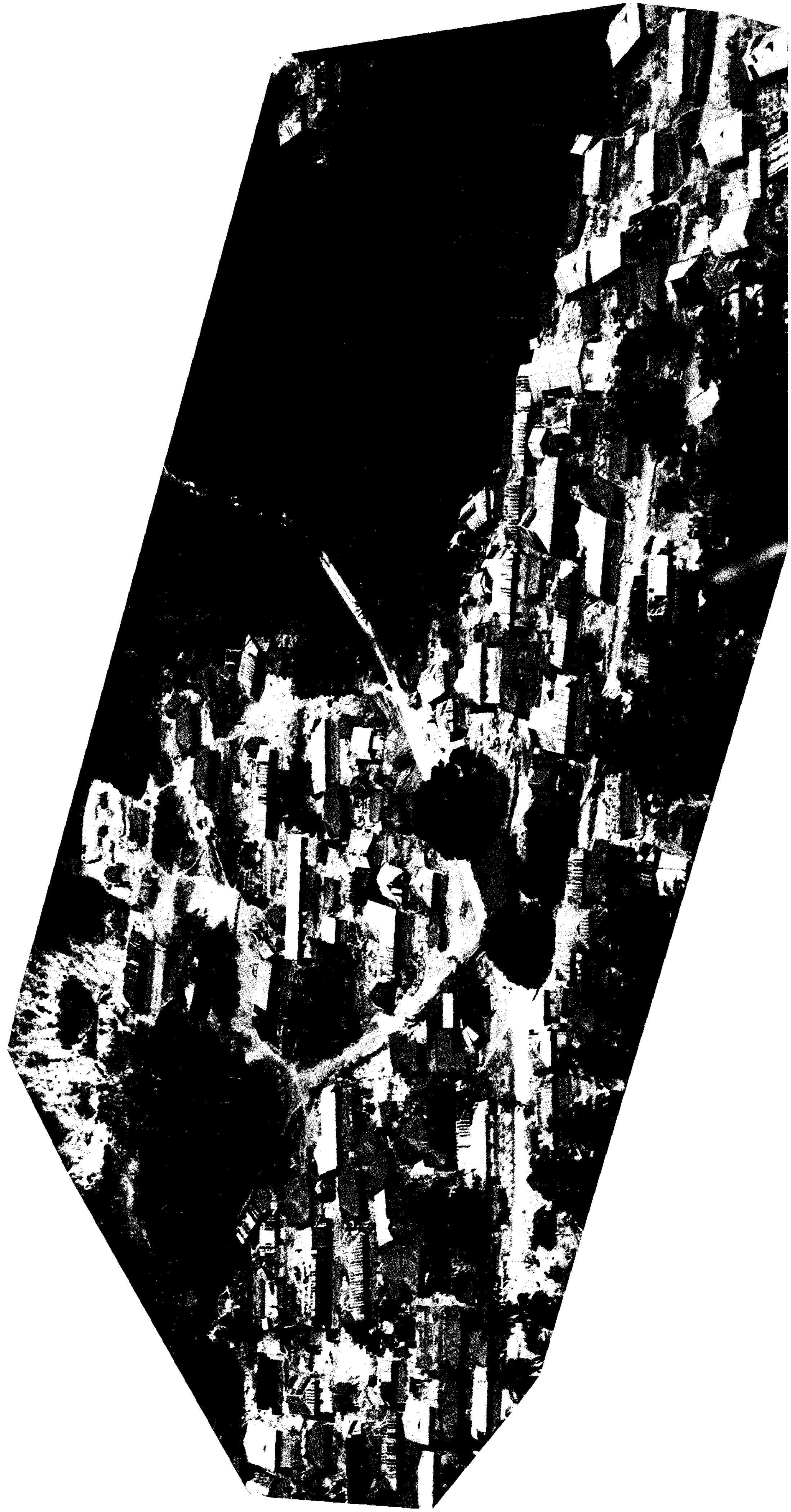
From Notsie, the walled city, the Ewes knew the method of building solid walls from mud in the "Atakpame" way. The large walls of Notsie, which they managed to break down at one place in order to escape, were built from mud. There are still remains today of this wall in Notsie.

Ewe building methods were described by J. Spieth in "Die Ewe-Staemme" (1906) also as wattle and daub walls with flat mud roofs supported by a timber framework in the Ho area. Early photographs of Akpafu (in the North of the Volta Region) show an interesting detail of thick thatch roofs with a low mono-pitch being supported by posts and beams. The posts are placed outside the house walls so that these are not load-bearing (Fig. 64). Spieth describes that the wattle and daub walls were, when completed, plastered by the women on both sides. The men then laid and beat the floors after the walls were finished. It is interesting to note that the same timber species are still being used today for such constructions and building of the roofs in the villages of this region as recorded at the beginning of this century by Spieth. No doubt the traditional building methods of the Ewe people have over the years been influenced by the missionaries since the establishment of the Bremen Mission (E.P. Church), the Catholic Church Mission and by the Germans during the colonial days.

HOUSE CONSTRUCTION: FOUNDATIONS

Three types can be recorded, of which the first type, normally used for a house constructed with wattle and daub walls, can be described as a rammed raft foundation which at the same time is the floor slab of the structure.

Fig. 64: Akpafu in the Volta region at the beginning of this century (from "DIE EWE-STAEMME" by J. SPIETH, 1911).



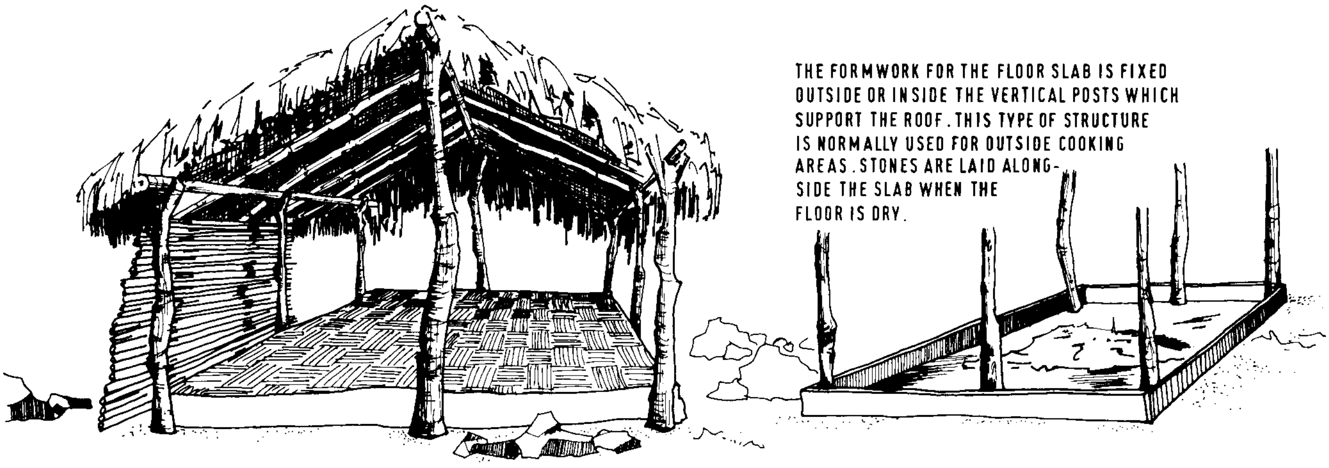


FIG.65: RAMMED LATERITE FLOOR IN AVIEFE

1. RAMMED LATERITE FOUNDATION:

The house owner will try to use lateritic gravel or sand for the slab. In most locations of the region this should not be difficult, the soils in the mountain areas are Regosolic Groundwater Laterites with Laterite-Ochrosol Intergrades and Forest Ochrosols, with shale, sandstone, weathered sandstone, phyllite and quartzite underneath or exposed.

This lateritic soil with an added aggregate of sand or gravel is mixed with water and left to set for about two days. A shallow framework of Banana or Plantain stems (cut down after the fruit has been harvested) is laid. The mixed soil is then placed into this area and beaten flat with a wooden implement. At the same time the posts for the roof structure and vertical timber members of the wall are fixed into the ground through the slab, so that the floor slab is finished together with this framework (Fig. 65).

2. STONE STRIP FOUNDATION:

In this area stones are available in abundance. They are quite carefully selected in the correct shapes to fit a trench about 500mm deep and 300mm wide after profiles with strings have been erected at the four corners of the building to achieve a more or less straight rectangular layout (Fig. 66 *and* 67). The bonding is done with soft mud and sand mortar (Fig. 68) or nowadays with cement-sand mortar.

3. SHALLOW SOLID MUD FOUNDATION:

Shallow trenches are dug about 150 to 250mm deep and about 300mm wide. The builders begin the first wall course of the Atakpame wall structure from this level, so that in the true sense of the word one cannot describe this as a foundation any longer, since it is already part of the wall.

WALLS

There are three typical types of wall construction in this area, the wattle and daub wall, the Atakpame wall and the wall from sundried bricks.

1. WATTLE AND DAUB:

Holes are dug into the ground at regular intervals after the desired shape of the building has been marked out with the help of pegs and strings. The vertical posts which are to carry the roof structure are inserted into the holes and stabilized with stones rammed around them at the base. This process goes on together with the laying of the floor (foundation) slab. For the timber framework, as well as for the main roof structure the wood of the **Fan Palm** *(Borassus Aethiopum)* is used. The **Raphia Palm** *(Raphia Hookeri)* wood and the rachis petioles of the leaves are also used for posts and beams. Leaves of this palm tree are used for thatching as well. For the horizontal and

Fig. 66: Stone foundations of an abandoned site in Aviefe, 1980.

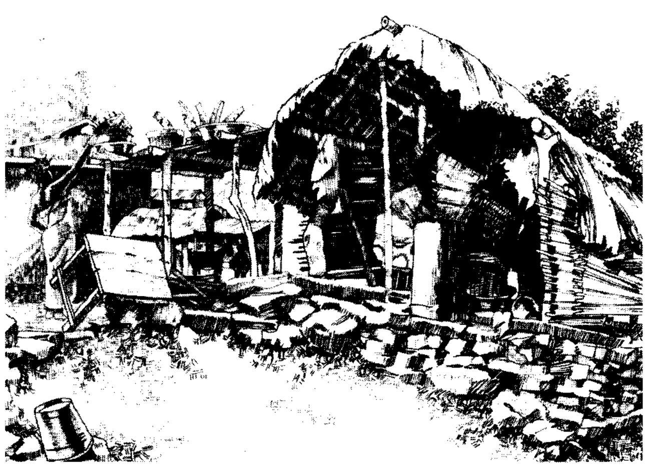
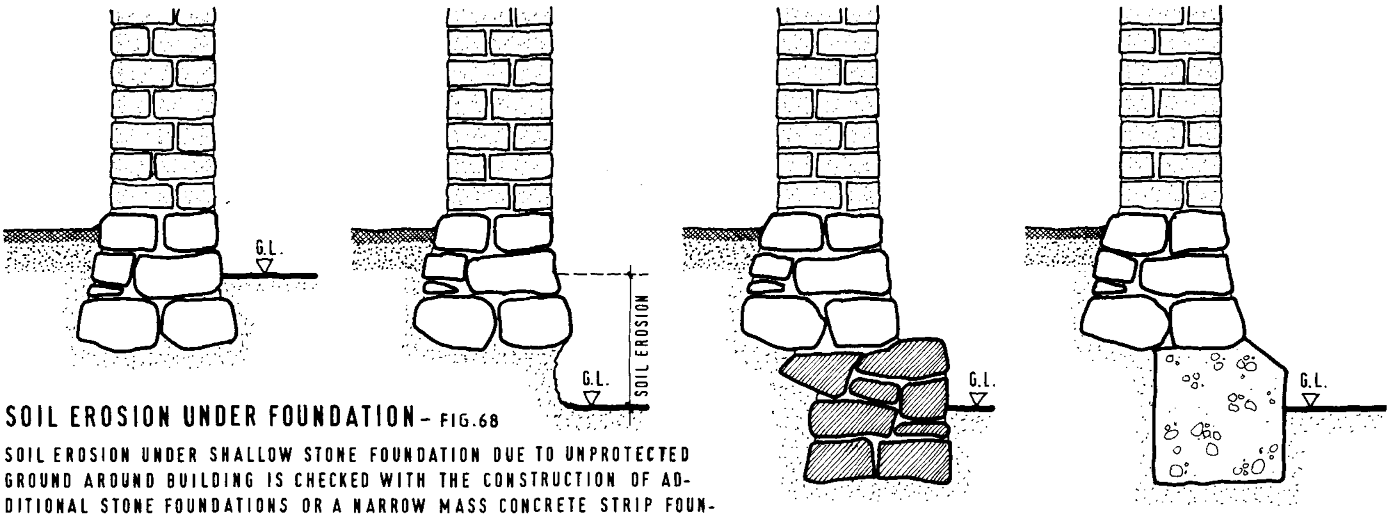


Fig. 67: Foundation wall of a kitchen in Aviefe (from the Ho – Taviefe Survey, Department of Architecture U.S.T., August 1980, sketch by B. K. ACHEAMPONG).



SOIL EROSION UNDER FOUNDATION – FIG.68

SOIL EROSION UNDER SHALLOW STONE FOUNDATION DUE TO UNPROTECTED GROUND AROUND BUILDING IS CHECKED WITH THE CONSTRUCTION OF ADDITIONAL STONE FOUNDATIONS OR A NARROW MASS CONCRETE STRIP FOUNDATION PARTLY UNDER EXISTING ONE.

vertical members of the framework, which are tied in before the mud is applied, the stems of *Thalia Geniculata,* a shrub, and split bamboo are used. When the framework has been completed, the roof is built. After this wet moulded mud balls are pressed and worked into the framework of the walls to a thickness of 150 to 200 mm. Generally the walls are only smoothened but in some cases rendered with a soft mud and sand mixture. This method of construction allows the builder to complete the walls, when he has the necessary help, in a few days, since he need not wait for each course to set and dry before he lays the next one. The walls also require no cover during rain, as the roof is already completed.

2. ATAKPAME WALLS:

The name of this wall building method is associated with the town **Atakpame** in Togo. Although the method of building with moulded wet mud balls is common in the northern part of Ghana, the "Atakpame" method refers to a rectangular wall which has been properly laid out by the builder with pegs and string. The preparation of the mud is similar to that by the northern people. A pit is dug near the building place, the mud mixed with water, kneaded with bare feet and moulded into balls of about 200 mm diameter. Courses of up to 600 mm in height are laid, each course covered with palm leaves and allowed to set and dry out gradually before the next course is added. Wet mud cannot bear its own weight and would slump otherwise. Each course is properly levelled out on the top, the sides of the wall are scraped smooth with an old cutlass. Openings for windows and doors are noted and left during construction. The wall tickness is generally about 300 mm. After five courses a wall height (excluding the foundation) of approximately 2.50 m has been reached. When the last course is still wet, holes are made into it every 600 mm at the top through which ropes are drawn for fixing the wall plate of the roof framework. Another way of supporting the roof is by driving short forked sticks into the top of the wall over which the framework is laid and tied. Lintels over doors and window openings are pieces of the Fan Palm. The walls are generally not rendered and the pronounced horizontal lines of the courses are clearly visible. During the survey for this book it was, however, noted that a mixture of soft mud and red clay was used in places externally. It was mixed with water into a thin paste which was applied to the walls with a sponge. Quite often a plaster mix of mud and bitumen has also been used (this method will be described under **"Walls and Wall Finishes"** in the **"Construction"** part of the book).

3. SUN-DRIED BRICK WALLS:

From a borrow-pit close to the building mud is dug up, mixed with water and kneaded. The mixture is then pressed into wooden casts. The size of a brick is approximately 200 × 90 × 90 mm. A drying shed is erected with timber posts, beams and a thatched roof. Under this the bricks are left to dry slowly. This may last, depending on the weather, up to two weeks. Only where a proper brick bond is used can long vertical cracks be avoided in the wall during construction. The bricks are laid with mud-sand mortar or a weak cement-sand mortar, where cement is available.

4. OTHER WALLS:

The Ewes in this area very skilfully produce screen walls from split bamboo and split palm fronds for the bathrooms and fences of their compounds.

ROOFS

The traditional thatched roof is a coupled-roof over a rectangular building layout with gable ends. The hipped-end-roof was introduced later. The roof has a pitch of about 45°. For its construction the following materials are used:

Fan Palm (locally called "Agobeam") – *Borassus Aethiopum,* resistant to termites and fungi, used for ridge beams, eaves beams, centre posts and wall plates, fronds are used as purlins;

Savannah Bamboo (locally called "Pamplo") – *Oxytenanthera Abyssinica,* used for rafters;

Thatch (locally known as "Ebe") – *Imperata Cylindrica,* a common grass throughout the savannah areas used for roof thatching;

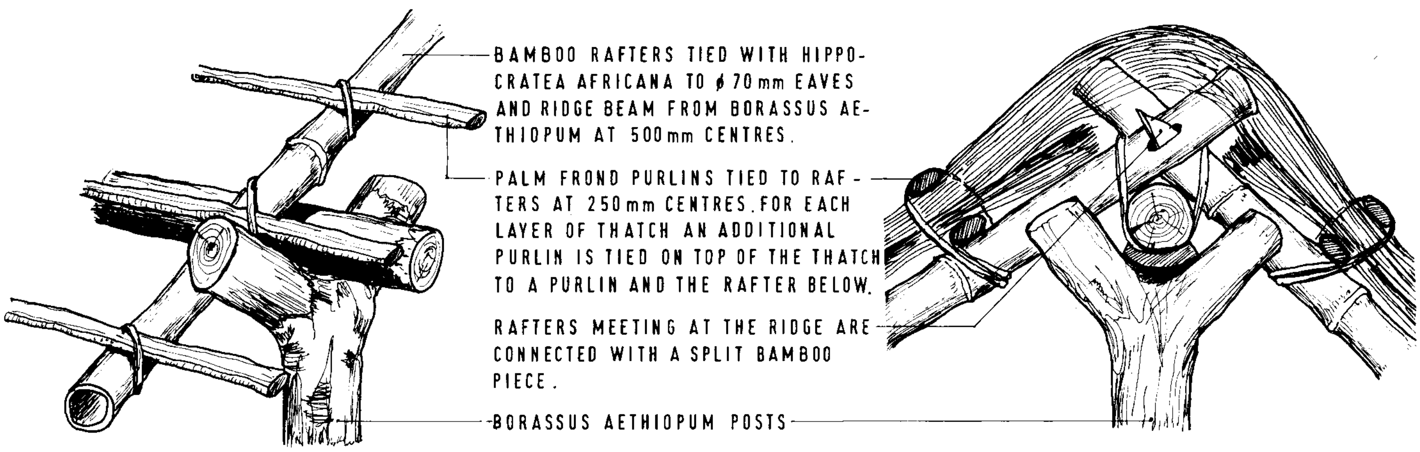


FIG. 69 EAVES AND RIDGE DETAIL OF A THATCH ROOF

Tie-ropes (locally known as "Nyido") – *Hippocratea Africana,* a woody climber used as a binding material in house and fence building.

The following sketches and photographs explain the sequence of construction (Fig. 69, 70, 71, 72).

In most rural areas visited the use of corrugated iron sheets or aluminium sheets has been introduced. Agobeams will still be used as rafters for such roofs, but in most cases, especially when the house has been built with landcrete or sandcrete blocks, properly cut timber members are purchased and used as roof sub-structure.

Fig. 70: Roofscape of Aviefe. Note the bamboo roof in the foreground.

Fig. 71: Aviefe roofs (from the Ho – Taviefe Survey, watercolour by M. BORTEI-DOKU).

BELOW :
THE GRASS FOR ROOFING , IMPERATA CYLINDRICA , IS CUT , BUNDLED AND LAID TO DRY ON RACKS .FROM THERE IT IS TAKEN TO THE MARKET OR TO THE SITE .

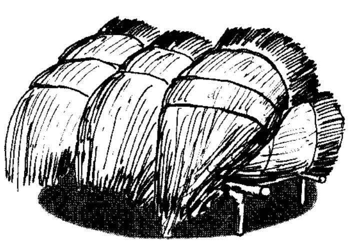


FIG.72 : ROOFSCAPE OF AVIEFE .NOTE THE BUNDLES OF THATCHING GRASS ON A DRYING RACK IN THE FORE-GROUND .

BATHROOMS AND TOILETS

For the construction of bathrooms in this area a method is being used which closely resembles a conventional soakaway structure (Fig. 73). A hole of 1.50 m in depth and about 1.00 × 1.50m in size is dug. It is filled with stones of different sizes. The top layer, which at the same time closes the hole consists of large flat stones, serving as the "floor". This area is then closed off with palm frond screen walls leaving a small opening on one side. The screens are 1.50 to 1.80m high (Fig. 74). Toilets are constructed as communal pit latrines with a thatched roof construction over, with low eaves, so that the roof acts as screen at the sides. One enters from the gable ends. The place for the latrine is fenced off and is situated at one end away from the village, in the direction of the prevailing winds (at the northeast end of the village).

WINDOWS AND DOORS

Windows and door frames are fitted into the wall during construction, mainly in the Atakpame and sun-dried brick walls. Properly constructed arches from brick can be found. The windows are wooden jalousie outward opening casement windows, or boarded and panelled window shutters, horizontally pivoted, with or without a fixed jalousie vent above. Doors are ledged, braced and boarded doors or panelled doors. The ironmongery for windows and doors, e.g. hinges, bolts, hasps and latches is manufactured by the local blacksmith in the village. In the Akpafu area and Amedume Hills iron ore can be found. The Ewes knew early the art and craft of blacksmithery.

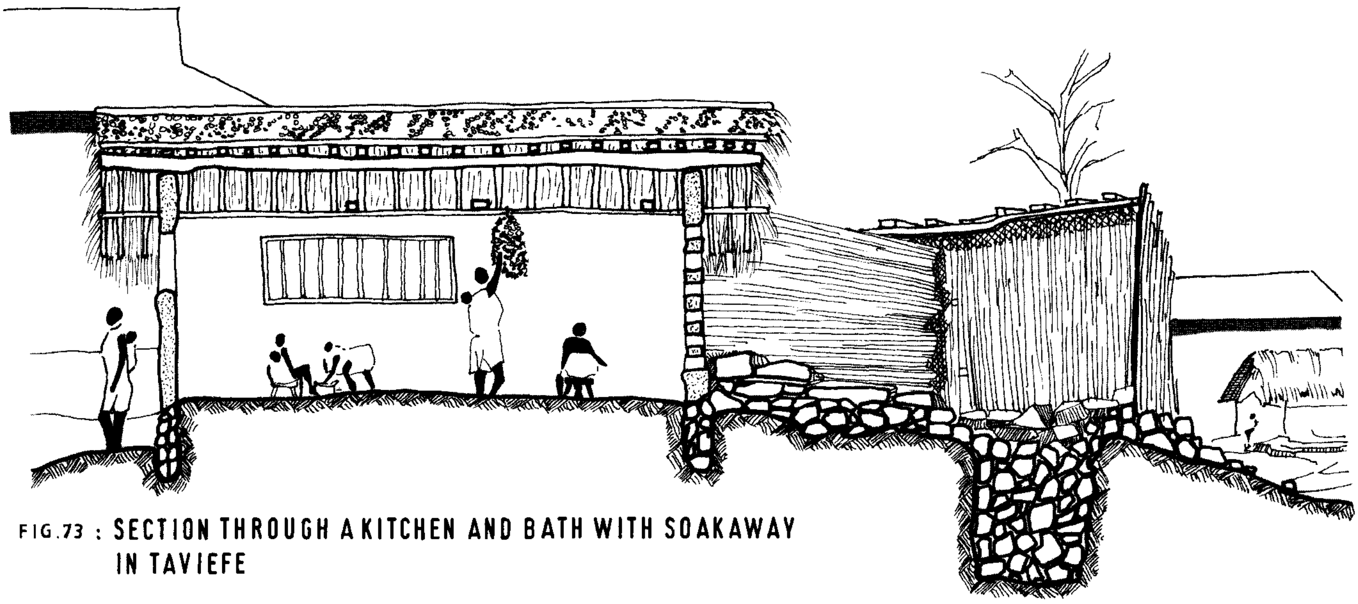


FIG.73 : SECTION THROUGH A KITCHEN AND BATH WITH SOAKAWAY IN TAVIEFE

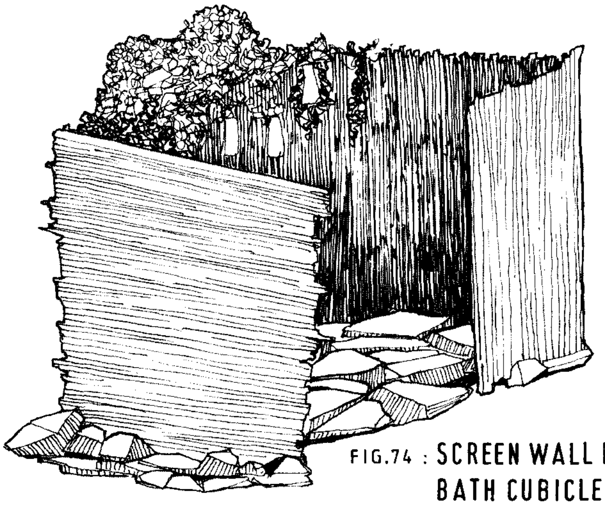


FIG.74 : SCREEN WALL FOR BATH CUBICLE

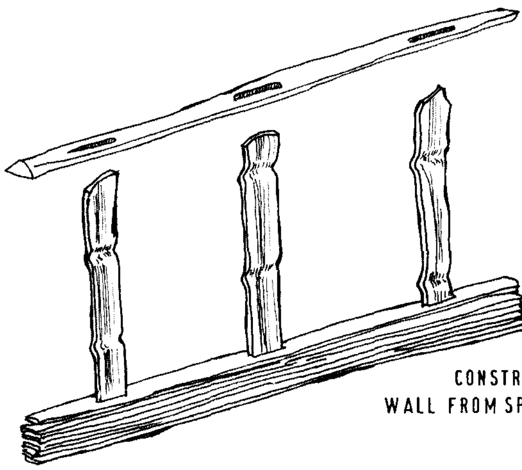
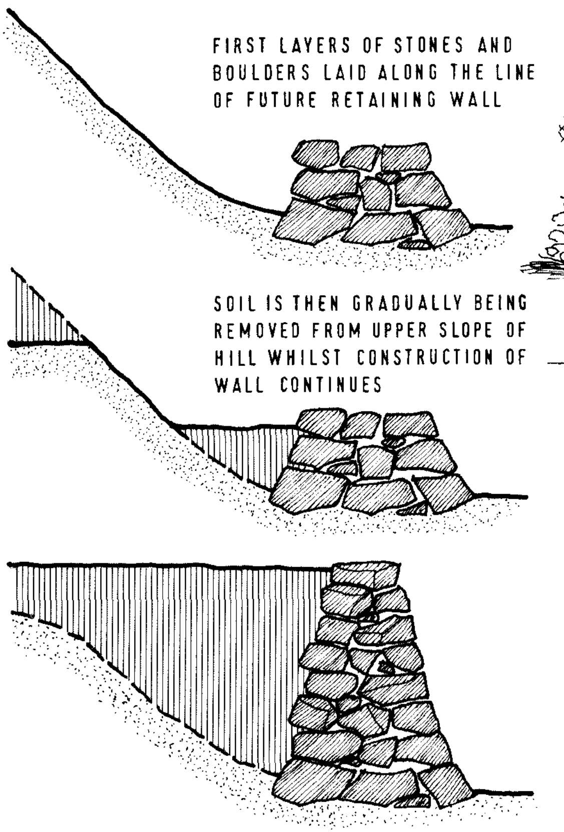


Fig. 75: Screen walls from split bamboo in Aviefe (from the Ho – Taviefe Survey, sketch by B. K. ACHEAMPONG).



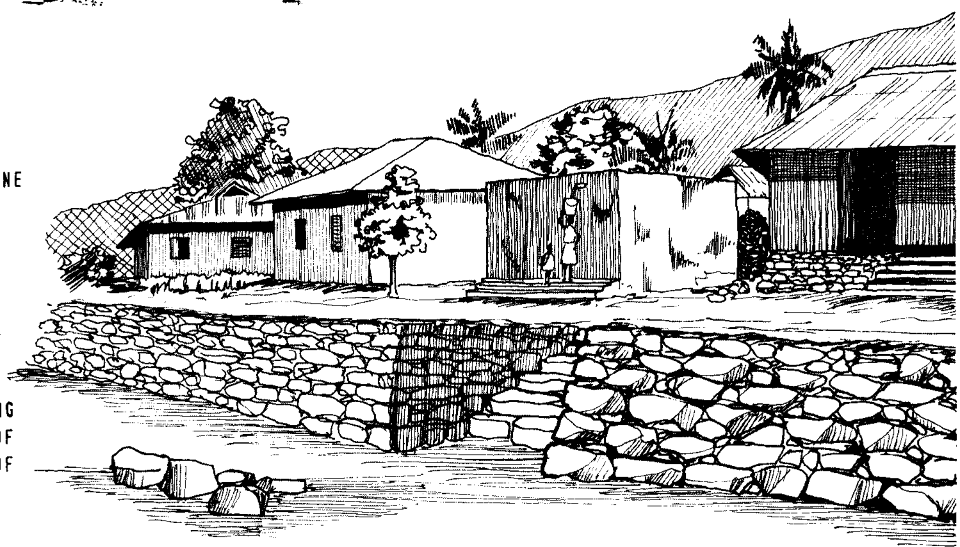


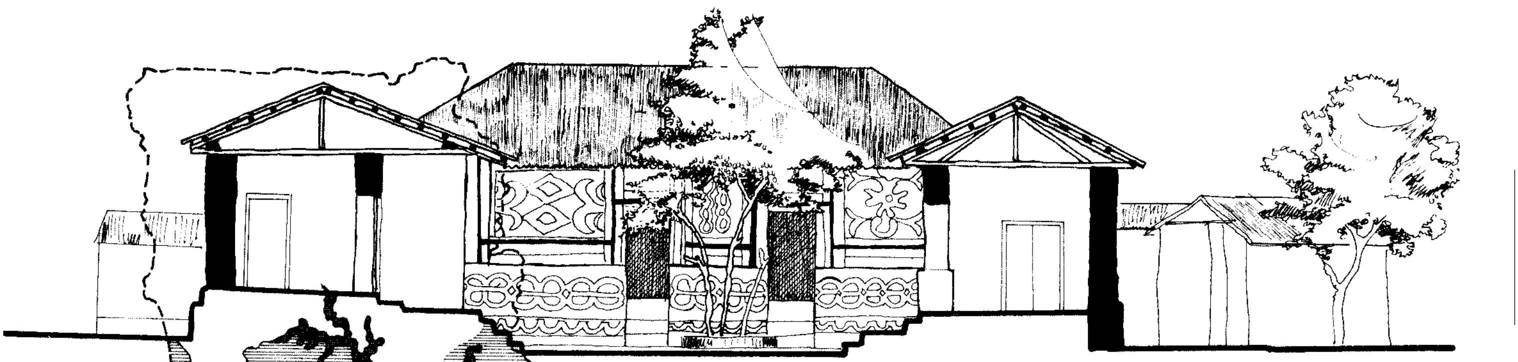
FIG.76 : TERRACING IN AVENYA - TAVIEFE, VOLTA REGION.
FROM THE HO - TAVIEFE - SURVEY, DEPARTMENT OF ARCHITECTURE, U.S.T., AUGUST 1980.

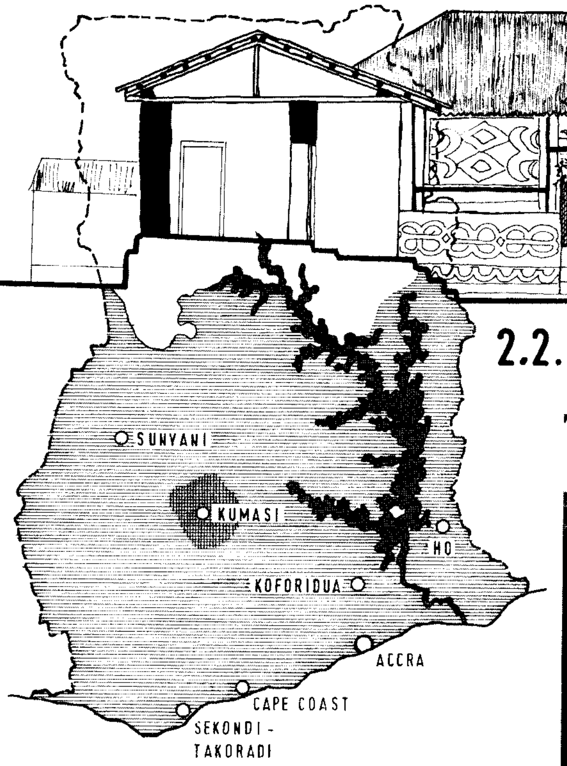
EXTERNAL WORKS

Certain features are typical for the Ewe mountain villages which are not found in other places, namely, the use of natural stone for landscaping. They are used for retaining and terracing walls (Fig. 76), steps, drainage, bridges (Fig. 77) and outdoor seats (Fig. 78), as can be seen from the illustrations.

Fig. 77: Stone drain and bridge over it in Aviefe.

Fig. 78: Outdoor stone seats in Aviefe.





2.2.2 CONSTRUCTION OF THE ASHANTI FETISH HOUSES

FIG. 79

From the description of all the early European travellers to Ashanti (Kumasi and other important towns) it is known that all were impressed by the beautiful, clean and comfortable houses, often two-storey, of the ordinary people, quite apart from the large, extensively decorated houses of the more important citizens and the palaces of the kings.

Of those houses nothing remains. But how they were built and what they must have looked like can at least be seen partly in the Ashanti Fetish Houses around Kumasi (Fig. 79, 80, 81). These are small temples designed to house the shrines of the **Abosom** (lesser gods). Their layout was similarly designed as a courtyard house, with four rectangular structures placed around an open court, linked by screen walls. The Ghana Government recognized the importance of preserving remaining examples of old Ashanti architecture and financed the restoration of quite a number of Fetish Houses in the mid-sixties under the supervision of the Public Works Department of the Ashanti Region for the Ghana Museum and Monuments Board. It was, however, not possible with the limited resources available to rebuild or reconstruct the shrines in the original way, that is with the traditional building methods and materials. But from the existing, restored and new Fetish Houses it is possible to have a glimpse of the past and to gain an understanding of the skill, knowledge and artistic talent of the traditional builder.

FLOOR CONSTRUCTION

The four units around the open court were raised on a solid platform of clay, about 1.00 m above the floor level of the courtyard. The open courtyard is today still the focus of activity, although the rooms are now built continuously around the inner yard. In a Fetish House the courtyard is used for religious ceremonies (Fig. 82).

The floor was from rammed gravel finished with red clay or mud, which was washed and touched up constantly.

WALLS

A timber framework of vertical posts (of approximately 100 to 150 mm and spaced closely around the perimeter of the mud platform) and horizontal members of bamboo or stems of the shrub **Babadua** *(Thalia Geniculata)* were tied together with creepers *(Hippocratea Africana,* in Ashanti, "noto" or *Hippocratea Rowlandii,* in Ashanti "ntwea"). Over this framework wet mud was applied. In this area with predominant Forest Ochrosols this would have been in most cases clayey lateritic soil, indeed an excellent building material. Wall thickness was about 250 mm. The walls were rendered both externally and internally and finished smooth with a wet fine mud plaster of the red soil.

Since three of the buildings set around the courtyard were open to the yard large beams were necessary to span across the front of these rooms. They were either timber beams plastered with clay or built in form of lattice girders with different designs. The supporting columns were constructed with a centre timber post of about 150 mm in diameter to which stakes of smaller diameter were tied. The columns were then plastered with clay to achieve a square shape.

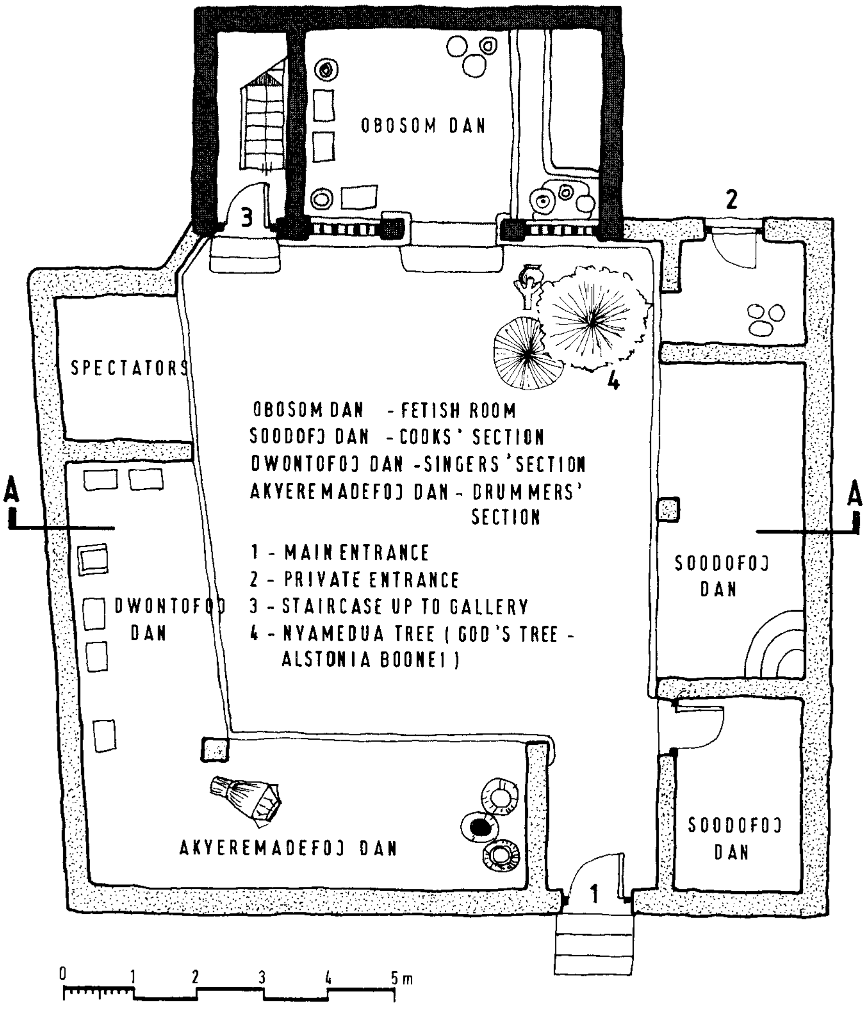


FIG.82: COURTYARD IN FETISH HOUSE AT ABIRIM, 1981.

FIG.80 PLAN FETISH HOUSE, ABIRIM
(FROM DOCUMENTATION OF GHANA BUILDINGS, DEPARTMENT OF ARCHITECTURE)

The shrine room normally had open-work screens towards the courtyard with a narrower opening into the room in the centre. These screen walls have cores of flexible Babadua stems tied with creepers when they have a curved design or a straight timber core when they have straight geometrical designs. These cores were then covered carefully with clay all round (Fig. 83, 84, 85).

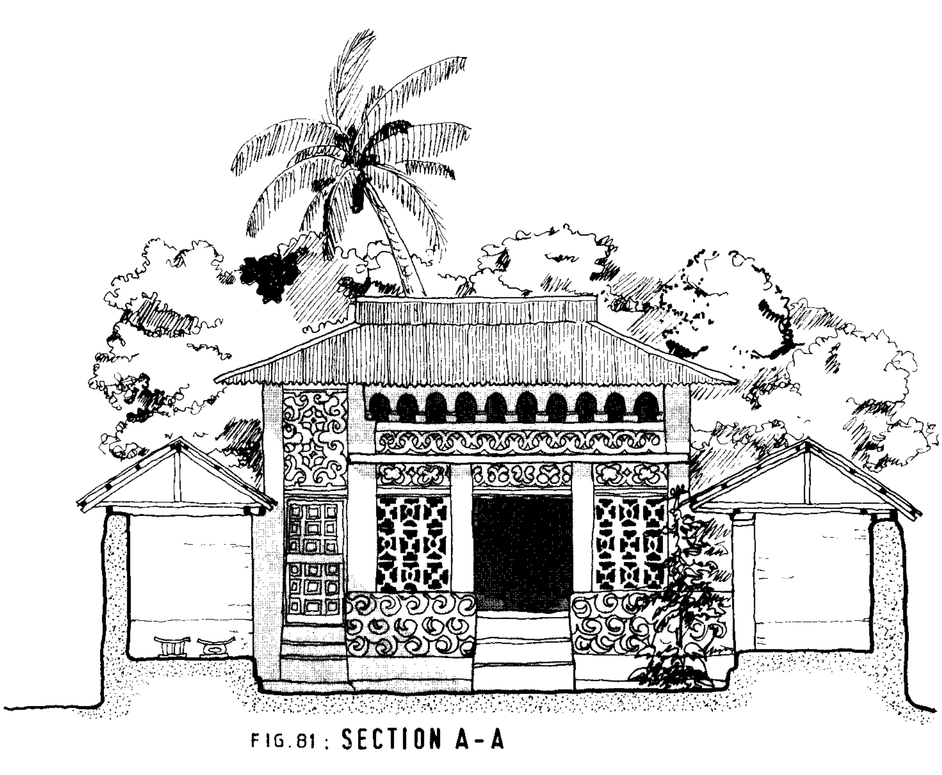


FIG.81: SECTION A-A

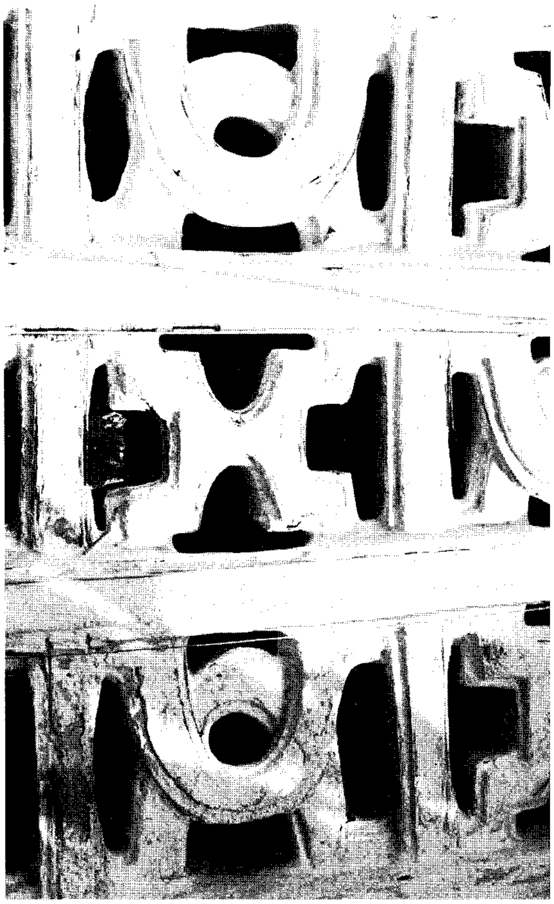


FIG.83: OPEN-WORK SCREEN WALL OF THE SHRINE ROOM

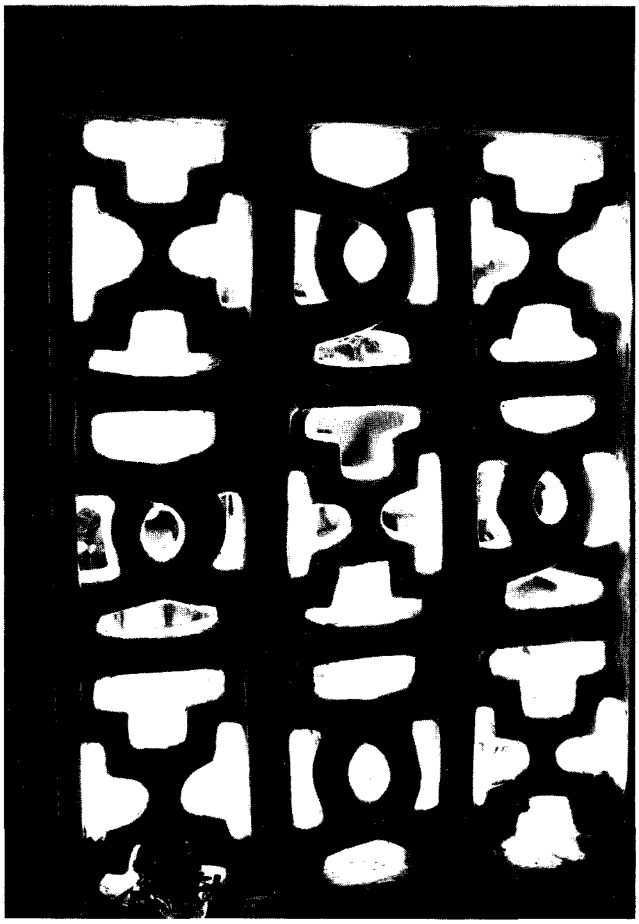


Fig. 84: View from the shrine room through the screen wall.

Fig. 85: Detail of screen wall showing part of the core.

Fig. 86: Wall decoration and traditional pots in the shrine room.

ROOFS

Of the old, steeply pitched (about 60°) roofs none remain. They were described as having a substructure of timber beams (at eaves and ridge) to which bamboo rafters were fixed. Palm-frond purlins were tied to the rafters.
The roof cover was from tightly inter-woven palm leaves (from the Raphia-palm) which were prepared on the ground and then tied into position with quite a large horizontal overlap (*see* **"Materials and their Uses in Construction", 3.1 Natural Materials, Plants and Woody Plants**). The buildings had gable ends.
The restored Fetish Houses have been roofed with corrugated iron sheets at a lower pitch with hipped ends.
The original rafters were painted black and polished. The appearance of the materials and finishes used, which complemented each other, must have been very beautiful. The relation between design and materials with its expression of an achieved balanced proportion is lost. The restored or newly built shrines do not have this quality of harmony.

DECORATIONS

Decorations were applied to all platform walls and to the fronts of the walls facing the courtyard and to the fronts of the linking screen walls facing the interior court. Decorations were also applied to the plinths of walls and columns, usually about 1.00m high. They are about 100 to 150mm thick red clay facings, boldly moulded in a number of different designs and motifs with naturalistic, geometrical, stylized character. The decorations on the lower parts of the walls and plinths were finished daily with red clay wash (Fig. 86).
The decorations in low relief on the upper parts of the walls and beams are of interlocking geometrical designs or show naturalistic designs. In the next chapter on "Traditional Housing in Kumasi" it will be described how the reliefs were made. These parts of the walls were finished with a wash of white clay.

Construction work was carried out by skilled artisans under the supervision of master builders who applied the decorations themselves. In some of the villages where Fetish Houses can be found some master builders may still live, but theirs is a skill which is dying out with the moving away of the youth from the villages to the towns, an occurrence similar to what is happening in the north of the country, where the traditional art and skill of constructing a mud silo may no longer be known in a few years time.

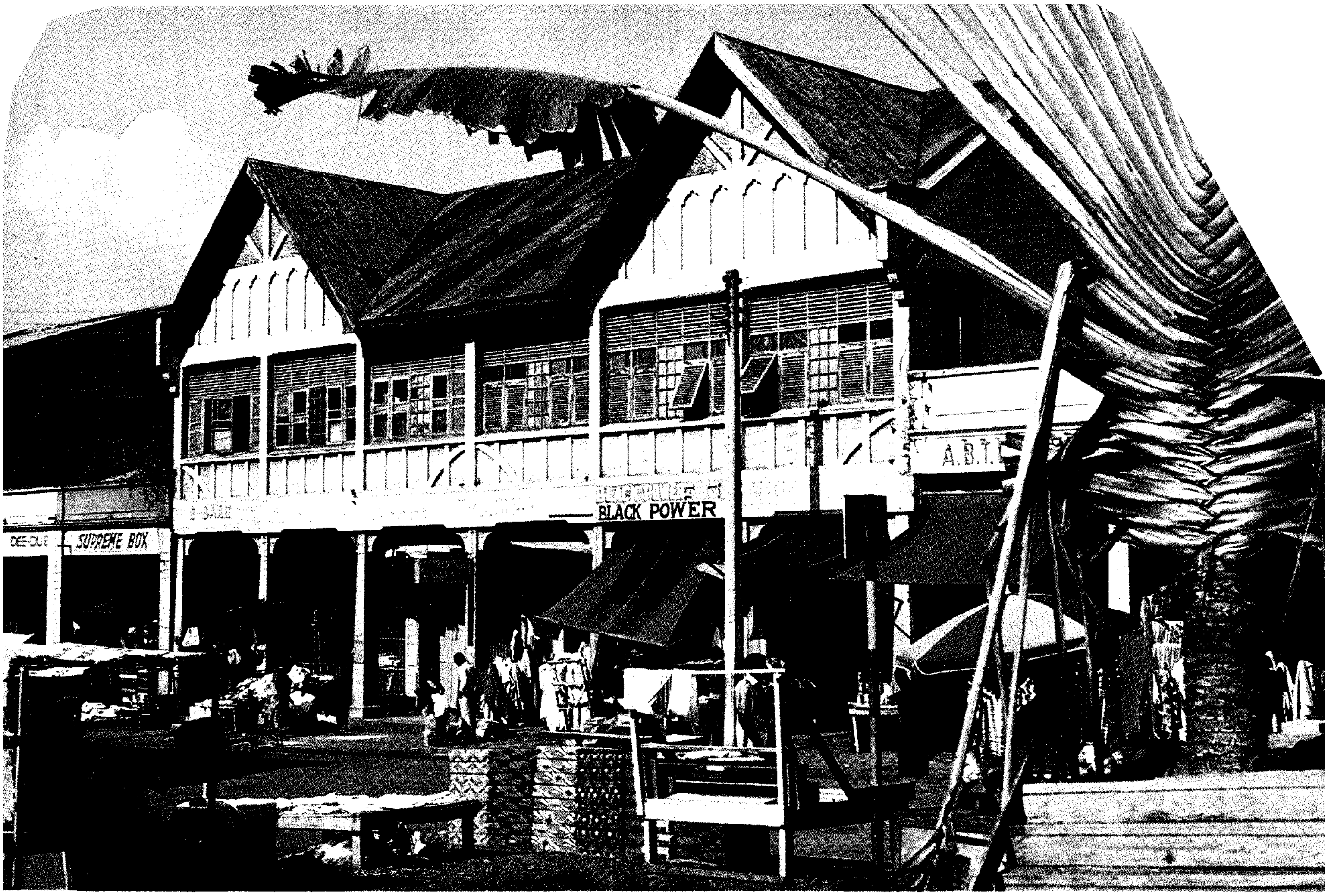
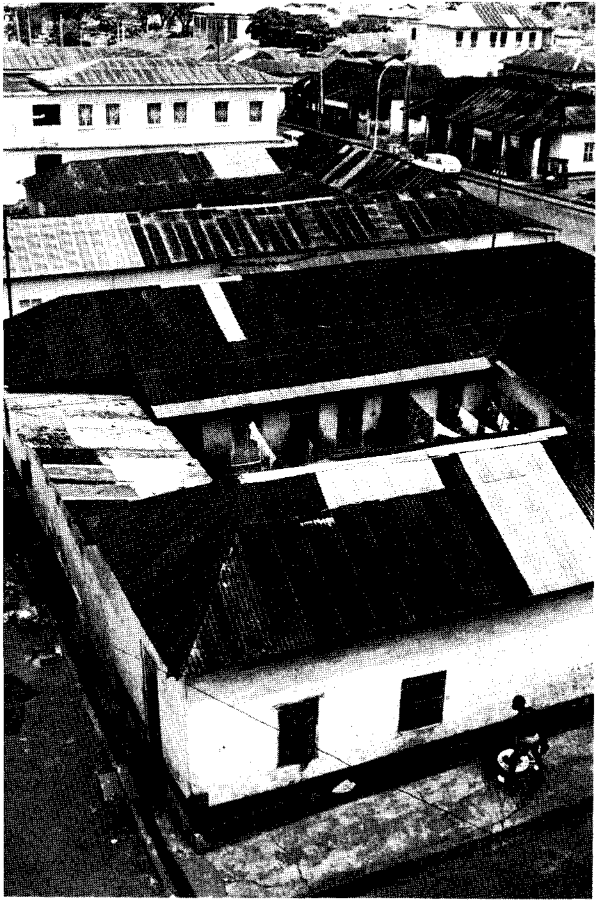
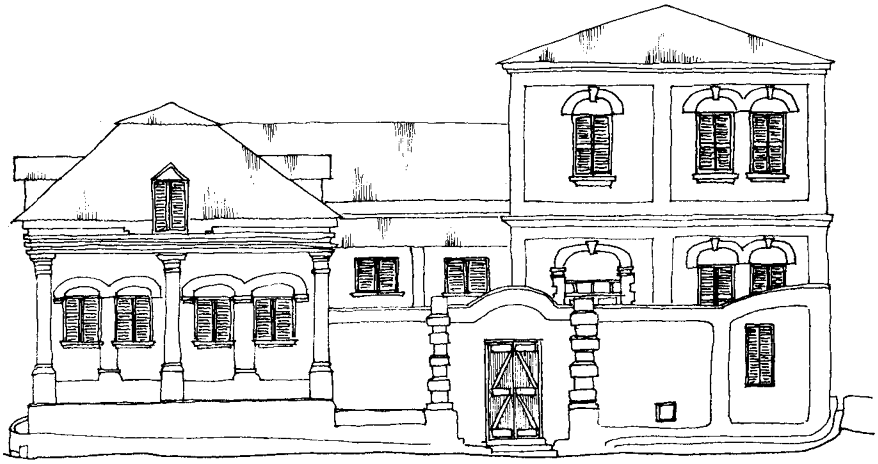


Fig. 89: Old and new Bantama in Kumasi, 1979.

Fig. 91: Typical old 2-storey house in the commercial area of Kumasi, 1978.





2.2.3 TRADITIONAL HOUSING IN KUMASI

Kumasi of the old days under different Ashanti Kings must have been a beautiful and interesting place. When Bowdich arrived in this town in May, 1817, the Ashanti Kingdom was at the height of its power. He describes in the "Mission from Cape Coast Castle to Ashantee" the splendour of the reception and the displayed regalia.

His descriptions of the construction methods of a house are very detailed. The walls were built from wattle and daub. The houses had all gable ends with six main timber poles for supporting the roof ridge and eaves beams which were joined to the gable walls. The roof structure was from bamboo, the roof finish from an interwoven thatch of palm leaves (Raphia palm) tied to palm frond purlins with creepers. The bamboo framework was painted black and polished. The vertical timber poles were plastered with swish in order to appear square. The floors of rammed gravel and red clay were washed daily with a watered-down infusion of the same red soil. With the walls still soft after the puddled mud had been applied to the stakes and wattle work, moulds were formed in patterns producing a profile formed out of thin slips of cane connected with grass. These patterns of moulded relief ornamentation can still be found in the Ashanti Fetish Houses nowadays. Plinths and lower parts of the walls were plastered and finished in red clay. The walls received a plaster and were then, as well as the moulded relief work, finished with whitewash from clay. The thatched roofs were very steeply pitched (Fig. 87).

R. A. Freeman writes in "Travels and Life in Ashanti and Jaman" about his stay in Kumasi in 1889 on his way to Bontuku (now in the Republic of Ivory Coast). He saw only the remains of Kumasi after its total destruction by the British in 1874 (**Sagrenti War**) but was very impressed by the remaining broad, well kept streets, "lined by houses of admirable construction, careful and artistic finishes and of excellent repair". He noted the departed prosperity and evidences of a superior culture. From his description we know some more details of the reliefs with which the remaining better-class houses were adorned and which were unfortunately not extensively detailed in Bowdich's notes although during his visit nearly all houses along the main streets of Kumasi must have been decorated in this fashion and must have been a striking sight (Fig. 88). Some of the designs are known as **"Adinkra"** signs from the symbols printed on King Adinkra's cloth, but form part of the Ashanti symbols, of which the **Sankofa** sign (signifying humility, literally: "Turn back and fetch it") is a common one. Doors to the houses appear to have been skilfully built as timber panelled doors in timber frames. Windows were small carved wooden shutters.

Lady Fuller's pen and ink drawings in the book "A Vanished Dynasty-Ashanti" by Sir Francis Fuller (a Chief Commissioner of Ashanti in his time), shows how Kumasi and the surrounding villages appeared in 1920. Although further destruction had been inflicted upon Kumasi with the burning down of Bantama in 1896 and during the **Yaa Asantewaa** uprising in 1900, rebuilding of the town had started almost immediately afterwards under the colonial administration. In June 1896 the **Ramseyers**, coming

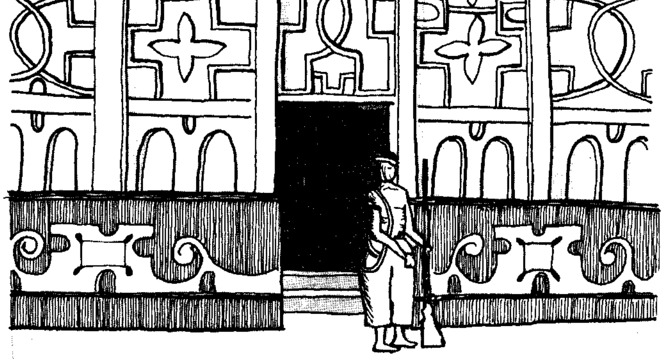


FIG. 87 : PART OF THE INNER SQUARE OF APOKOO'S HOUSE, FROM "MISSION FROM CAPE COAST TO ASHANTEE" BY T.E. BOWDICH

from Abetifi, had founded the first Basel Mission station in Kumasi. The town developed rapidly from then onwards into an important commercial centre with cocoa cultivation having been introduced into the area a few years earlier. Foreign influence brought in different building methods. Many of the traditional thatched roofs were replaced with wooden shingle roofs or imported corrugated iron roofing sheets. Walls were built with burnt bricks. A new network of roads linked the different parts of Kumasi. The central market was established in 1925. The town prospered from then onwards and became the country's most important inland trade centre, with many imposing structures.

Yet in some of the old areas of Kumasi, expecially in Bantama, a few old single-storey courtyard houses built in sun-dried mud bricks or with the Atakpame method can still be found among the modern 2-to 3-storey structures from cement-sand blocks (Fig. 89). The traditional roofing material of thatch has, however, long been replaced with corrugated iron or aluminium sheets.

From the original decorative relief works on the house walls nothing remains. Through foreign influence certain features have been adopted: Decorated, moulded columns, perforated verandah and balcony walls (Fig. 90), moulded projections on the exterior of the walls at floor levels, decorative entrance gates to the compounds and timber jalousie windows (Fig. 91).

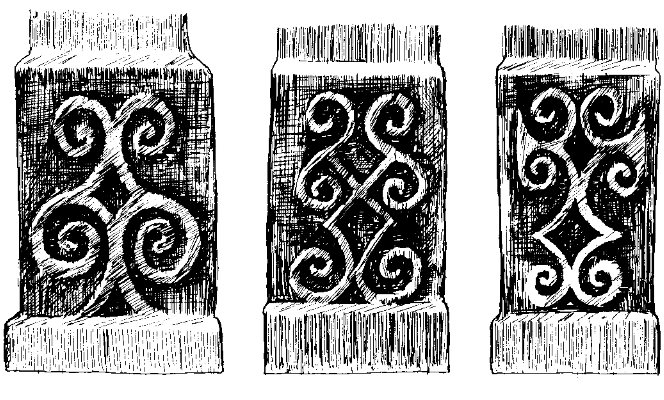
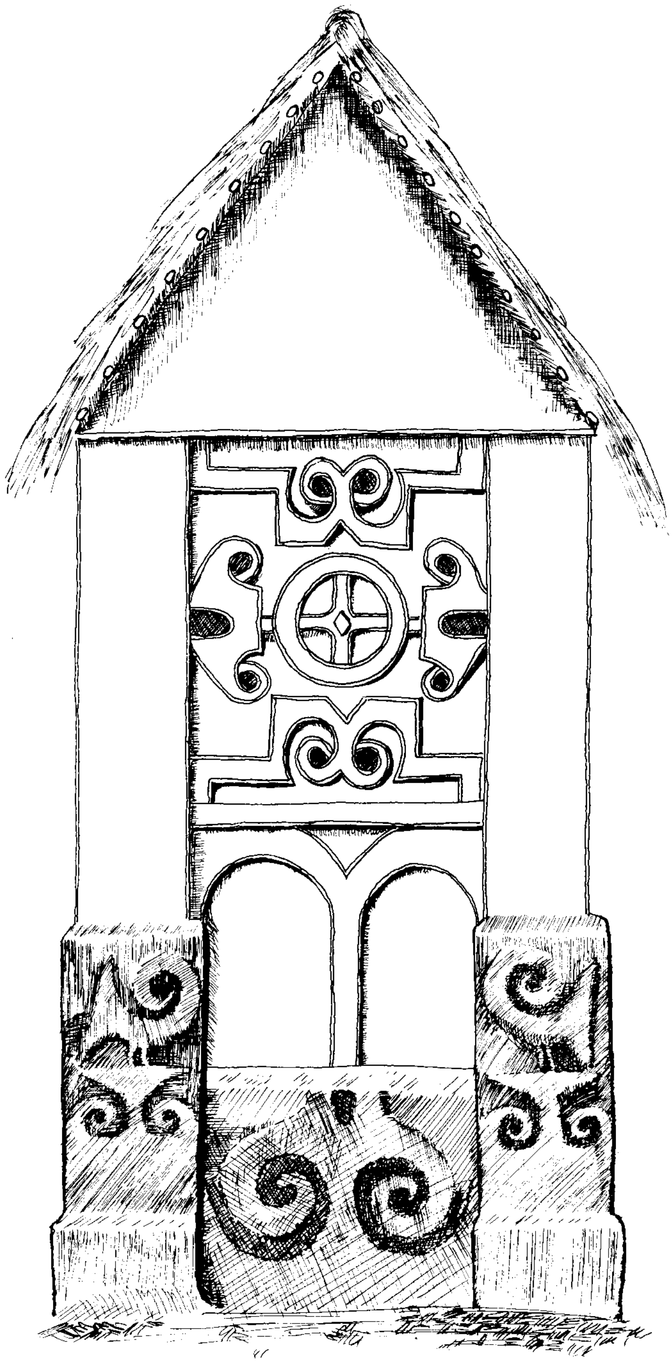


FIG.88 : **ORNAMENTS** : RELIEF ON THE PLINTHS OF PILASTERS IN KUMASI AS DESCRIBED BY R.A.FREEMAN, WITH VARIATIONS OF THE ASHANTI SYMBOL "SANKƆFA" (LIT. "GO BACK AND FETCH IT", MEANING "HUMILITY").



PART OF THE KING'S GUEST-HOUSE IN KUMASI AFTER R.A.FREEMAN FROM HIS BOOK "TRAVELS AND LIFE IN ASHANTI AND JAMAN" (1898). THE LOWER PORTION OF THE WALL WAS FINISHED IN POLISHED RED CLAY. THE FRIEZES OF THE UPPER WALL PANEL, THE FLAT PILASTERS ON BOTH SIDES OF IT AND THE UNDECORATED GABLE PANEL WERE FINISHED WITH LIME WASH.

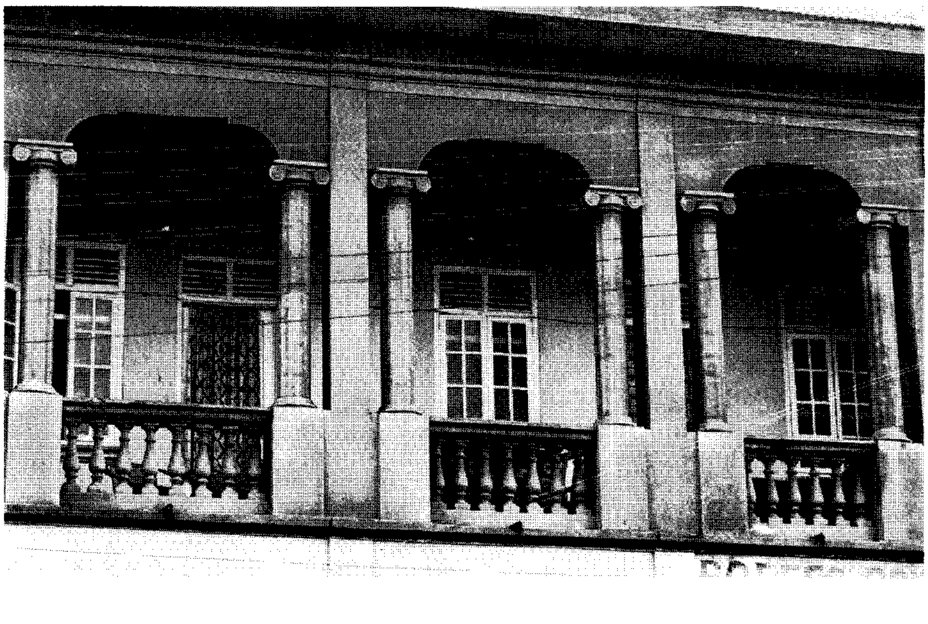
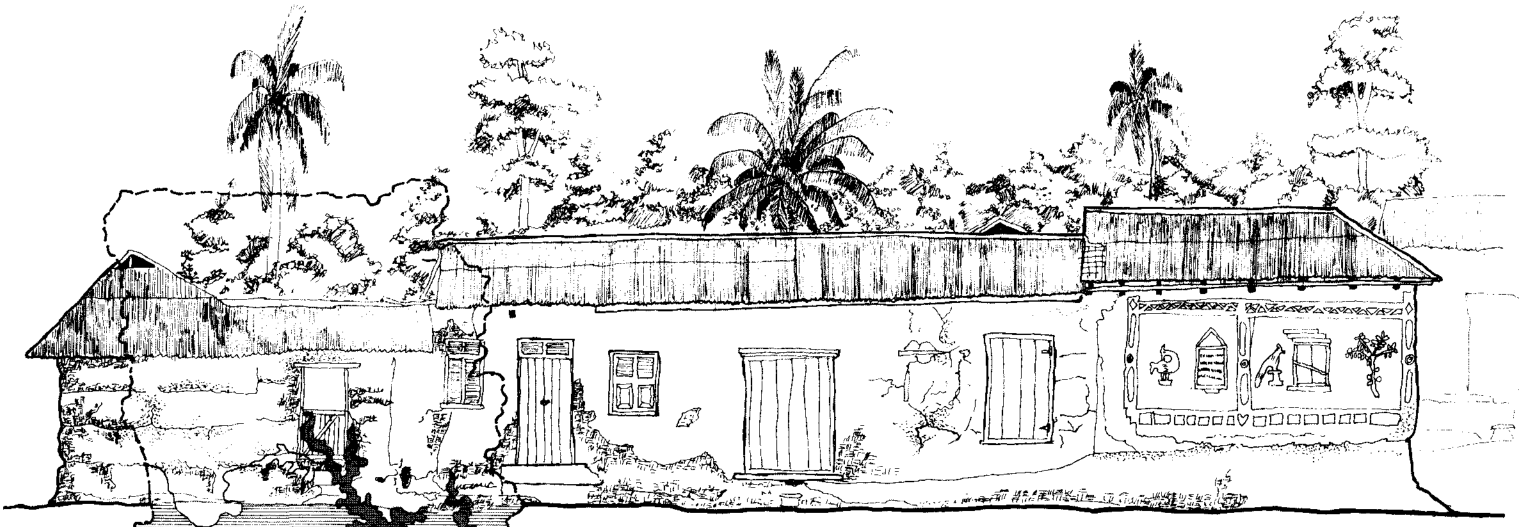
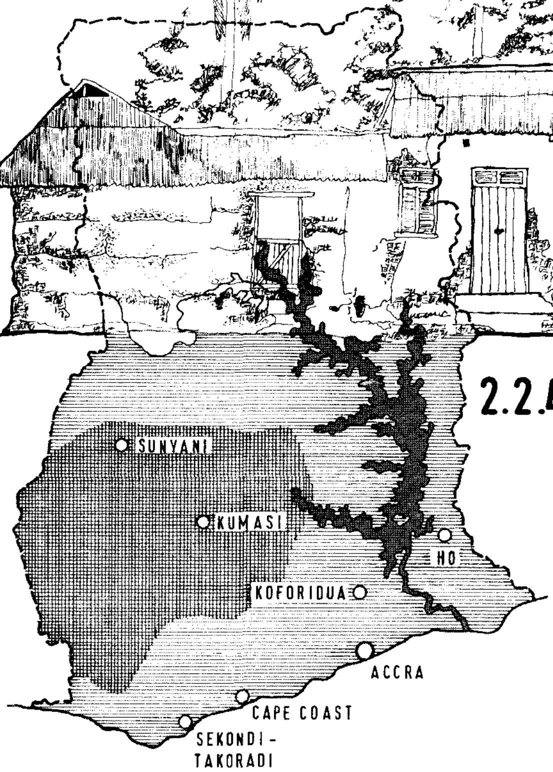


Fig. 90: Verandah detail of a 2-storey house in the central area of Kumasi, 1978.





2.2.4 CONSTRUCTION METHODS IN THE FOREST VILLAGES - FIG. 93

FIG. 92 : WATTLE AND DAUB WALLS IN AN ASHANTI FOREST VILLAGE (ABOVE AND ABOVE RIGHT), 1981.

Similar to the indigenous builder in the northern savannah the farmer and builder in the transitional forest and forest area exploits the natural materials which he can obtain from the soil, from riversides, from the forest. With these materials he has been and still is able to construct buildings which are designed for comfort under tropical conditions, which are reasonably resistant to the elements and destructive forces of the tropics and which, if regularly maintained, can last more than a lifetime.

The rural communities in the forest areas are small communities with a strong traditional social structure and organisation. People know one another. Farming is their main occupation, cash crop farming or cocoa farming. The economy is largely non-monetary. Houses are normally self-built.

The traditional building methods are wattle and daub walls with thatch roof (Fig. 92 *and* 93); in many cases these have been replaced with corrugated iron sheets. The buildings are rectangular, placed continuously around an inner courtyard, or courtyards (Fig. 94). There is normally only one main entrance into the compound from the outside. In many villages quite skilfully manufactured wooden panelled doors in timber frames and wooden shutter and jalousie windows can be found (Fig. 95 *to* 104).

In the Brong-Ahafo and Ashanti Regions quite often the wattle and daub walls have been replaced with walls built in the Atakpame method. The builders are Ewes who

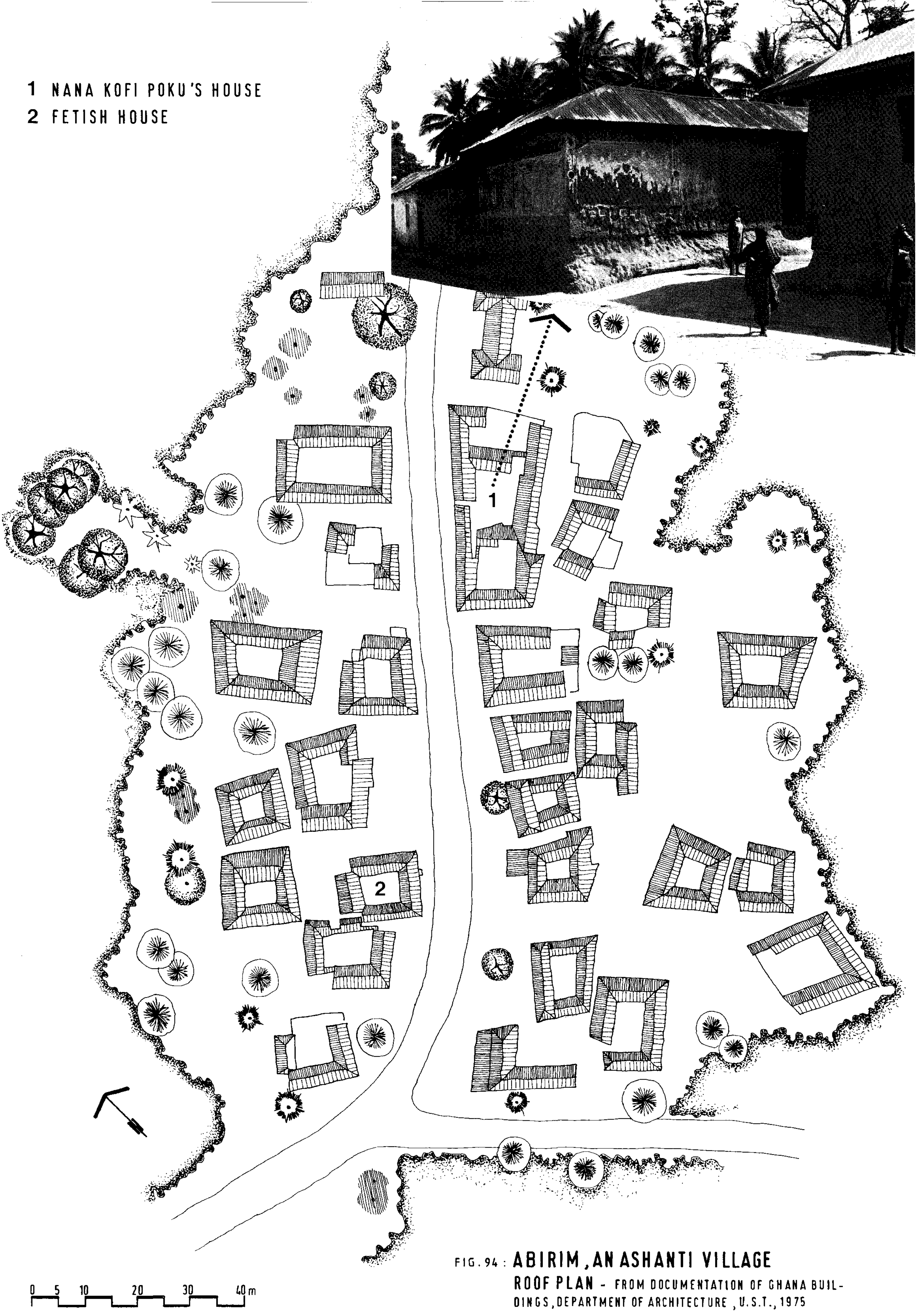


FIG. 94 : **ABIRIM, AN ASHANTI VILLAGE**
ROOF PLAN - FROM DOCUMENTATION OF GHANA BUILDINGS, DEPARTMENT OF ARCHITECTURE, U.S.T., 1975

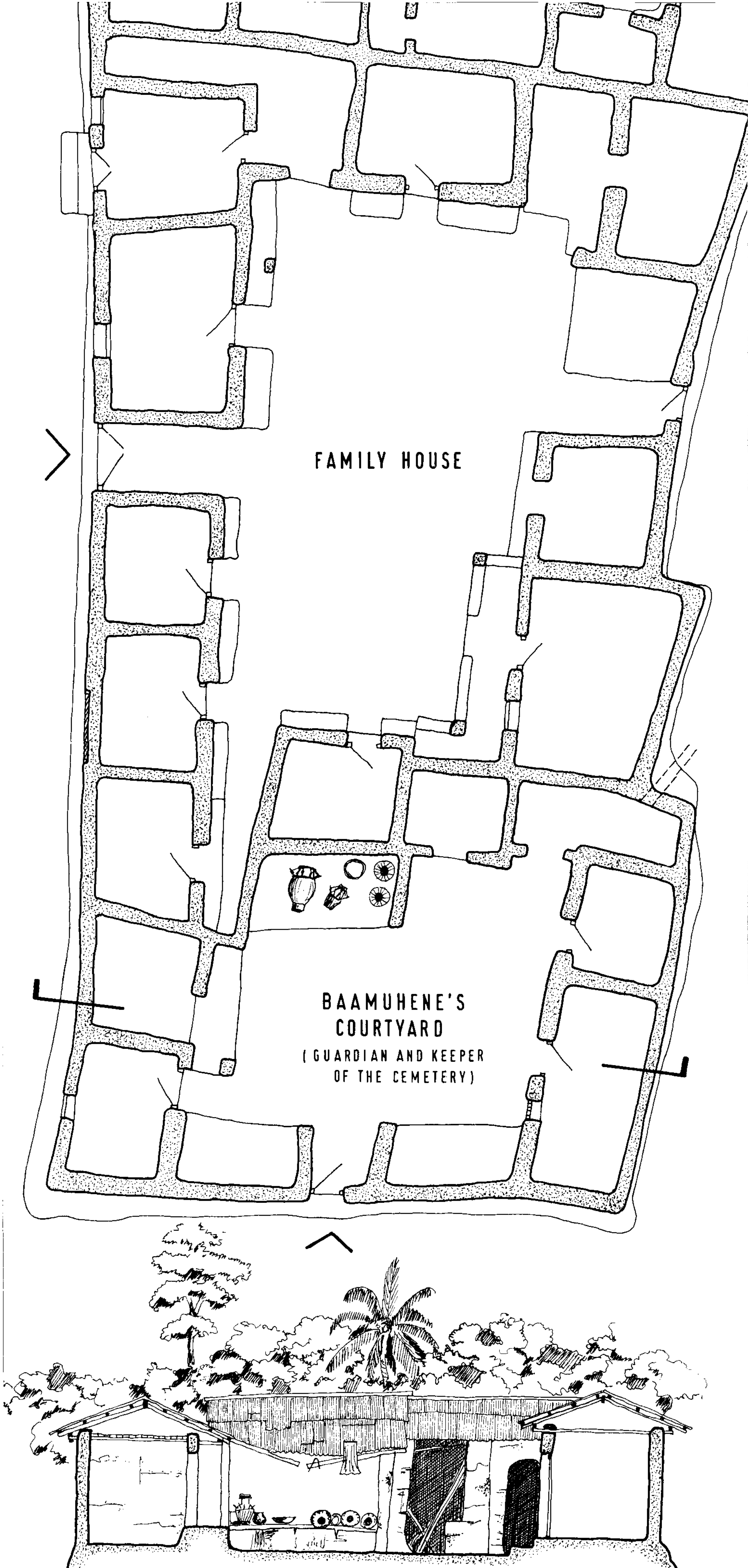


FIG. 95 : **PART PLAN AND SECTION OF NANA KOFI POKU'S HOUSE AT ABIRIM** - FROM DOKUMENTATION OF GHANA BUILDINGS

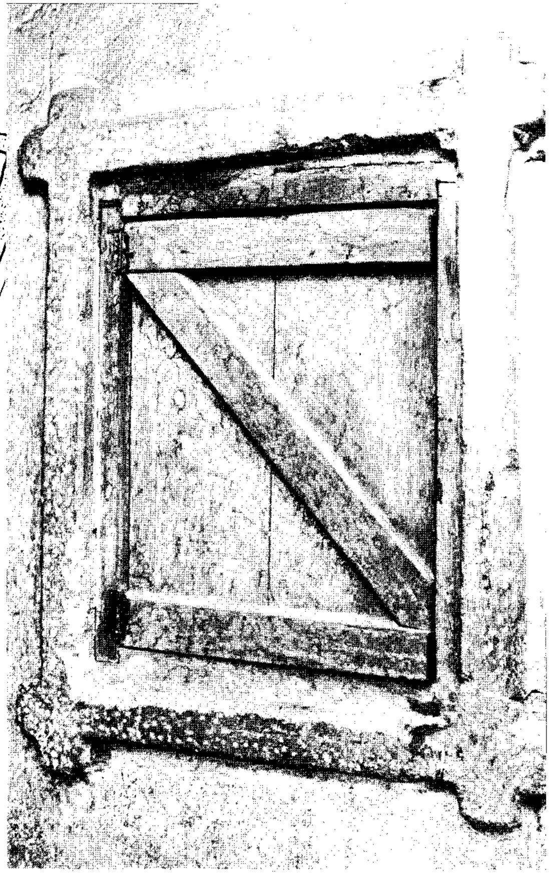
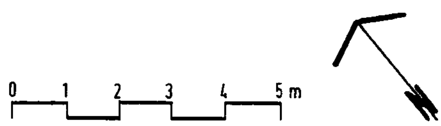


FIG. 96 : **WINDOW IN NANA KOFI POKU'S HOUSE**

FIG. 97 : **DOOR IN NANA KOFI POKU'S HOUSE**



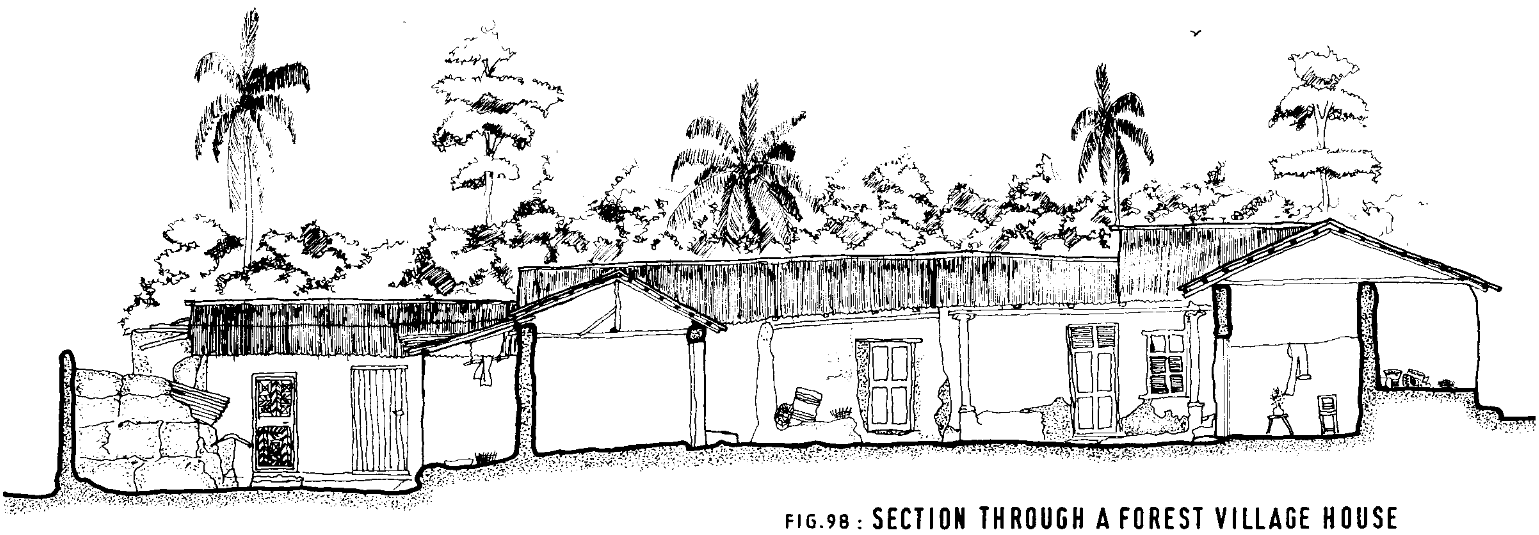


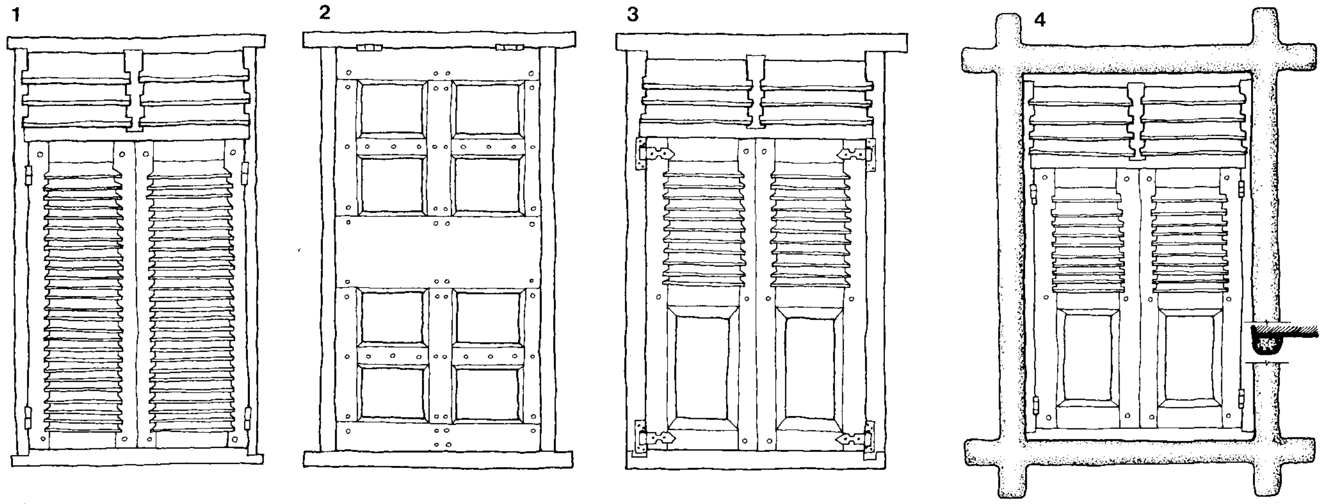
FIG.98: **SECTION THROUGH A FOREST VILLAGE HOUSE**

have come to these regions in the search for employment opportunities. When they built their houses in the Atakpame way, it was soon realized by their neighbours that this construction method was less tedious than the wattle and daub construction. The "Ewe-houses" became very popular. The Ewes found one employment opportunity, they became the "Atakpame Builders" in these regions. By now, up to three generations of Ewes have followed this occupation. They have settled in different places in the regions, but normally returned home every 1½ years for one farming season after which they returned for another "house building tour". Most of these Ewes came from the area around Atakpame (now in the Republic of Togo). After the independence of Ghana and Togo and different political developments in the two countries, free movement between the countries became somewhat restricted. Some of the builder-settlers became Ghanaian nationals, some returned to their home-country. One can perhaps describe these settlers as the local building contractors who are hired by the local farmer or trader. The interesting thing is that the Atakpame builders are hired for the construction of walls up to roof level only. The owner himself will build the roof (or hire additional labour for this work), render the walls, lay and finish the floor, fix doors and windows. Quite often only the roof will be finished. For the other work time and money may not be available, with the result that early deterioration sets in.

The Atakpame builders use virtually no modern tools for their work: Hoes for digging up the soil (they have "an eye" for good quality soil), their feet for kneading the mud mixed with water, their hands for forming the wet mud balls and for moulding the different layers, their eyes and sometimes pegs and strings for checking the alignment, a cutlass for scraping the walls smooth and leaving proper rectangular openings for windows and doors.

Both wattle and daub and Atakpame building methods have already been described in detail in foregoing chapters.

In some of the forest villages the Atakpame builder will build up a plinth of stones at the foot of the wall and a system of gutters with stone aprons around the house to check erosion. Where this is not done the results are early deterioration, a common sight in many villages with houses from wattle and daub walls. In the forest zone with average annual rainfalls of 1.50 m to above 2.00 m, protection of the external walls and the foot of the walls is very important.



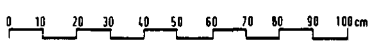
WINDOWS 1,3 & 4 ARE OUTWARD OPENING JALOUSIED CASEMENT WINDOWS, PARTLY PANELLED, WITH FIXED LOUVRE VENTS ABOVE.

WINDOW 2 IS A TOP-HUNG, OUTWARD OPENING PANELLED SHUTTER.

A MOULDED FRAME IS BUILT AROUND WINDOW 4 FROM CLAY PRESSED INTO A PROFILE FORMED OUT OF THIN SLIPS OF CANE.

FIG. 99: **TYPICAL WINDOWS IN AN ASHANTI VILLAGE**

FROM DOCUMENTATION OF GHANA BUILDINGS, DEPARTMENT OF ARCHITECTURE, U.S.T., 1975



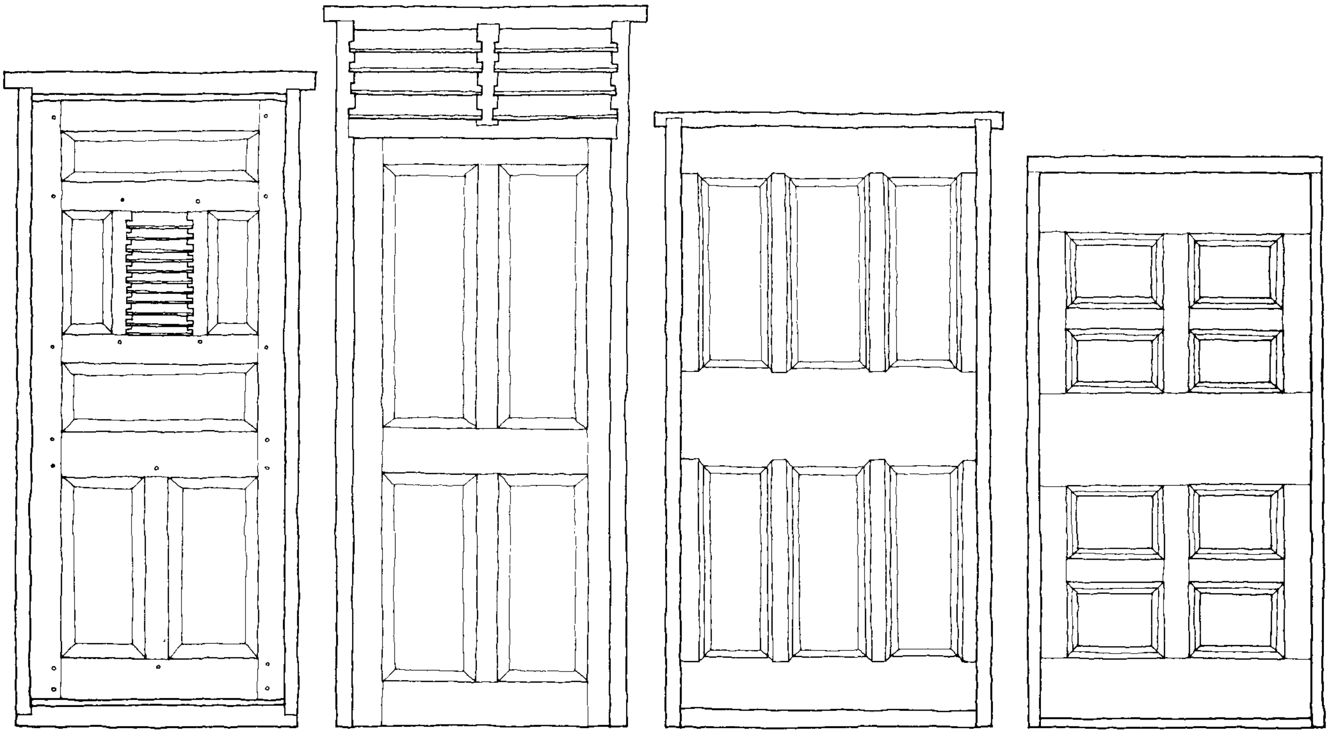


FIG.100 : **TRADITIONAL WOODEN PANELLED DOORS IN AN ASHANTI VILLAGE** - FROM DOCUMENTATION OF GHANA BUILDINGS, 1975

SOME OF THE DOORS HAVE SMALL JALOUSIED OPENINGS IN ONE PART OF THE DOOR OR FIXED LOUVRE VENTS ABOVE.

0 10 20 30 40 50 60 70 80 90 100 cm

Sun-dried brick construction is also known and preferred in some areas. Neat horizontal and vertical alignment is achieved with proper bonding. Windows and door frames are fitted straightaway during construction. Mortar joints (from mud mortar) also achieve a solid construction. Finished walls are sometimes mud-washed or rendered with a soft mud mixture internally.

The floors are from rammed soil. In compounds where the walls are properly rendered and painted, the floors are normally well constructed with a layer of stones and gravel first, well compacted, and a screed on top, of sand and mud (sometimes mixed with bitumen, often with cement).

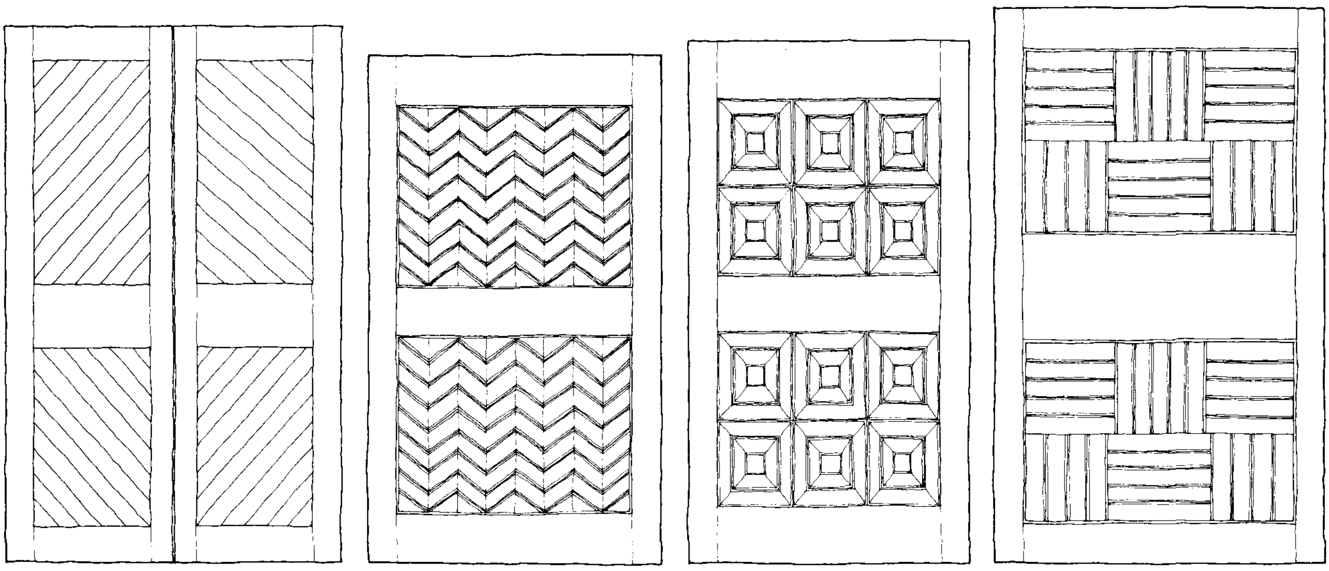


FIG.101 : **TRADITIONAL WOODEN PANELLED DOORS** - FROM DOCUMENTATION OF GHANA BUILDINGS

THE DOORS ARE NOT TRUE PANELLED DOORS BUT RATHER FRAMED AND BOARDED DOORS WITH PANELLING PIECES FIXED OVER THE VERTICAL BOARDING. THICKNESS OF STILES AND RAILS ABOUT 30mm, PANELLING BOARDS ARE 12 TO 15mm THICK. TIMBER USED : TERMINALIA SUPERBA (OFRAM).

0 10 20 30 40 50 60 70 80 90 100 cm

Fig. 103: Traditional wooden panelled door in an Ashanti village, 1981.

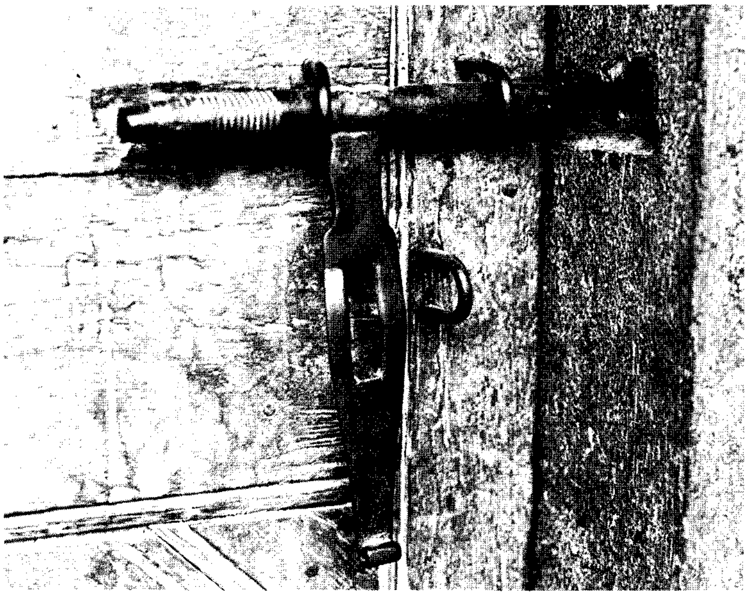


Fig. 104: A door lock and hinge produced by the local blacksmith, 1981.

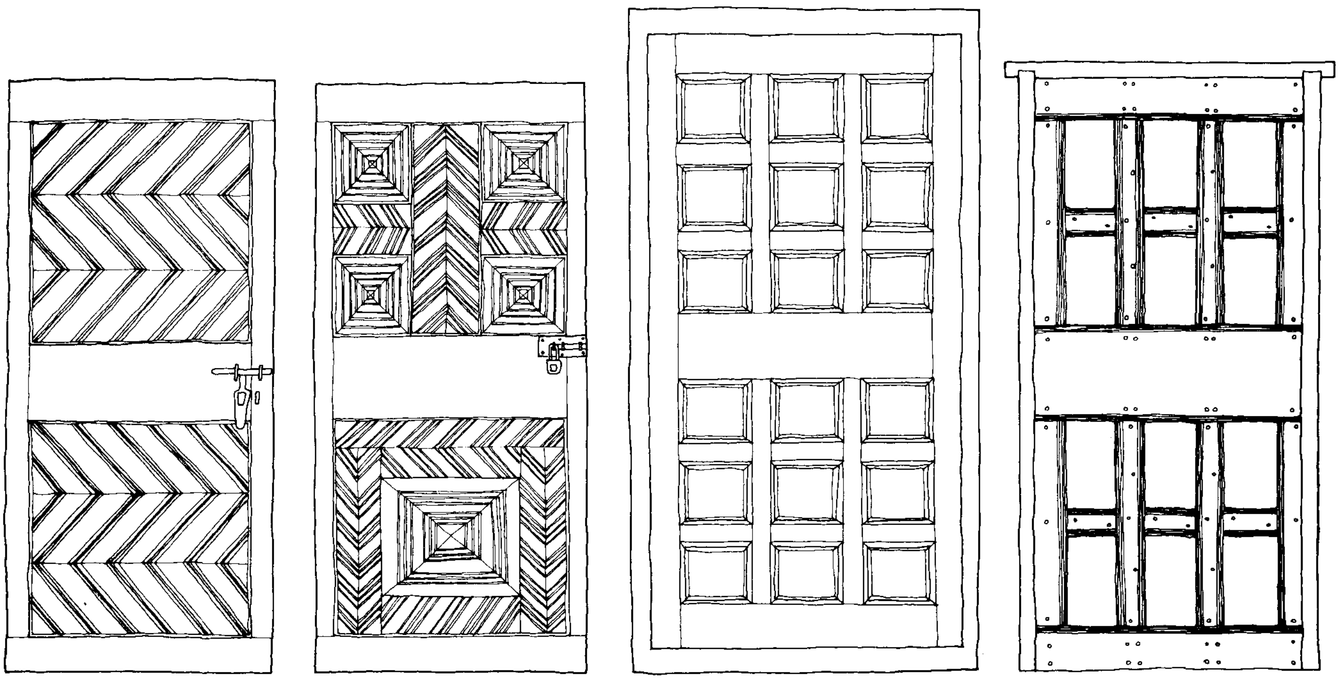
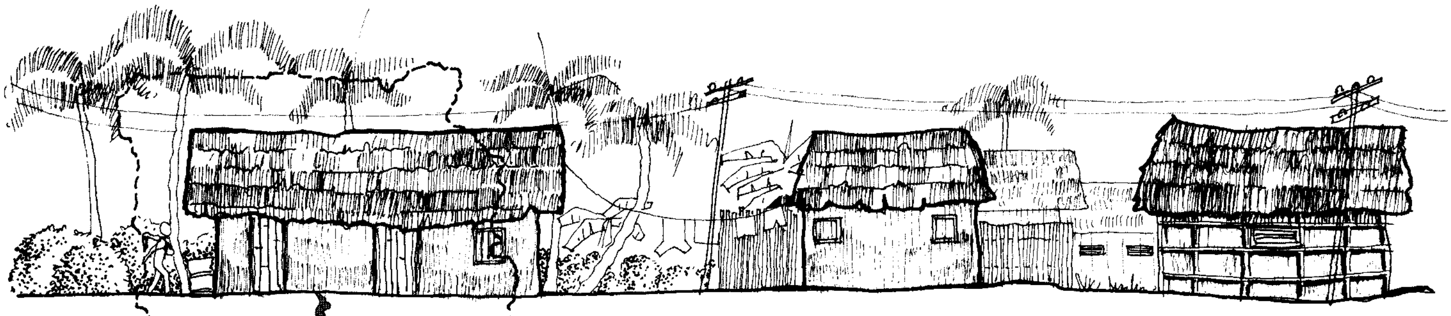
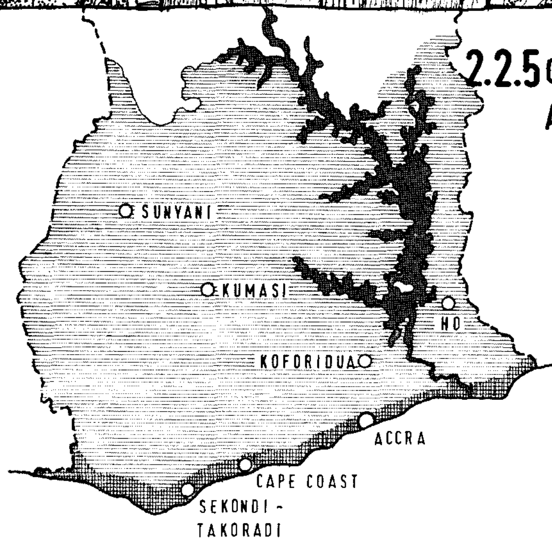


FIG.102 : TRADITIONAL WOODEN PANELLED DOORS





2.2.5 CONSTRUCTION METHODS IN THE FISHING COMMUNITIES ALONG THE COAST OF GHANA

The fishermen of the Gold Coast and Ghana have never known borders. The Anlos (Ewes from Anloga, Keta area) have migrated up the coast to Gambia and down to Zaire. Within Ghana they have established settlements outside their home area from Tema, Accra, Winneba to Half Assini. The Efutus and Fantes have also moved to the shores of the Ewes, when the fish they catch moves eastwards. The Ghanaian fishermen with their dug-out canoes with or without outboard motors are expert and courageous fishermen. When they "move with the fish", they do not interfere with the traditions of the people in whose areas they settle temporarily, they respect the local gods of their new homes. But they bring with them their building methods.

The coastal climate is humid with a steady South-South-westerly sea breeze. Houses are constructed to permit a free flow of air through the entire building. The roofs are built with thatch, in many areas an air space is provided underneath and a ceiling constructed of woven mats and mud. This and wide overhangs of the roof and covered verandahs achieve a marked reduction of solar heat transmission (Fig. 105 *and* 106.) Bedrooms of the houses are concentrated on the windward side, the cooking area etc. on the leeward.

2.2.5.1 BUILDINGS OF THE ANLOS

The Anlos do not only fish in the sea, they also fish in the large Keta Lagoon. Along the lagoon they have also started shallot and cash crop farming. In the villages here, for example in Anyako, houses built with wattle and daub and in monolithic mud (Atakpame) can be found next to those built completely in thatch construction. It is this method of building (in Ewe "Klobaxotutu") which is used by the migrant Anlo fishermen when they build their houses along the coast, where they settle temporarily (Fig. 107).

The thatch houses have a timber frame structure of posts and beams from Fan palm trees and split trunks of

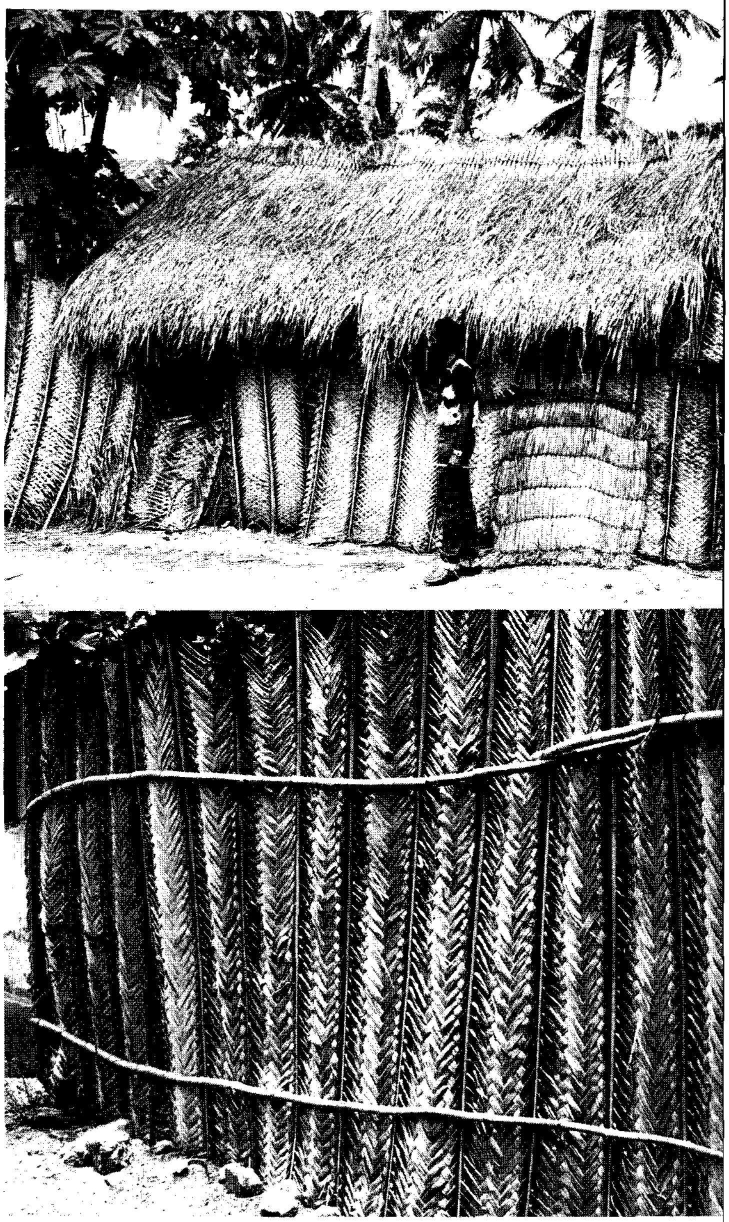


FIG. 107: MAT-WALLS IN AN ANLO-EWE VILLAGE NEAR AFLAO IN THE VOLTA REGION, 1981.

Coconut palm trees *(Borassus Aethiopum,* "Agoti" in Ewe and *Cocos Nucifera,* "Neti" in Ewe). This framework is tied together and carries the roof (gable and hipped-end roofs) from rafters of bamboo or Red Mangroves (*Rhizophora,* "Atrasi" in Ewe), purlins of mangroves or coconut leaf fronds. The walls are made from coconut palm leaves plaited in the early morning hours when the dew makes the leaves soft. The single unit is approximately 3.00 m long by 2.30 m wide.

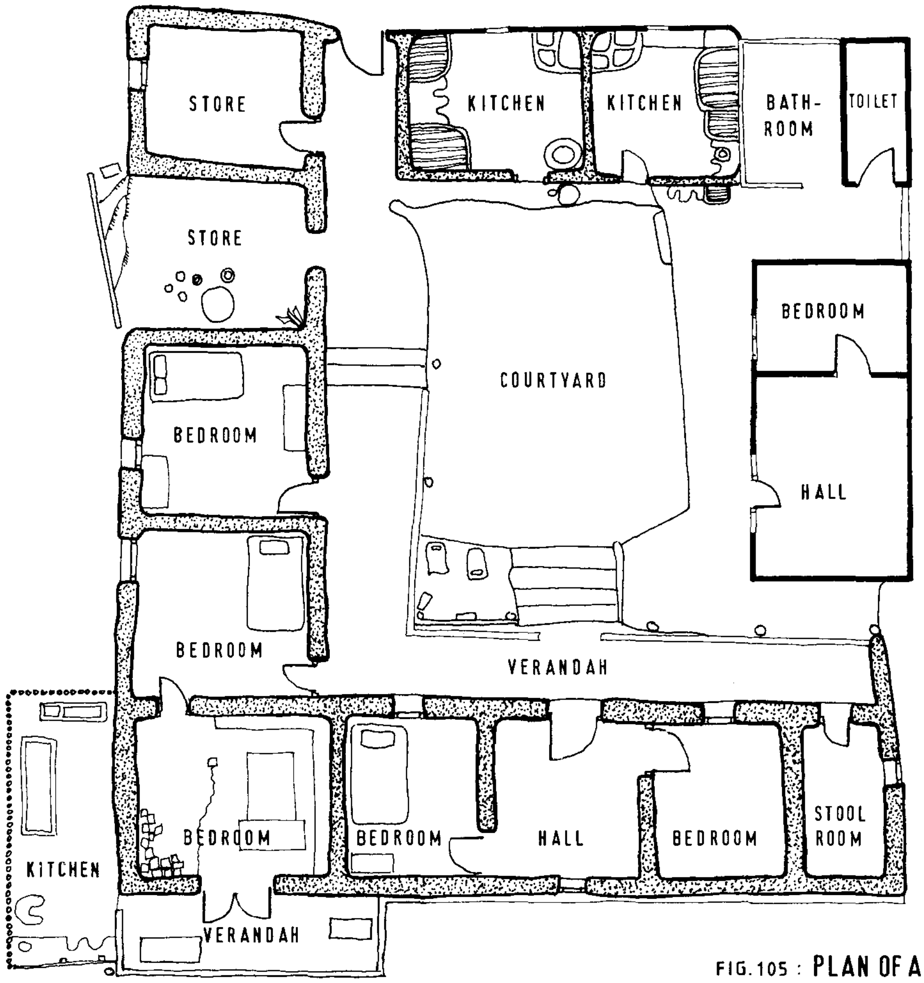


FIG. 105 : PLAN OF A HOUSE IN AKYINIM NEAR AXIM, WESTERN REGION

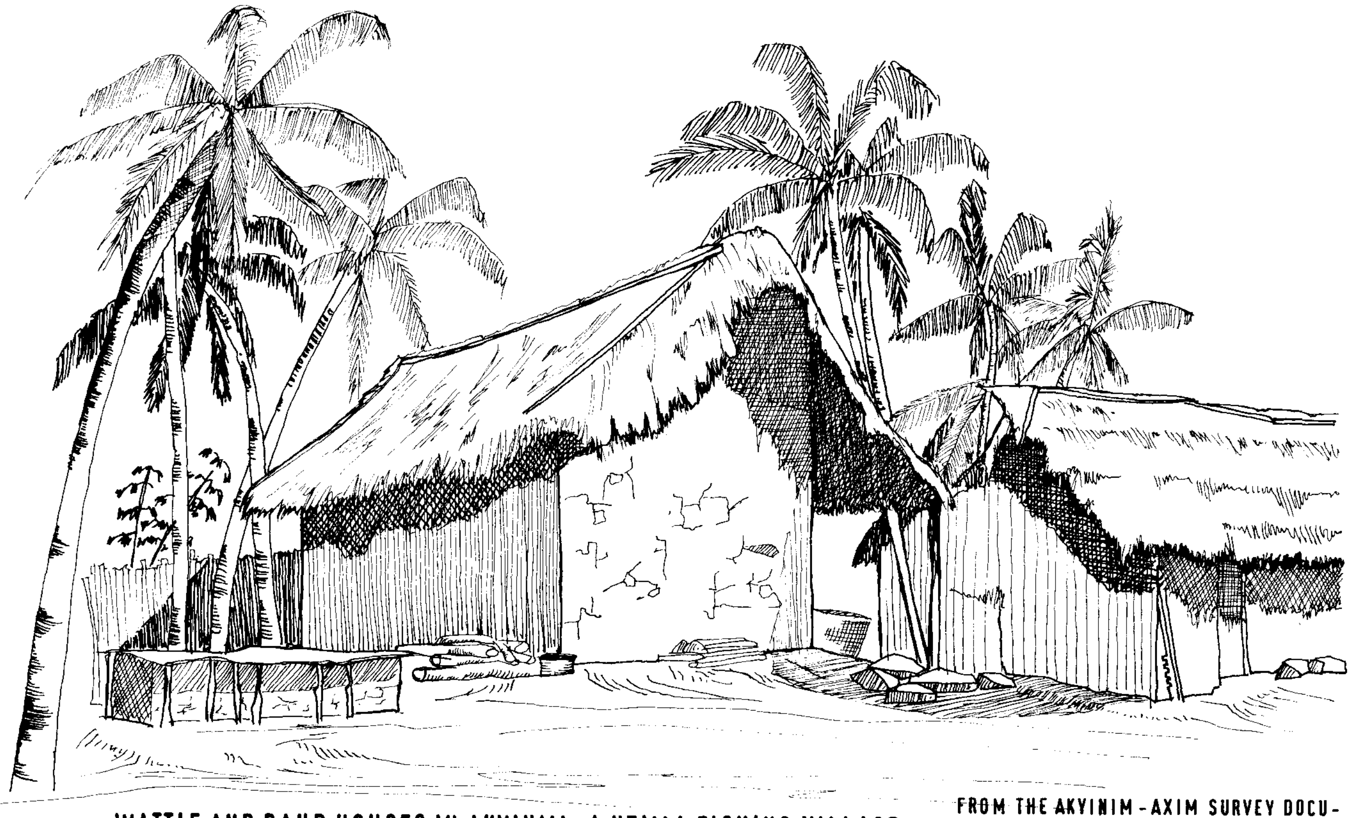


FIG. 106 : WATTLE AND DAUB HOUSES IN AKYINIM, A NZIMA FISHING VILLAGE

FROM THE AKYINIM-AXIM SURVEY DOCUMENTATION, DEPARTMENT OF ARCHITECTURE, U.S.T., 1976

The main posts are dug and wedged into the ground 350mm deep. These posts have forked top ends to receive the eaves and ridge beams. Intermittent posts are then added. Rafters and purlins are fixed. Thatch is prepared from *Imperata Cylindrica.* The grass is cut and left to dry for a few days and tied up in bundles afterwards. From these the roof cover is plaited into mats of about 1.80m in length. Thatch is laid in layers from the eaves upwards with two layers "head downwards" under the eaves layer for additional thickness, all other layers are laid "head upwards". The wall mats are then fixed to the framework with horizontal battens tied over coconut leaf fronds. At the bottom of the wall a small trench is dug of 150mm depth and nearly filled with ash. The plaited wall panels are pushed down into the ash when they are fixed to the framework. The trench is afterwards filled with sand. The horizontal battens are either fixed over the mats from the outside or inside, according to taste, or mats are tied to the framework from both sides so as to create a "cavity wall".

This wall structure allows a fair amount of ventilation to pass through. In most cases therefore these houses are without window openings. A door opening which can be covered with a thick woven grass mat (these are sometimes also used for the walls) is left between two of the posts.

The floor is made from a slab of 150mm thick wet clay and beaten flat. The sand has been removed to this depth and a layer of ash sprinkled on the ground before the wet mud is laid.

2.2.5.2 BUILDINGS OF THE FANTES

The traditional way of construction predominant along the coast is the timber frame structure with mud infill (wattle and daub). Among the Fantes, especially around Anomabu, rammed wet mud structures, often two-storey high with steeply pitched hipped roofs of thatch from coconut palm leaves are preferred. The walls are quite thick, from 450 to 600mm. This area quite obviously contains much early European influence which has modified the traditional indigenous Fante building methods.

Anomabu was an important port and trading centre in the 18th century with the large English (second) fort completed in 1770. Cape Coast and Elmina contain more foreign influenced elements which will be detailed in the next chapter. But some of these identified elements are common throughout Fante coastal villages. Thatch roofs are, however, rapidly vanishing from these villages and are being replaced by corrugated iron sheets or, more recently by corrugated aluminium sheets.

Windows (generally small) and doors are simple wooden panelled shutters or louvered jalousies and panelled doors. Houses are rendered in mud-sand plaster in-and outside with moulded architraves to doors and windows.

Under the pitched roof a ceiling is usually built in the same way as the ceiling to the upper floor, with the beams built into the wall.

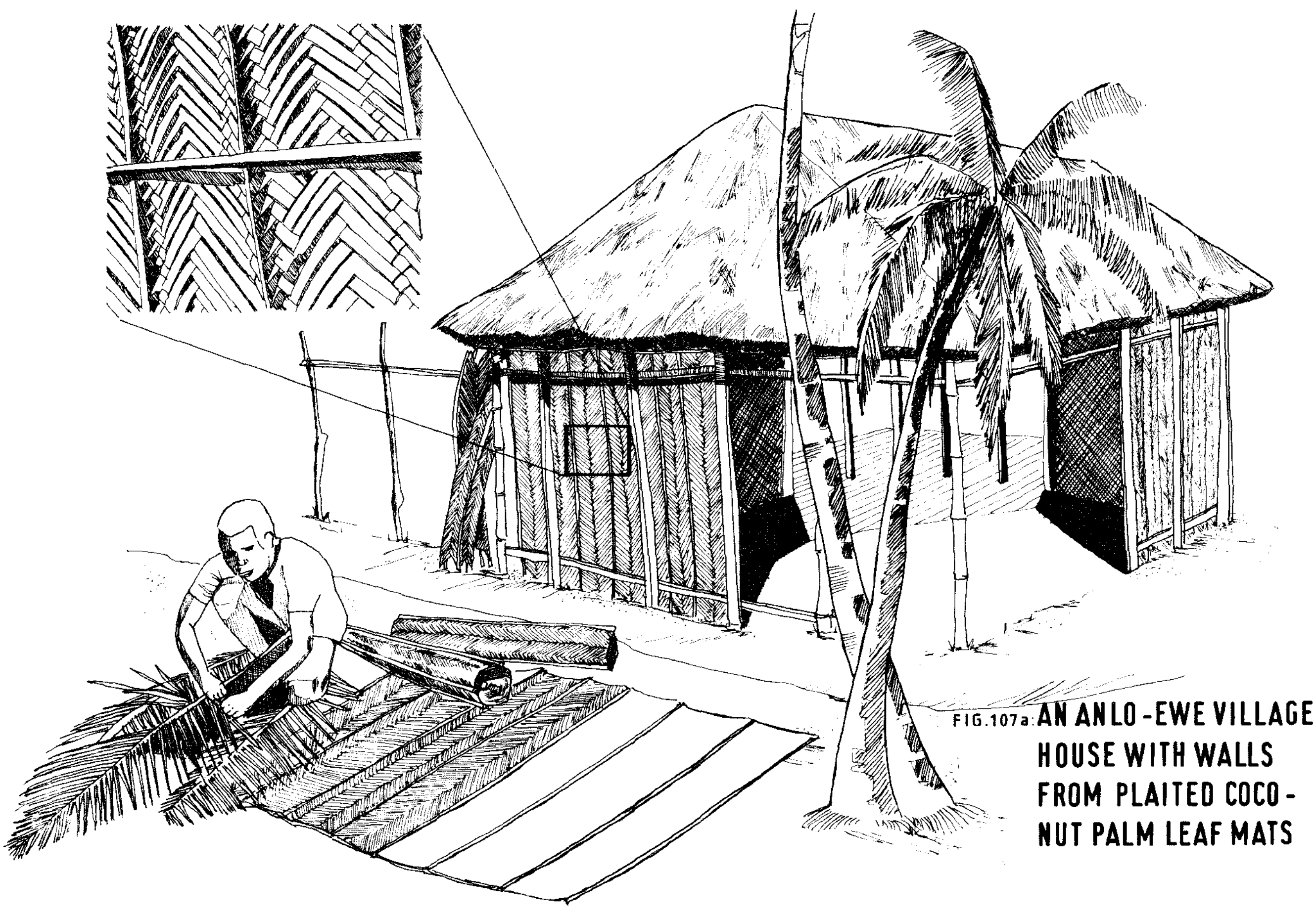


FIG.107a: AN ANLO-EWE VILLAGE HOUSE WITH WALLS FROM PLAITED COCONUT PALM LEAF MATS

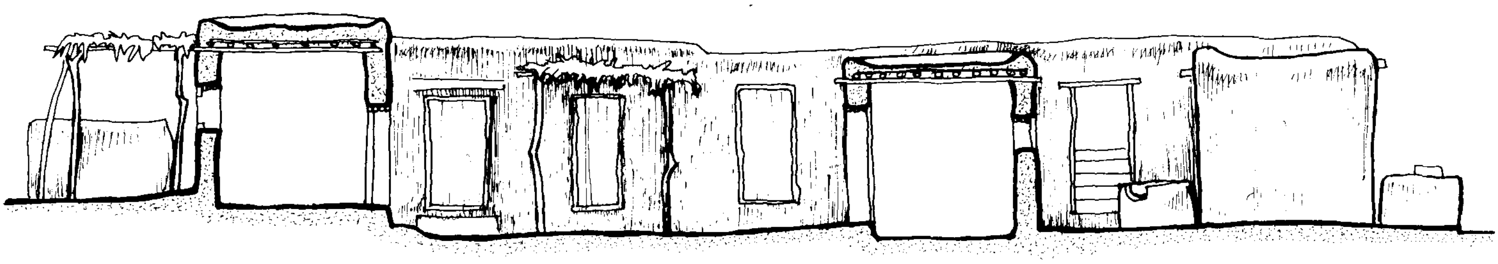


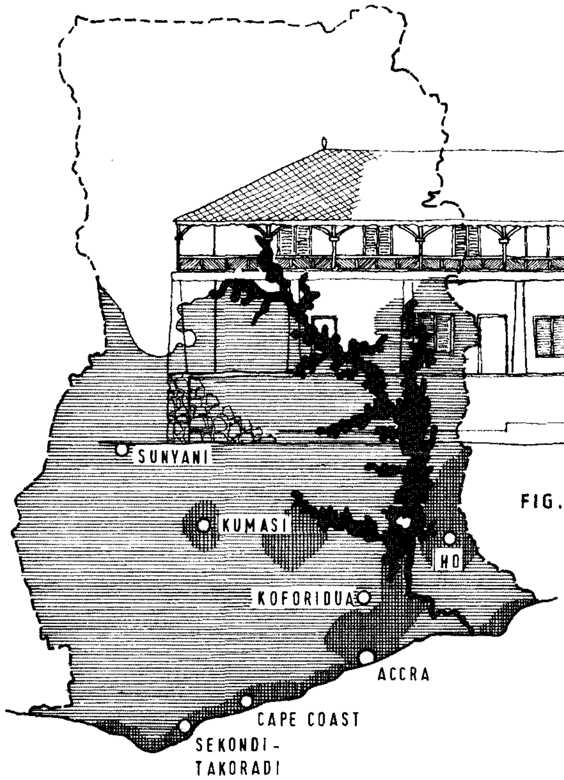
FIG.108 : **SECTION THROUGH A HOUSE IN BIRIWA**

Only 5km to the west of Anomabu is Biriwa, a small fishing village. Here one finds houses built with walls from monolithic mud or wattle and daub usually rendered on both sides, but with flat mud roofs, quite unusual for this area (Fig. 108). Some more of these roofs can be found in Cape Coast, but they are concealed underneath subsequently added pitched roofs from corrugated iron sheets. It is said that the Fantes migrated to the coast from the savannah country to the north of the forest belt and brought this building method with them. Also in Biriwa one finds the original mud roof in many cases concealed beneath a pitched corrugated iron roof (Fig. 109 *and* 110). The flat mud roof was built in a similar way to that described in the part on "Construction Methods in the Northwest of Ghana". The beams carrying the roof are built into the walls. These therefore are load-bearing. The surface of the mud roofs is laid to fall towards rainwater spouts. Low parapet walls are built around the roof.

The main house, situated north-south, is single-storey with a row of rooms, normally three, with ancillary buildings as stores, kitchens, bathrooms arranged loosely around, with fish-smoking ovens in between. There are no clearly defined compounds. This arrangement makes full use of the sea breeze.

Fig. 109: Biriwa, a Fante fishing village, near Cape Coast, 1965.

Fig. 110: Biriwa village houses, 1982.



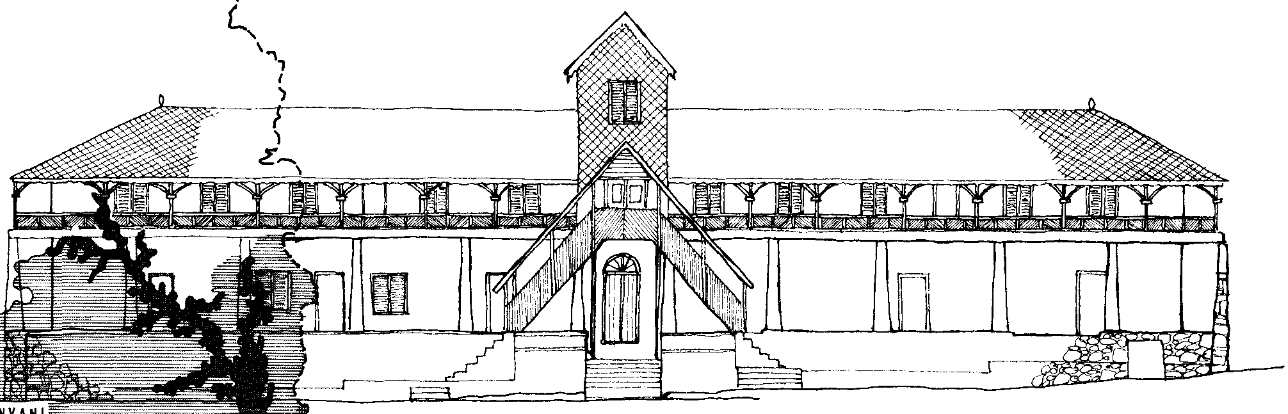


FIG.116 : **THE ANTI HOUSE IN MAMPONG, AKWAPIM** - FOREIGN INFLUENCES : DUTCH, DANISH, GERMAN, MISSIONARY, COLONIAL.

2.2.6 FOREIGN INFLUENCES

2.2.6.1 INFLUENCES OF THE EUROPEAN TRADING POSTS ALONG THE COAST

The Portuguese were the first Europeans to touch the Gold Coast in 1471. They recognized the great economic potential of the area and built a substantial castle (Sao Jorge da Mina) in 1482. The town of Elmina grew up to the west of the castle and was raised to the status of a city in 1486 with a defence wall around. The Portuguese also established a number of other trading posts along the Coast. Their influence on indigenous building methods can be witnessed in the Ahanta and Fante villages with their rectangular cottages, thick mud walls or sundried mud brick walls, steep pitched, thick thatched roofs, and moulded or white-painted architraves to doors and windows along the coast (Fig. 111).

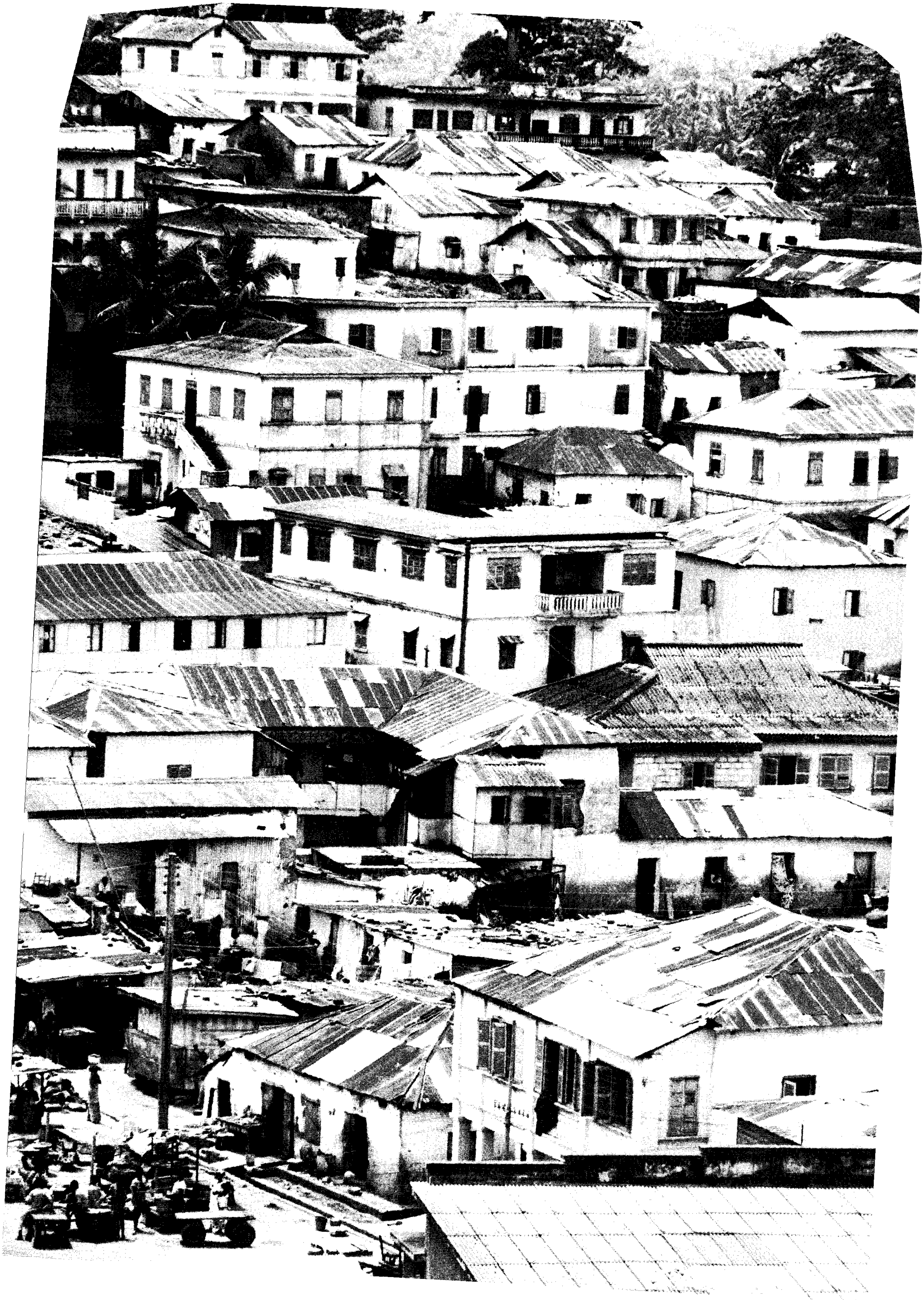
By the middle of the 17th century the Portuguese had been expelled from the Coast by the Dutch. The French and English were already established on the Gold Coast and by the end of the 17th century the Danes and Brandenburgers also joined the establishment of trading posts with the building of trade forts or castles. All these forts attracted settlements of the native people under their walls. The size of these settlements were dependent on the trade in the area. The booming slave trade in the 18th century made towns like Elmina, Cape Coast, Anomabu and Accra prosperous, other towns became important service centres supplying different areas along the coast and prospered likewise. European traders married into local chiefs' or merchants' families. Their families soon became the enterpreneurs of the area.

Building materials for the houses of these rich merchants were imported – burnt bricks, cast iron columns and balcony brackets, iron roofing sheets, Canadian pine etc.

Some of the early single or 2-storey houses in Elmina (Fig. 112) of which a number still exist, though generally in a very bad condition of maintenance, were built with walls from rabble stone or stone, clearly influenced by the building methods used for the construction of the forts, which were built from stone and bricks (carried as ballast to the Coast in the ships). Window and door openings were often semi-circular arched, with jalousied shutter windows (top-hung outward opening) and wooden panelled doors. Sometimes the arched openings had brick dressings.

Most of the houses, similar to the structure of the forts and castles had flat roofs paved in tarras. Subsequently these were roofed over with low pitched roofs of corrugated metal sheets or flat asbestos tiles.

FIG.111 : **OLD VILLAGE HOUSES IN ANOMABU** - SKETCH BY THE AUTHOR, 1981.



An early house-type for Danish civil servants from the middle of the 19th century in Christiansborg, Accra, introduced the first floor verandahs running the whole of the building at both front and rear. The houses were two-storey with the living accommodation upstairs. The verandahs were built of wood supported by stone columns.

This type of construction was adopted very quickly by the more prosperous Africans in the Danish colony, especially in the Akwapim area, where the Danish tried to establish plantations, and on the plains to the south and east of it.

It is interesting to read how DR. P. E. Isert, who served the **Danish Guinea Company** in 1783, in a letter he wrote to his father, described the houses he saw during his first visit to the Akwapim Hills in 1786:

> "The houses of the mountain peoples are square built with beams, the intervals between which they fill with clay. Inside they are kept very neat. The floor is scrubbed each day with red earth, which gives a good appearance..."

The indigenous building methods in the Akwapim area were not much different from those elsewhere in the forest and transitional forest zones. The houses were rectangular gable-roofed with thatch.

Dr. Isert's own house near Akropong was the first stone building recorded in Akwapim. Of this building nothing remains today. A plantation building at Dakobi on the lower slopes of the Akwapim Hills, built at the same time was described after measuring up its ruins in 1956 as a two-storey rectangular structure with a flat roof.

2.2.6.2 INFLUENCES OF THE BASEL MISSION

In 1835 Andreas Riis laid the foundation of the Basel Mission Church in Akropong. The influence of the Basel Mission in Akwapim and the South of Ghana has been significant. The name of Riis is connected with the buildings the missionaries put up in the area. These buildings were built of stone and roofed with shingles. Despite opposition from the local fetish priests against the use of stone and **Odum** timber in building (the Odum tree – *Chlorophora Excelsa* is regarded as a sacred tree) this construction method was adopted by the people. Clear traces of this can still be seen at Akropong, Larteh and Mampong (Fig. 113, 114, 115). Moreover the Basel missionaries established training workshops where they taught local artisans new skills in masonry, joinery and blacksmithing.

With the introduction of cocoa farming a prosperous period started in the Akwapim area. 2-storey, stately stone houses became a familiar feature of several Akwapim towns.

The walls of these and the mission houses were built from the local excellent granite stone, at first with dry courses without mortar. Later, when cement was introduced, walls were plastered. The designs were simple.

Opposite: Fig. 112: Old houses in Elmina, 1982.

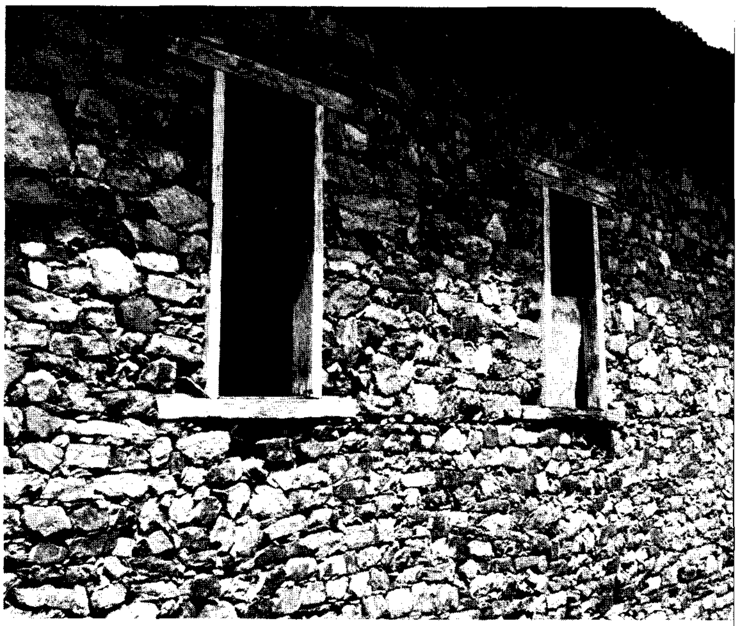


Fig. 113: A newly constructed stone house in Akropong, Akwapim, 1981 (Photograph by G. OWUSU).

Fig. 114: A stone and mud wall house in Akropong, 1981 (Photograph by G. OWUSU).

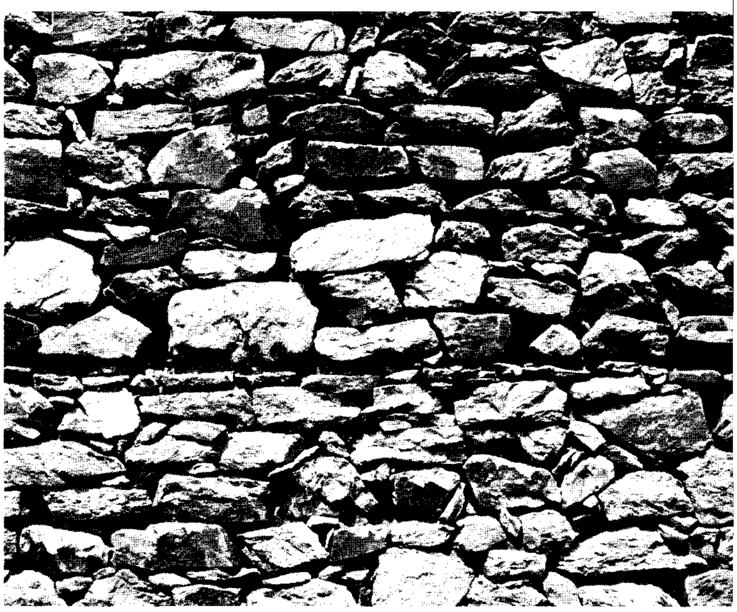


Fig. 115: Details of the stone wall (by G. OWUSU).

The houses were two-storey, with a room-deep core and verandahs surrounding the whole building at first floor level, constructed entirely of timber.

The **Anti House** in Mampong (Fig. 116) was built at the beginning of the 20th century between 1910 and 1915 by a rich cocoa farmer, Isaac Kofi Anti of Mampong. The foundation and walls were built from stone. All timber structures (roof substructures and floor beams) were sawn from Odum. Boarding and verandah balusters were from Pine wood, ordered through the Basel Mission and imported from abroad (Fig. 117). Roofing material consisted of imported slates.

This house, which was a prominent structure on the outskirts of Mampong and reflected the legacy of a successful early cocoa farmer and was at the same time a reminder of the former prosperity cocoa farming in the early days brought to the towns on the Akwapim Ridge, is now nearly collapsed. Only a few parts of the walls are still standing.

In other areas with Basel Mission influence the core walls were also built of solid mud or bricks. The verandah was supported with stone or stucco faced brick columns. For many of the early British colonial buildings cast iron columns were used. The timber balcony balusters were elaborately treated, the eaves of the hipped-end roofs had fretwork fascias. Although the Akwapim area, as already mentioned, is particularly rich in examples of such buildings, by the end of the 19th century this building type had widely been adopted by other missions, by the colonial government, and by the more prosperous people in other towns in the south (Fig. 118 *to* 122). It was used for schools, hospitals, etc. A single-storey version raised above the ground approximately 1 to 1.50 m on stubby columns had completely closed verandahs around with mosquito-screens. The Cantonment Residential Area in Accra still has many examples occupied by civil servants. The Ridge Hospital in Accra is another example (Fig. 123).

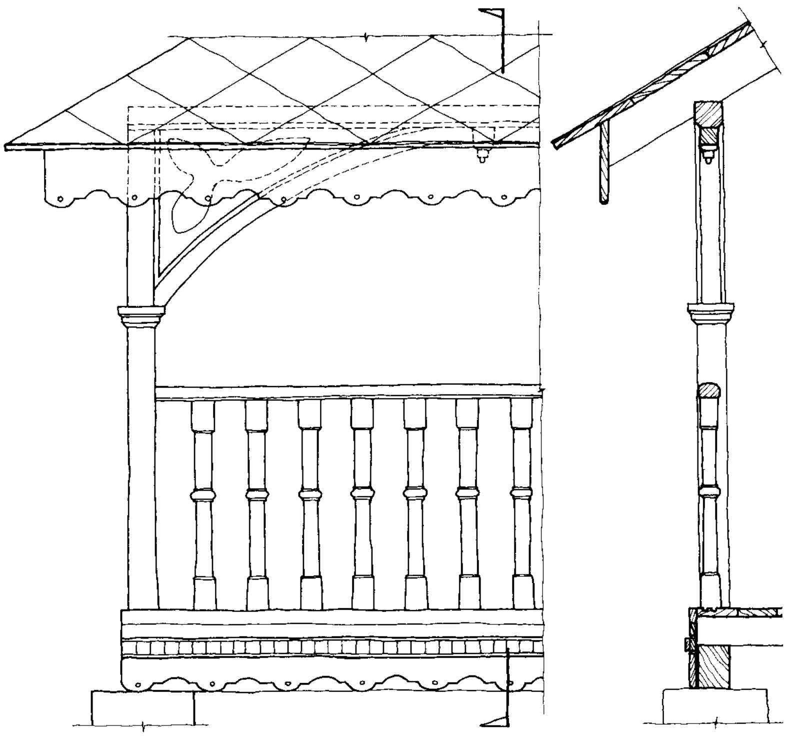


FIG. 117 : FIRST FLOOR VERANDAH DETAIL, ANTI'S HOUSE IN MAMPONG, AKWAPIM. FROM MEASURED DRAWINGS, DEPARTMENT OF ARCHITECTURE, U.S.T., 1969. NOT TO SCALE.

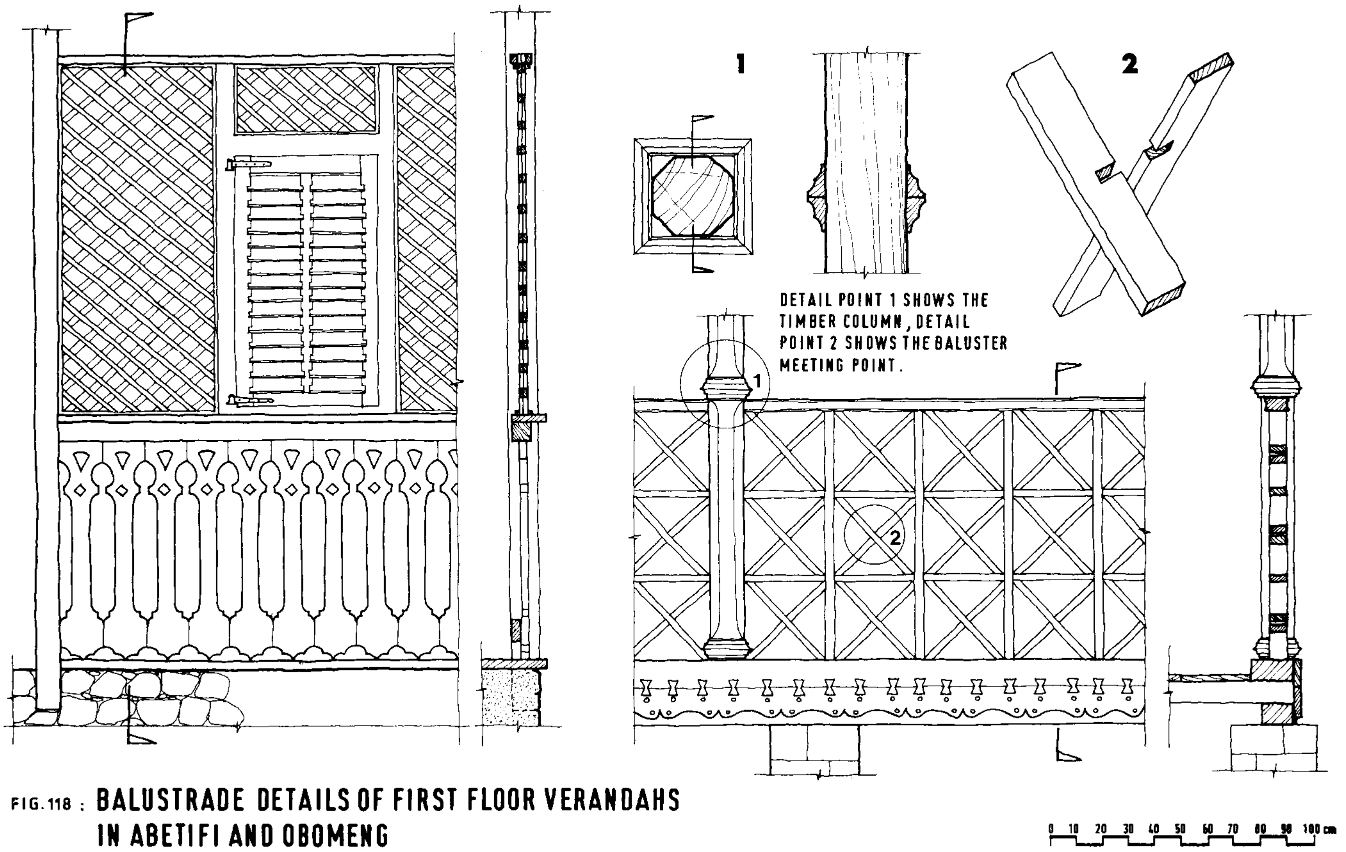


FIG. 118 : BALUSTRADE DETAILS OF FIRST FLOOR VERANDAHS IN ABETIFI AND OBOMENG

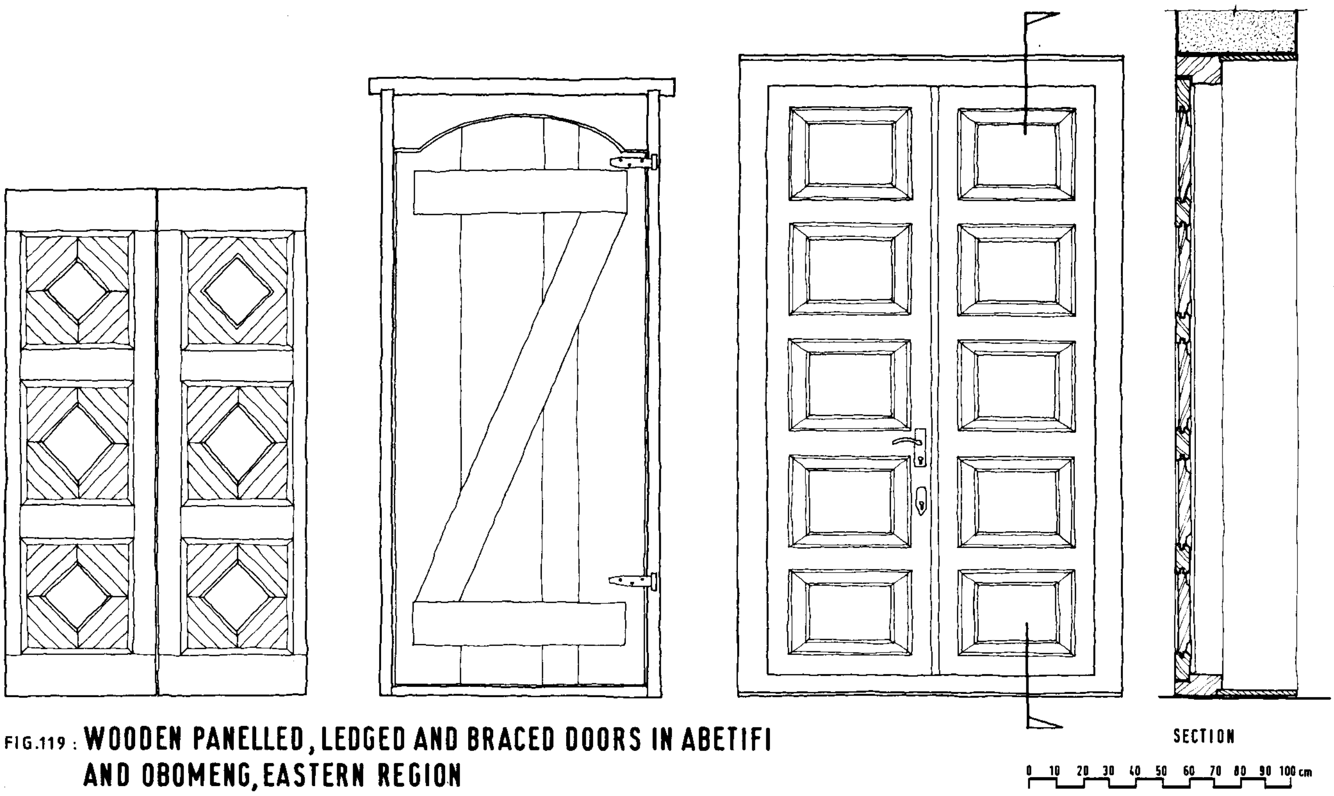


FIG.119: WOODEN PANELLED, LEDGED AND BRACED DOORS IN ABETIFI AND OBOMENG, EASTERN REGION

Fig. 120 and 121: A brick-core house with cantilevered first floor verandah in Konongo, Ashanti Region, 1981.

Fig. 122: Old house in James Town in Accra, with cantilevered first floor, 1969.

Fig. 123: A part of the Ridge Hospital in Accra, 1981.

2.2.7 SUMMARY AND CONCLUSION

From the Nzima pile dwellings of Nzulezo in the Unvaiye Lagoon in the far West of Ghana near the border with the Republic of Ivory Coast, to the Fetish Houses in Ashanti, the coastal towns built up near former European trading posts, forts and castles, the fishing and forest villages, the Ewe villages in the hills of the Volta Region, to the Basel Mission influenced buildings in the South of Ghana, the indigenous people used building methods and created an architecture which grew out of the soil, which received its form through the geology, topography and climate of the area and which was influenced by the social and historical development of this part of the country. Throughout the rural areas and the fishing communities along the coast the traditional construction methods are still used. With new skills and introduction of materials like burnt bricks, cement, corrugated iron, aluminium and cement-asbestos sheets new variants in plan form appeared, yet were more or less still based on the old concept of the courtyard or compound house to provide shelter for the extended family.

However, with an economy which has rapidly declined since the oil crisis in 1973 (which has badly affected many developing countries and especially Ghana), and a dependency on fluctuating world prices for main exports – cocoa, gold, diamonds, timber, bauxite etc. – foreign currency available for the importation of materials used in the building industry is very limited. The local factories producing building materials for which they need varying percentages of imported raw materials, do not produce to full capacity. Some of them manufacture to only 25 to 30% of their normal capacity. Yet the population is growing and the demand for shelter is increasing.

It is therefore important to fully explore and utilize all available local building materials as well as possible production of materials for construction from industrial and agricultural wastes. Doing this, **it is necessary to know traditional technologies** with which some of these materials have been used in the past. **It is also necessary to examine possibilities of introducing improved technologies** which will assist in constructing low-cost, yet more durable buildings, suitable for tropical conditions based on the concept of the traditional way of life of their occupants.

At the same time this increased use of locally available and produced building materials for the construction of government financed public buildings, from housing, schools, colleges to health centres, clinics and hospitals requires a change of attitude on the side of the designer and the client. It is hoped that the educational process leading to this can be positively influenced by the contents of this book.

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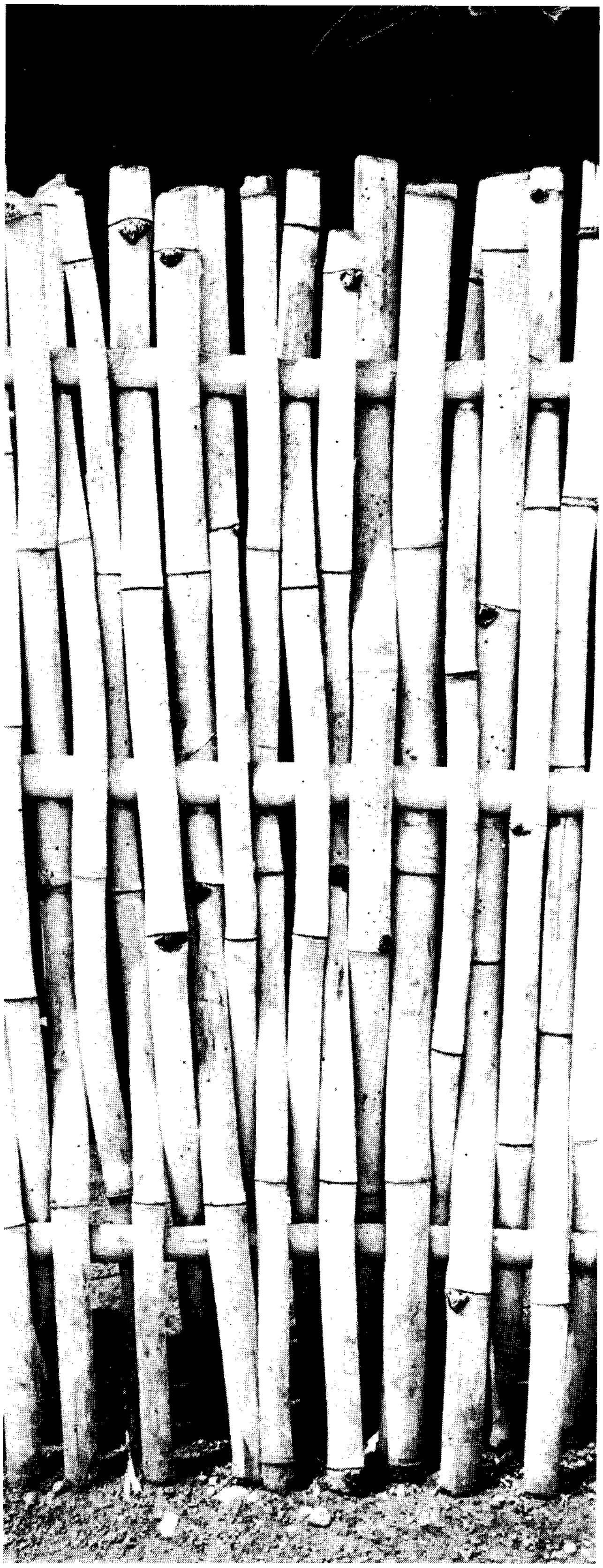
3 MATERIALS AND THEIR USES IN CONSTRUCTION



Since time immemorial, man has used materials provided by the earth for building shelter against the weather, against attack by animal predators and human enemies.

The importance of building materials in all types of construction is very great, especially when considering that materials account for as much as 60 % of the total costs of construction of domestic buildings. It is necessary to understand that each of these materials used will contribute in its own way to the structural strength, to the aesthetic appearance and to the performance requirements of a building.

With exception of a small percentage of wood, a building is constructed entirely of parts which originate from mineral products. Some of these are used directly, like they were used by early man and still by the "traditional builder" in most of the rural areas of the world – sand, clay, stones. Others undergo preparation through processing, with the ultimate setting up of large industries for this purpose, like factories for cement, steel and aluminium products etc.

"Natural Materials" in this section are locally available materials which nature provides and which can either be used directly after some preparation or can be extracted, dressed and prepared for use without the establishment of huge factories. The uses of these materials are shown and explained.

"Man-made Materials" are materials which have been developed from a raw material to a finished product in a process which requires an industrial set-up for their production together with a sophisticated technology. But here also it is possible to use appropriate technologies for the production of some of these materials. Attempts are being made in many tropical developing countries, including Ghana.

Materials covered in this part refer to Ghana, but examples will also be explained and shown from other tropical developing countries with conditions similar to this country.

Timbers of Ghana and **Timber-Frame Construction** form a separate part.

"Building Materials from Agricultural and Industrial Wastes" are included in the "Man-made" materials section.

Materials and Their Uses in Construction:
A bamboo fence wall, 1981.

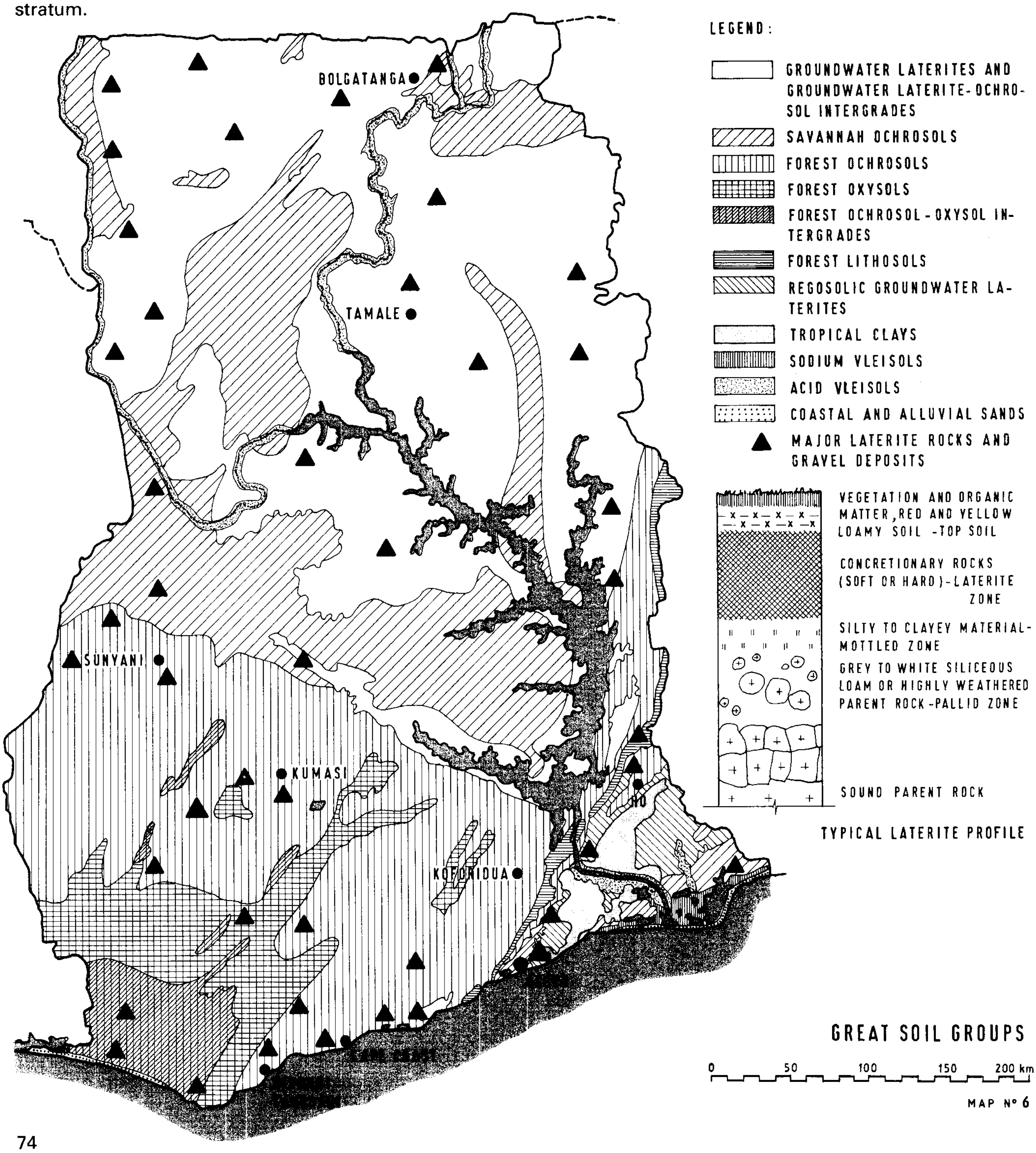
3.1 NATURAL MATERIALS

3.1.1 SOILS AND STONES

The soils referred to here are not only the thin layer of soil at the surface of the earth which is the home of the plant and of special interest to the agriculturalist, but include the subsoil and the weathered substratum below, which contain the sands, gravels, laterites and clays which will be discussed further on (Map No. 6). The top layer of soil – topsoil – contains a high proportion of organic matter and is normally removed to reach the subsoil from which the materials used in construction are extracted. These "subsoils", which vary in coarseness, have been formed through decomposition of rocks and the remains of living creatures which can be found in it. The parent rock is found below the weathered sub-stratum. The stones mentioned in this section are exposed rock, parent rock or stones contained in the subsoil and weathered substratum.

SAND

Sand is widely distributed in Ghana and usually it is composed of silica in the form of quartz particles. Quartz is the parent material of the Voltaian sandstones and of the quartzites of the Akwapim-Togo Ranges. In size sand ranges between 0.074 mm to 2 mm in diameter. These sands, on the condition that they are free of organic matter and other impurities, are suitable for construction and therefore useful to the construction industry. They are used for concrete mix, mortar mix and for block-making (sand-cement blocks, *see* also **"Walls and Wall Finishes"**). Extraction of sand should be carefully controlled to avoid severe inland erosion after removal of the topsoil (Fig. 124). High-grade sands which are used for manufacturing glass are found in deposits in the incipient stages of streams draining sandstone formations (*see* **"Glass"**).



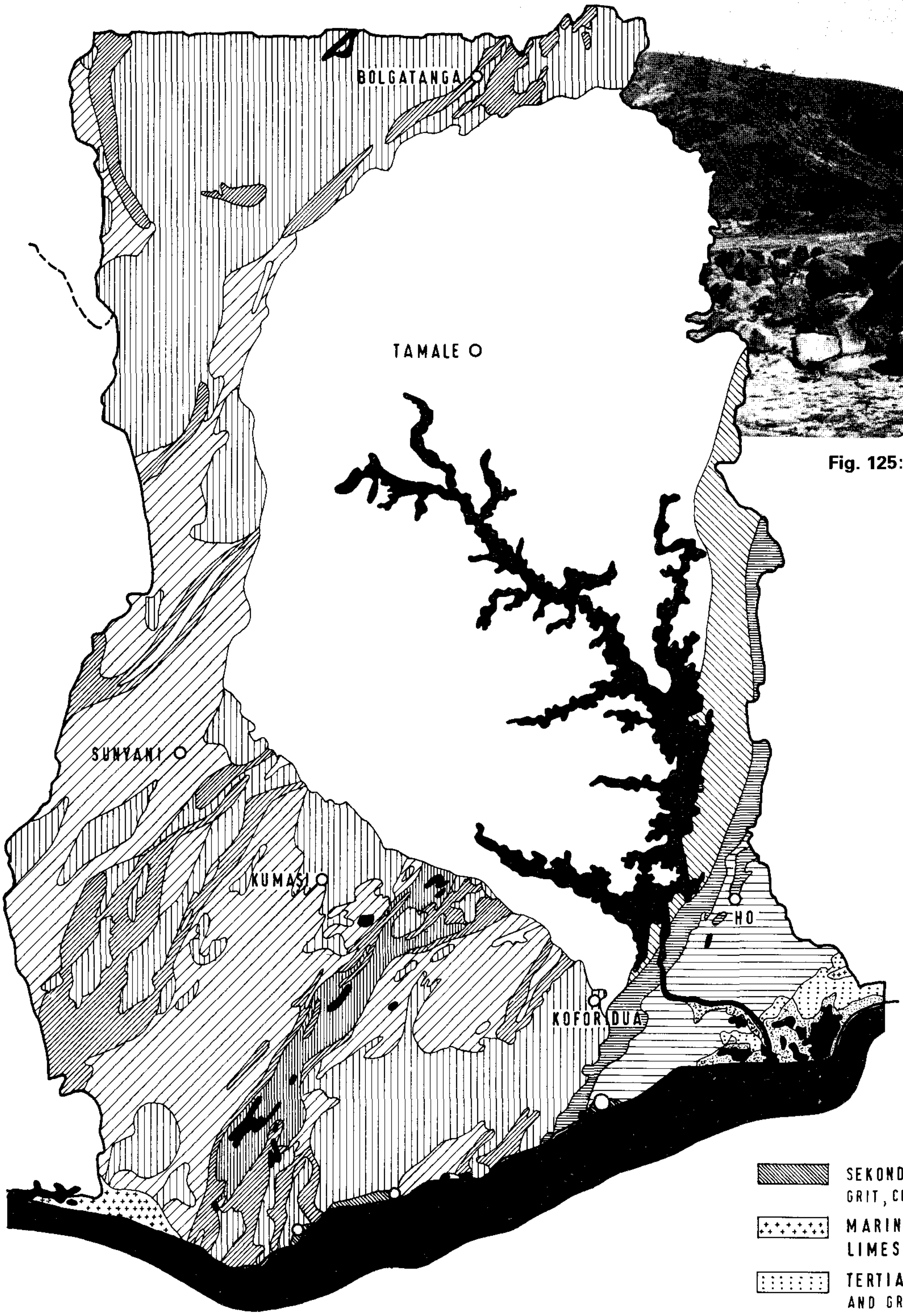


Fig. 125: Granites in the Tongo Hills, 1976.

Fig. 126: Mount Adaklu, a granite "Inselberg" near Ho in the Volta Region, 1980.

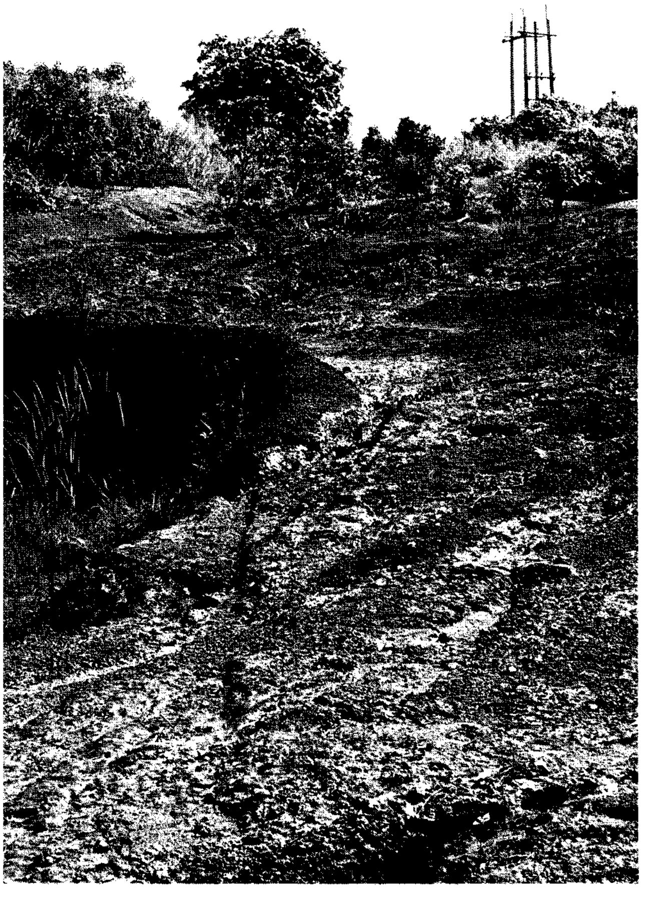


Fig. 124: Land erosion due to indiscriminate laterite extraction in Kumasi, 1981.

Fig. 128: Laterite rock outcrops in Kumasi, Airport Road, 1981.

GRAVELS

Due to the geology of Ghana (Map No. 7 *and* Fig. 125, 126) there are abundant gravel deposits in every region of the country with gravelly material contained in the subsoil in large quantities. The material, in ranges from 2 to 20 mm in diameter, is also referred to as "pea gravel". It is roughly spherical in shape and about the size of a large pea (Fig. 127). Washed quartz gravels are used as fine and coarse aggregate for concrete mix and for road construction (nowadays crushed rock is used for both in places where natural gravel cannot be found, and where crushed gravel is more economical, especially when large quantities for road surfacing are needed).

LATERITE

Nearly all tropical red soils are generally described as laterites. A more detailed geological and chemical definition is appropriate, especially when describing the properties of lateritic soils and their uses in construction: "Laterite is a hardened or soft (reddish to brownish) product of tropical and sub-tropical weathering which is leached of bases, but enriched in sesquioxides of iron and alumina in the form of clay minerals... There is little or no combined silica in laterite, but depending on the parent rock, laterite may have high quantities of quartz" (B.R.R.I., SM-Report No. 12/1970 by J. K. Ayetey: "Engineering-geological study of some of Ghana's lateritic soils and their profiles." *see* Laterite Profile on Map No. 7).

Fig. 127: Pea gravel and crushed stone gravel.

Laterite has been used for centuries as a building material in many tropical countries in Africa, South-America, in South-east Asia and India, as compacted monolithic wall and floor building material, often stabilized with fibreous materials and other materials from plants to improve its durability, strength and water-proofing ability. In South-east Asia monumental buildings have been built with indurated laterite and laterite rocks (temple of Angkor Vat in Cambodia).

There are three main groups of laterite soils:

1. Laterite fine-grained soils (with gravel fraction of less than 10 %) in the range of 0.06 mm to 2 mm in diameter, with lateritic silts and lateritic clays in the ranges from 0.06 mm downwards to 0.002 mm (if one looks at the "textural" significance of laterite).
2. Lateritic gravelly soils with particle sizes from 2 mm to 60 mm in diameter.
3. Laterite rocks and boulders with particle sizes larger than 60 mm in diameter (Fig. 128).

Specific gravity of laterite varies between 2.5 and 3.2. The darker laterite is in colour, the heavier it is. As a simple guidance to determination of physical properties of laterite it can be said that a dark red to reddish-black laterite has a higher iron oxide content and is harder than the reddish-pinkish, reddish-light brown laterite, which contains more aluminium oxide (Fig. 129).

All three groups of laterite listed above are useful as material for construction. The fine-grained laterite soils are most suitable for building because of their plasticity.

In Ghana laterite soils are still used in the rural areas for building in the following ways:

(a) Monolithic or wattle-and-daub construction, both known as "swish" building;
(b) Sun-dried laterite bricks;
(c) Swishcrete. This is formed by adding lime or cement to the soil. The stabilized laterite is then compacted between a timber formwork or used for making blocks;
(d) Burnt bricks from lateritic clay. Of all construction materials from lateritic soils these are the most durable.
(e) Ironstone – hardpans (also known as **Cuirasse**) from weathered laterite rock. Care should be taken to select compact hardpans from rock in the earliest weathering stage, since rock at an advanced stage of weathering will disintegrate into gravel. Laterite rocks and boulders (concretionary laterite rocks and rock pieces) are also used as concrete aggregates and as road surfacing material in some African countries. In Ghana, natural gravels are available in abundance for such use as well as crushed rock aggregate. Studies have, however, been undertaken to examine the use of crushed laterite rock for concrete aggregate in areas where these rocks are available and where washed quartz gravels are not found. These studies have revealed that the more ferrugineous laterite rocks of the woodland savannah have higher mechanical strength since they are more dessicated with low natural water contents and higher specific gravity values than the aluminious laterite rocks from the forest zone. These are more hydrated under the wet forest cover and have lower strenghts. ("Potential Use of Crushed Laterite Rock for Concrete Aggregate" by M. D. Gidigasu, B.R.R.I., Seventh Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Accra, June, 1980).

In order to achieve a better durability and longer life for buildings built with laterite swish or sun-dried laterite bricks, water-proofing agents should be added to the plaster with which the buildings are rendered. Main defects of unplastered soil walls are cracks due to shrinkage and erosion. Long eaves, proper gutters and solid aprons around the building to allow quick drainage of surface water into an open or partly covered drain are additional measures with which a swish building wall can be kept dry and therefore stable (*see* **"Walls and Wall Finishes"**).

CLAYS AND CLAY PRODUCTS

The term "clay" is usually applied to certain earthly rocks which are plastic when wet. This plasticity allows clays to be moulded into almost any shape, which they retain when dry.

In Ghana there are many widespread deposits of clays which can be used in the building industry. The two main types of clays suitable for this are:

1. Brown plastic clays;

2. High grade Kaolins.

The first group of clays is used for the production of burnt bricks and tiles. These clays are mostly alluvial or residual in origin and are derived from granites, gneisses, shales and clayey sandstones of the various rock formations in the country through the process of weathering, erosion and sedimentation (Fig. 138 *and* 139). The deposits in Ghana (conservative estimate of the Geological Survey Department over 200 million m^3) are located close enough to population centres to be used in brick manufacturing. The clays are in general of excellent quality and burn from red to buff.

Burnt bricks and roofing tiles are manufactured in the industrialised countries in highly automated brick plants. These plants rely on electric power and higher grades of fossil fuels. They are very expensive to set up.

Investigations conducted in different developing countries have, however, shown, that a method of production can be adopted which utilizes cheap available labour and appropriate technologies for the establishment of local brick and tile factories, based on clay mixing with a pug mixer (driven by a Diesel engine), hand moulding of the bricks in multiple moulds and firing in kilns.

In a country like Ghana where the cost of one bag of cement is beyond the means of most of the average prospective buyers (and is only available in insufficient quantities) the setting up of small-scale brick factories producing a variety of different burnt bricks and roofing tiles provides an alternative to the "fashionable" (but too expensive) conventional cement-sand block. It is often not known that clay products are about the oldest building materials made by man (early civilizations: Egypt, Sumer, Babylon).

The setting-up of a brick and tile plant for a tropical developing country needs a considerable amount of research and development work. The following will have to be examined and decided:

Fig. 129: Laterite profile; excavation for an extension to the U.S.T. library, Kumasi, 1981.

I. Availability and size of clay deposit (the quantity of usable clay should be at least 75.000 to 100.000 tons of clay to produce about 37.5 million bricks over a period of 25 years).
II. Suitability of the raw materials:
  - II.1 Brick clay;
  - II.2 Sand (used as an additive of up to 40 % by weight of the clay to reduce drying shinkage and as release agent to coat the inside of moulds);
  - II.3 Sawdust (as mould release or fuel);
  - II.4 Water (to make the clay workable).
III. Analysis of commercial feasibility (including market studies);
IV. Choice of technology;
V. Decision of fuel for firing (firewood, oil, gas);
VI. Availability of power (electricity or internal combustion engine);
VII. Design and preparation of project.

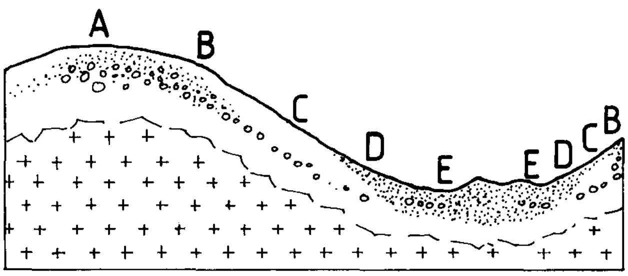
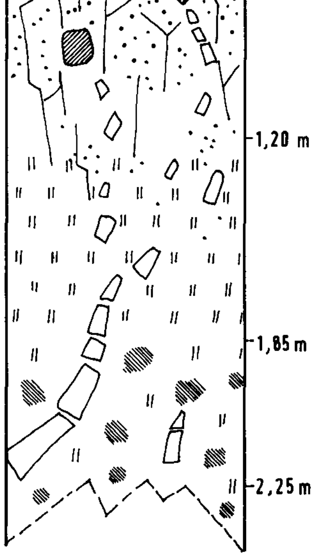


FIG.138 : DIAGRAM OF A SIMPLE FOREST SOIL CATENA OVER GRANITE. FROM "WESTAFRICAN SOILS" BY PETER M. AHN, OXFORD UNIVERSITY PRESS, LONDON.

A,B – GRAVELLY RED AND BROWN UPLAND SEDENTARY SOILS ARE FOUND AT 'A' AND 'B' ON SUMMITS AND UPPER SLOPES. THESE GRADE DOWN-SLOPE INTO YELLOW-BROWN SANDY LIGHT
C – CLAY SOILS DEVELOPED IN MIDDLE SLOPE COLLUVIUM AT 'C' AND INTO YELLOW-BROWN SANDY LOAM AND LOAMY SAND
D – COLLUVIUM AT 'D'. THE SOILS DEVELOPED IN LOCAL GRANITE-
E – DERIVED ALLUVIUM AT 'E' ARE MOSTLY GREY TO WHITE SANDS WITH SUBORDINATE AREAS OF GRITTY OR SANDY GREY CLAYS.

In a country like Ghana the production of burnt clay bricks has hitherto depended heavily on firewood as the source of fuel for firing. Although this is a renewable source of energy it is not available in cheap quantities in more than half of the country (e.g. in the Savannah areas). Since the establishment of the refinery in Tema successful tests have been made to burn residual oil in a continuous oil-fired kiln at Fumesua, near Kumasi (B.R.R.I. Brick Project).



SURFACE - LEAF LITTER LAYER.
TOPSOIL - 0 TO 7,5 cm: VERY DARK GREYISH-BROWN HUMUS LOAM, CRUMBLY AND LOOSE. 7,5 TO 15 cm: DARK GREYISH-BROWN LOAM, LESS HUMUS THAN ABOVE, WEAKLY CRUMBLY.

SUBSOIL - 15 cm TO 1,2 m: REDDISH-BROWN LIGHT CLAY, WEAK FINE SUBANGULAR BLOCKY STRUCTURE, CONTAINING FREQUENT TO ABUNDANT IRONSTONE CONCRETIONS AND SOME QUARTZ GRAVEL AND STONES. 1,2 TO 1,85 m: REDDISH-BROWN LIGHT CLAY TO HEAVY LOAM, TRANSITIONAL TO THE HORIZON BELOW, USUALLY COARSELY MOTTLED AND SOMETIMES INDURATED.

WEATHERED SUBSTRATUM - BELOW 1,85 m: BROWN TO RED SILTY LOAM, WITH TRACES OF SOFT WEATHERED PARENT ROCK (PHYLLITE OR SCHIST).

FIG.139: DIAGRAM OF A WELL-DRAINED UPLAND SEDENTARY SOIL DEVELOPED OVER PHYLLITE OR SCHIST. FROM "WESTAFRICAN SOILS" BY PETER M. AHN, OXFORD UNIVERSITY PRESS, LONDON.

Fig. 140: Brickmaking at Fumesua, B.R.R.I. brick plant near Kumasi, 1981: Preparing the clods;

Fig. 141: ...cutting off surplus clay from mould;

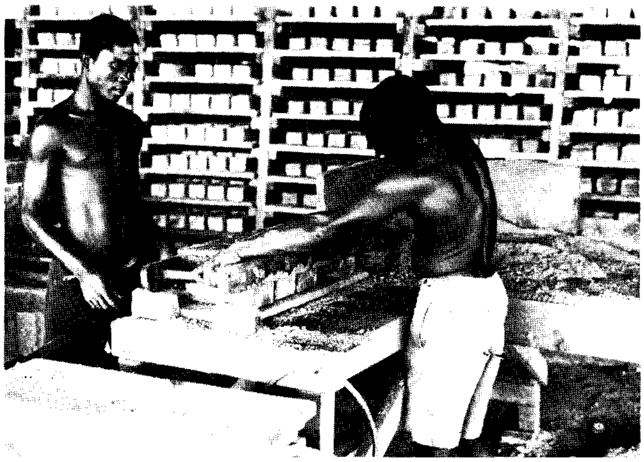


Fig. 142: ...removing bricks from mould onto drying board. Note drying racks in the background.

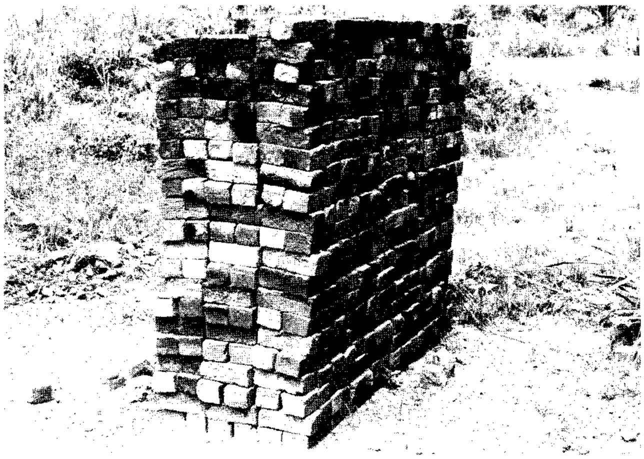


Fig. 143: Ready fired bricks.

With the cost of firewood steadily rising this method of firing might prove cheaper even with expected increases in the price of oil (Fig. 140 *to* 143).

Next to the Fumesua Brick Plant a pyrolytic converter (which has been developed by the Georgia Institute of Technology, U.S.A.) has been built which uses forestry and agricultural wastes which are in abundance available in this area (saw-dust and timber offal from the many sawmills and carpentry workshops in and around Kumasi etc.) for conversion into oil, char and gas.

In a rural set-up small brick plants could be built using wood-fired clamps (Fig. 144). This is done in many African and Asian countries. If later the demand for bricks increases the clamp-fired bricks can be used to construct a larger kiln e.g. **Hoffmann** continuous kiln or others. In India, where coal is available, a local adaption of the Hoffmann Kiln is used. It is known as Bull's trench kiln and has virtually replaced clamp burning in areas around India's large towns and cities where the demand for bricks as building material is very high. In Pakistan the same kiln is used and fired with natural gas.

Design constraints which will be faced in many tropical developing countries with similar conditions as Ghana, and which will be decisive in choosing the size of the plant, output, energy used for kiln-firing etc. are:

(a) Low capital investment (including low foreign currency component);
(b) Technology which makes use of largely unskilled labour force;
(c) Simple machinery which should be such that spare parts for maintenance or repairs can be produced locally;
(d) Production activity will be restricted during the rainy season. Place for stock of about a month's supply of clay, dry bricks and firewood (if this is used for firing) is therefore needed;
(e) Necessary equipment for the plant (except certain machines) should be produced locally;
(f) In case of increase in labour costs the production process should be thus that single operations (clay digging, loading and un-loading of the kiln and dryer) are suitable for mechanisation in the future;
(g) In the event of an increased demand for the product it should be easy to extend the "operation sections".

Brick and tile sizes: Table 1.

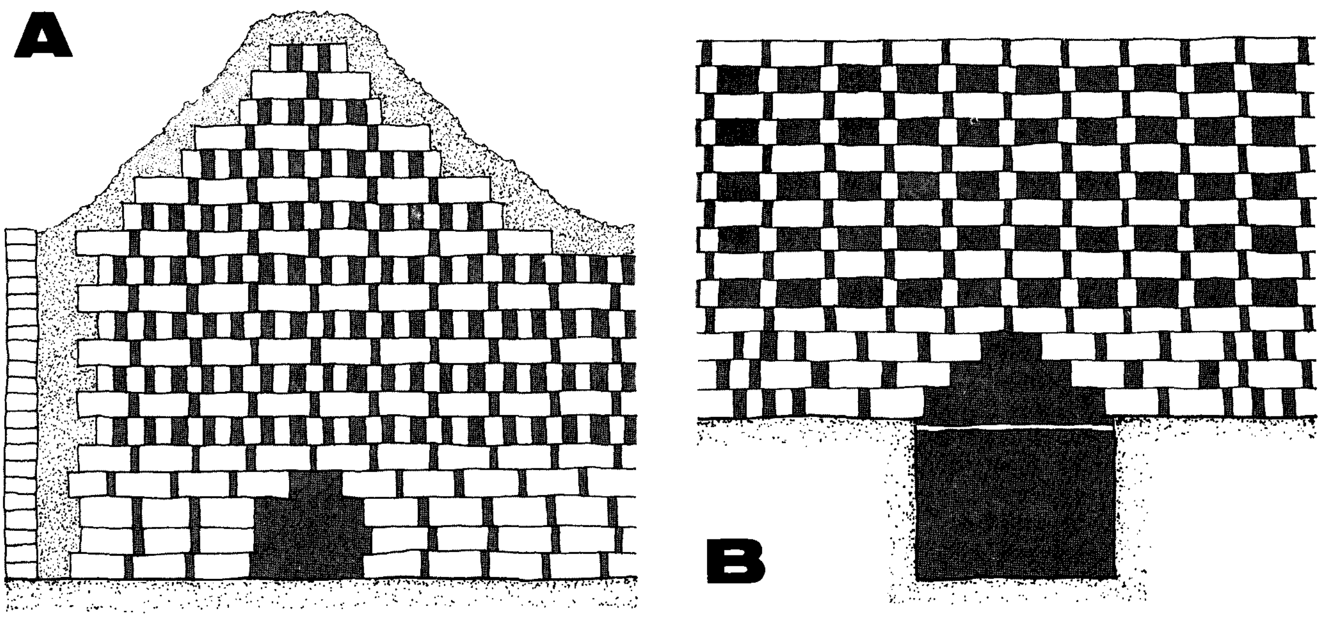


FIG.144 : **SIMPLE WOOD-FIRED CLAMPS**. FROM"APPROPRIATE TECHNOLOGY", VOL.7 N°1, JUNE 1980 AND"BRICKMAKING IN DEVELOPING COUNTRIES" BY J.P.M.PARRY.

A SMALL CLAMP FOR ABOUT 4000 BRICKS IN WEST JAVA. EXTERNAL DIMENSIONS : 2 m x 1,5 m WIDE, MAX. HEIGHT 2 m (20 LAYERS OF BRICKS PLACED ON EDGE). FIREHOLE (AT ONE END ONLY) IS ABOUT 400 x 500 mm. BRICKS ARE LAID IN ALTERNATING DIRECTIONS. DRIED BRICKS ARE BUILT UP AROUND THE CLAMP AS AN INSULATIVE COVER. THE CAVITY BETWEEN THIS WALL AND THE CLAMP AND ALSO THE TOP OF THE CLAMP ARE FILLED WITH RICE HUSK. AFTER THE FIRING THE ASH CONTINUES TO CONSERVE HEAT IN THE CLAMP. LOGS OF WOOD ARE BURNT IN THE FIRE-HOLE, WHICH IS BLOCKED OFF AFTER TWO DAYS TO ALLOW THE CLAMP TO BURN ITSELF OUT AND COOL DOWN. CAVITY WALL BRICKS AND OUTER CLAMP BRICKS ARE RE-FIRED.

B FIRING IS DONE IN CHANNELS UNDER THE CLAMP SETTING, ACTING AS HEARTH WITH A GRATE (SOUTHERN SUDAN). THE CHANNEL MAINTAINS THE FIRE WHILE PREVENTING TOO MUCH COLD EXCESS AIR FROM ENTERING THE BRICKSETTING.

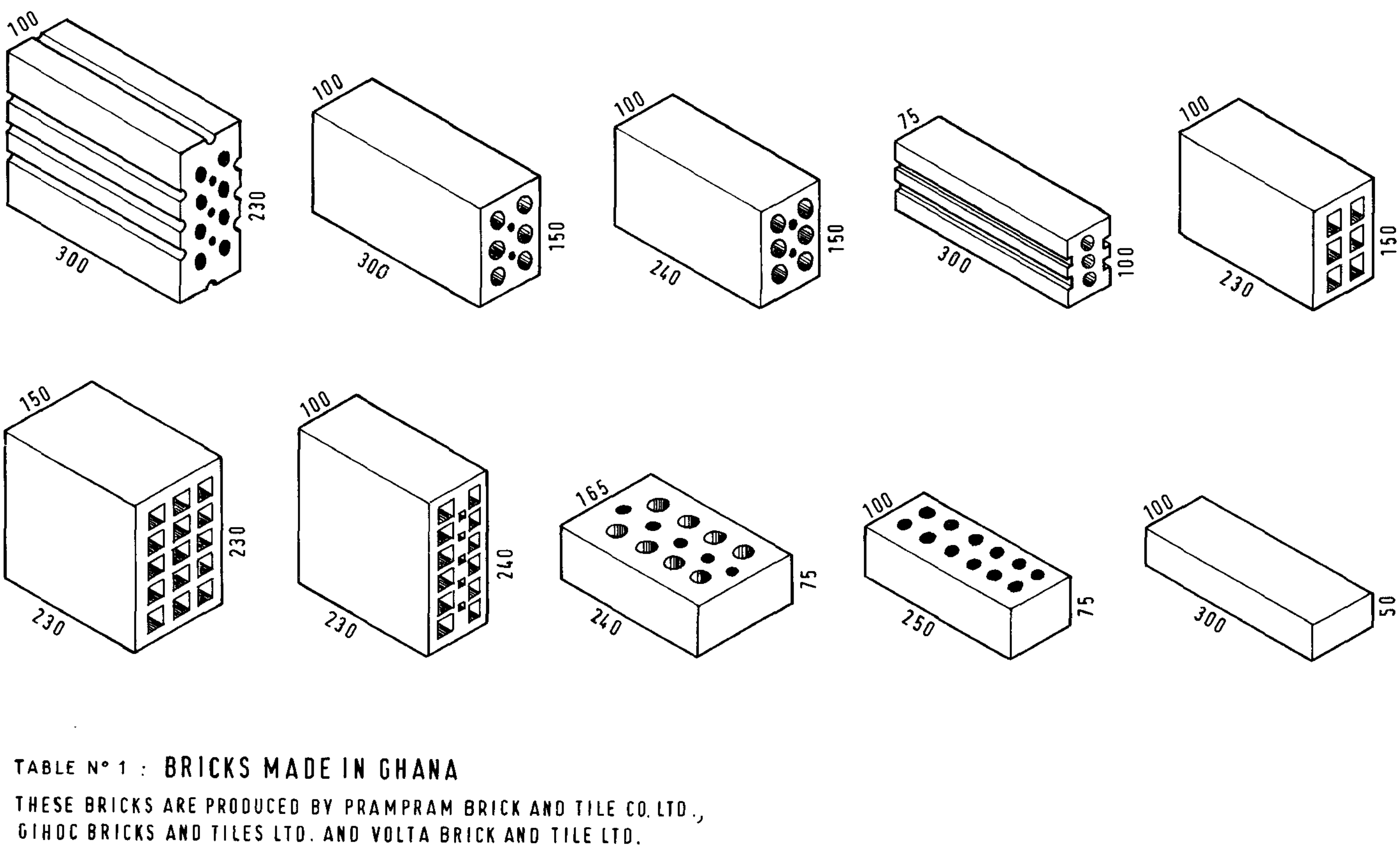


TABLE N° 1 : **BRICKS MADE IN GHANA**

THESE BRICKS ARE PRODUCED BY PRAMPRAM BRICK AND TILE CO. LTD., GIHOC BRICKS AND TILES LTD. AND VOLTA BRICK AND TILE LTD.

KAOLIN

Kaolin is also known as **"China Clay"**. This mineral commonly occurs as the decayed product of feldspars in granite and pegmatites. Kaolin is a raw material used in the production of sanitary wares, wall tiles and china wares.

Locally produced ceramic products in Ghana (**Saltpont Ceramics**) are:

Vitreous china water closets, urinals and cisterns;
Wash basins – 630 x 510 mm and 560 x 460 mm;
Hand basins – 500 x 320 mm;
Soap dishes – 150 x 150 mm;
Wall tiles (white and coloured) – 150 x 150 mm.

(Ghana Standards Applicable:

G.S. 168-1976: Glazed ceramic tiles and tile fittings for internal walls.
G.S. 197-1978: Quality of vitreous china sanitary appliances.)

STONES AND THEIR USES

Stone has been one of man's earliest natural building materials and one of great endurance and beauty. The pyramids of Egypt were built with cut stones around 2500 B.C. (Fig. 145). Cut stones of incredible size have been used by the Incas to build temple, palace and fortress walls, floors and roads in Cuzco, Peru (Fig. 146) more than 500 years ago, many of which still stand firm today. Some of these rocks weigh more than 100 tons. The Inca settlement of Machu Picchu in Peru built with stones and carefully terraced up a steep mountain top, still remains a puzzle today (Fig. 147).

As a material stone can have immense strength in compression. Stones can therefore easily be used for the construction of load-bearing elements in a building.
Stones are part of the parent material of soil. They are classified in three main groups according to their formation:

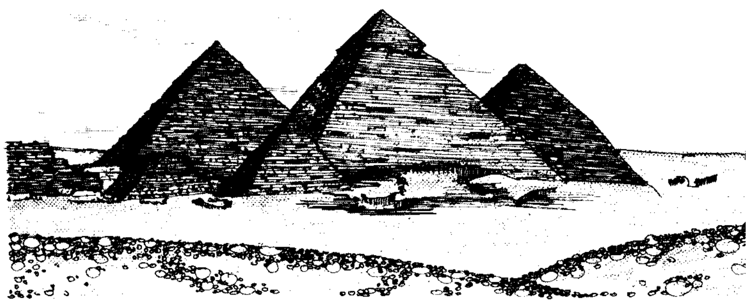


FIG.145 : GROUP OF EGYPTIAN PYRAMIDS AT GIZEH, 2723 - 2475 B.C. (SKETCH FROM AN EGYPTIAN POST CARD).

I. **Igneous Rocks**: These are predominantly crystalline; formed by the molten rock magma, they are primary rocks from which the other classes of rocks are ultimately derived. They can be acid rocks (of light colour – because of the presence of free quartz) and basic rocks (of dark colour – because of the presence of ferro-magnesium).

II. **Sedimentary Rocks:** These result from disintegration of pre-existing rocks through weathering after exposure at the surface of the earth. The weathered material has been worn down, transported and deposited as sediment. They contain calcareous minerals (limestone, dolomite), siliceous minerals (sandstone) and argillaceous minerals (shale).

III. **Metamorphic Rocks:** These are igneous or sedimentary rocks that have been changed substantially by heat and pressure.

FIG. 146 : THE ANCIENT INCA WALLS IN CUZCO, PERU - FROM "THE INCREDIBLE INCAS AND THEIR TIMELESS LAND" BY L. MC INTYRE, NATIONAL GEOGRAPHIC SOCIETY.

FIG.147 : THE RUINS OF MACHU PICHU - AN IMPRESSION BY THE AUTHOR.

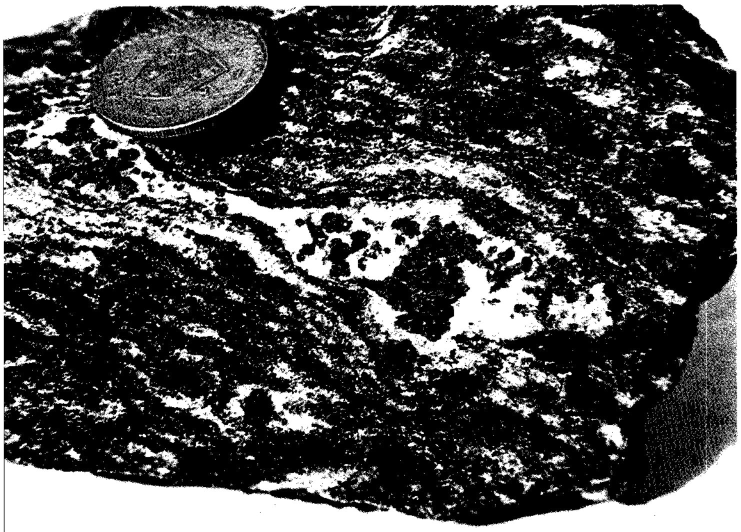


Fig. 148: Garnet hornblende Gneiss from the Shai Hills near Tema, 1981.

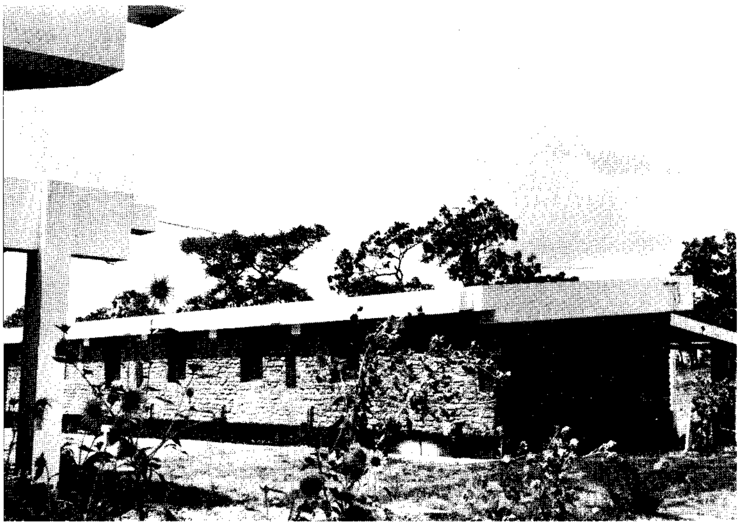


Fig. 149: Mole Game Reserve Motel near Larabanga, Northern Region, built with sandstones. Architect: HANNAH SCHRECKENBACH, 1962.

Ghana's geology is such that many durable construction stones can be found in various parts of the country (Map No. 7). These are:

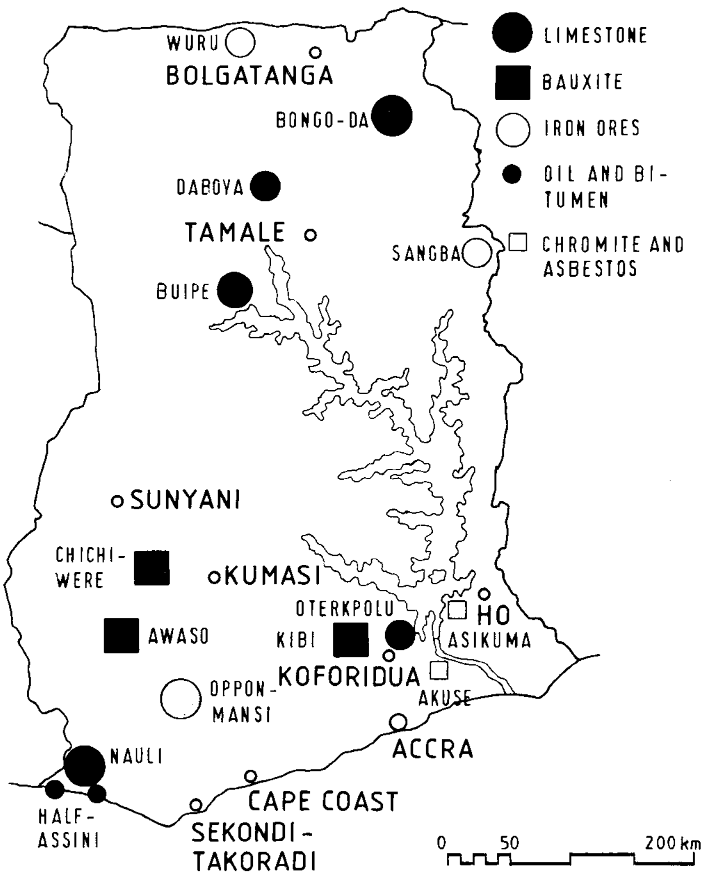
(a) Granites and granodiorites from the post-Birrimian granitic rocks (Fig. 125);
(b) Gneisses (garnet hornblende gneisses) from the Dahomeyan rocks (Fig. 148);
(c) Sandstones (compacted and cemented quartz grains) from the Voltaian formation which is covering nearly half of the country;
(d) Quartzites from the Togo series;
(e) Porphyries, syenite, andesite, dolerite and gabbro from the Birrimian and post-Birrimian granitic rocks.

Some of these stones are very beautiful and can be used – polished – as ornamental stones.

Dimension stones are expensive to produce and require an own industry for cutting and dressing. Moreover the cost of transportation of the stones to the sites is very high. Untreated stones have been used where they are found exposed. Cutting and dressing them (especially in the case of sandstones) can be done by unskilled labour at reasonable costs on the site (Fig. 149).
Broken and crushed stones are extensively used for concrete aggregates and road building materials.
Calcareous stones and their uses are the following:

(a) **Limestone**: Together with clay limestone is one of the main ingredients in the manufacturing process of cement (*see* **3.2.2 Concrete, Cement**). When limestone (calcium carbonate) is calcined lime is obtained. Although the most modern plants are highly mechanized and automated, lime is still burned in very simple kilns as it was done long ago. Lime is an important material for the building industry as well as for the glass producing, chemical and pharmaceutical industries. Limestone is not only used for making lime, and for cement production, it is used directly as a flux in iron and steel and other metal production. It is also used in road construction. Indeed, limestone ranks amongst the most important mineral products processed in the industrially developed countries. Its importance for the developing countries in their efforts to develop their own local building material industries is being recognized. Ghana has large limestone deposits (Map No. 8).

(b) **Dolomite**: This is a calcium magnesium carbonate. Besides its main use in the manufacture of refractories and as a flux in the manufacture of steel, it is used in the manufacture of concrete aggregate. In glass-making, as much as 30 % of the charges may be dolomite or limestone. As with limestone, dolomite is available in Ghana and is used by the Steel Works (Tema), Glass Factory (Aboso) and Ceramic Works (Saltpond). Dolomitic variegated limestone which is also found can be used as chippings for terrazzo works. Terrazzo chippings have hitherto been imported from Italy. Dolomitic limestone can also be used for cement manufacture, though a special technology will be required for this.



MAP N°8 : MAJOR DEPOSITS OF MINERALS SUITABLE FOR THE PRODUCTION OF CONSTRUCTION MATERIALS

Fig. 151: ZANA-mat door in a Kusasi house at Binaba, 1976.

3.1.2 PLANTS AND WOODY PLANTS

The traditional builder still uses plants in many different ways. Different grasses are used for thatching. Leaves of different palm trees are used for making mats, screens and for thatching (Fig. 150). Some of the most common species will be listed here and their uses described.

GRASSES AND LEAVES

(a) ***Andropogon Gayanus:*** A common thatching grass found in the coastal and interior savannahs. It grows very high (up to 3.5 m), with long, linear blades, tapering to a fine point. This grass is also used in the North of Ghana for weaving coarse rough grass mats (Zana-mats) for walls, screens and wind-protection (Fig. 151).

(b) ***Cymbopogon Giganteus:*** Also used for roof thatching. It is a tall bunch grass (up to 3 m) with long blades. The leaves have a strong lemon-like scent when crushed (the grass is also called "Lemon-grass") – they can be boiled and drunk as tea. The grass is distributed throughout the coastal and interior savannahs.

(c) ***Heteropogon Contortus*** (Speargrass): This is a grass of the northern savannah and used for thatching in the areas where it is found.

(d) ***Imperata Cylindrica:*** A bunch grass which grows to about 1.2 m high. Its blades are stiff, long and erect up to 1 m in length. It is a common grass found in the savannah woodland, near rivers (Fig. 152). This grass is mainly used for thatching (*see* **"Construction Methods in the Fishing Communities along the Coast of Ghana, Buildings of the Anlos"**).

Fig. 150: Dried millet and guinea corn stalks for floor mats outside a Kusasi compound at Zebila, Upper Region. In the foreground grass bundles for thatching, 1968.

Fig. 152: IMPERATA CYLINDRICA bundles for thatching.

(e) ***Jardinea Congoensis:*** A very tall bunch grass (up to 4 m) with long linear blades tapering to a fine point. Infrequent but widely distributed in coastal and interior savannahs and occuring also in shallow water and marshy areas. Used for thatching and making mats for screen walls.

(f) ***Schizachirium Sanguineum:*** A bunch grass up to 3 m high in the northern interior savannah, where it is used for thatching.

(g) ***Marantochloa Flexuosa:*** A tall, bamboo-like shrub. The leaves are used for thatching.

(h) ***Raphia Hookeri*** (Raphia palm): A palm tree of the forest and transitional forest areas. Leaflets of this palm tree are used for making "palm leave tiles" (Fig. 153). They are taken off the midrib, folded around a thin sliver of bamboo and then "sewn" together with thin and small bamboo pieces. A size of one such tile is about 1 m by 500 mm. After they have been allowed to dry for a few days, the "prefabricated" tiles are then tied to split bamboo purlins which in turn are fixed to the rafters (also bamboo or timber), a work normally done by men (Fig. 154 *to* 157). The petioles of the leaves are often used as purlins and framework for daubing. Split, they are used for screens and fences.

(i) ***Cocos Nucifera*** (Coconut palm): The leaflets, with the split midribs are used for thatching. The same applies to:

(j) ***Elaeis Guineensis*** (Oil palm): The leaflets and petioles are used as in h) and i).

(k) ***Cola Gigantea:*** A medium to large forest tree of which the broad leaves are used for thatching.

(l) ***Phragmites Vulgaris*** (ph. Karka): The stems of this reed are used for roofing, hut walls and fencing. Split, they are used for screens.

(m) ***Hippocratea Africana:*** A tough woody climber, very flexible, durable and termite resistant. It is the traditional tying and binding material for house and fence building.

(n) ***Pandanus Candelabrum***: The leaves of this tree are arranged spirally, long, broadly linear. The young leaves are woven into sleeping mats after they are scraped with a knife to expose the fibre which is laid into the sun do dry (Fig. 158). The fibre is also used for rope making.

Fig. 153: Making rooftiles from the leaves of RAPHIA HOOKERI: Folding the leaves;

Fig. 154: ...fixing them around two split pieces of bamboo;

Fig. 155: ...tying the leaves together with small bamboo splits.

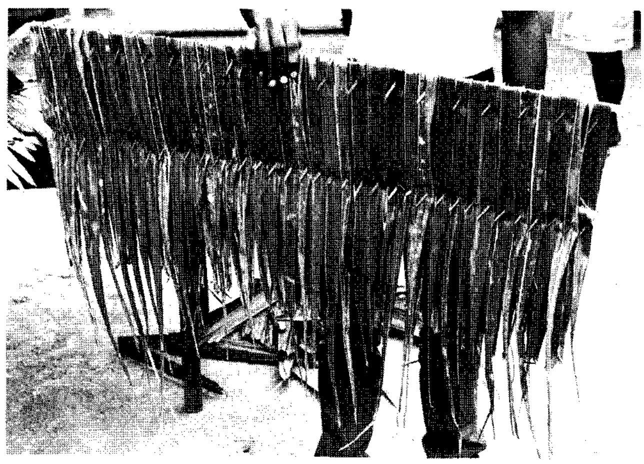


Fig. 156: A complete tile.

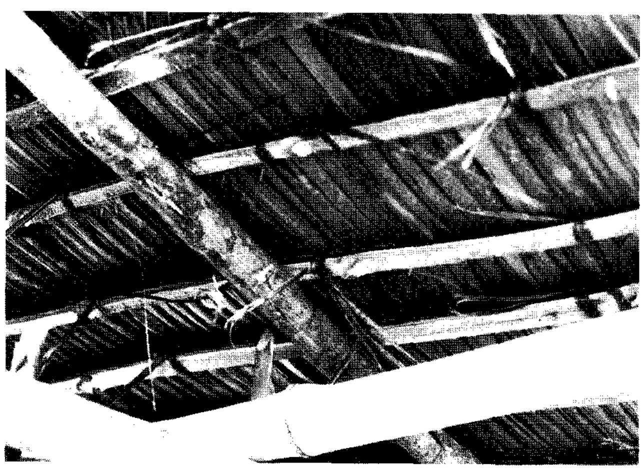


Fig. 157: Detail of a roof covered with Raphia palm leave tiles, shown from underneath.

Fig. 158: PANDAMUS leaves laid out for drying in Aviefe, Volta Region, 1980.

FRUITS AND BARK

The acqueous extracts of empty fruit pods, as well as from boiling the bark of some common savannah trees are used as plaster, wall and floor stabilizer in Northern Ghana.

(a) ***Parkia Clappertoniana*** (or West African Locus Bean): The acqueous extract gained from boiling the empty fruit pods is of purple brown colour. When mixed with cow-dung, it hardens laterite walls and floors (Fig. 159 *and* 160). It is more often applied on top of the freshly plastered or decorated walls. As already described and shown in Fig. 34 (**"Wall Finishes, Traditional Building Methods in the Northeast of Ghana"**), where it is also acting as waterproofing agent. Sometimes, the bark (possibly due to its tannin content) ist also boiled out and the extract used for the same purpose.
(b) ***Syzygium Guineense:*** This tree is common along stream banks, in the savannah or in wet forests and on the edges of closed forest. Its bark contains tannin and is often used instead of *Parkia Clappertoniana* for hardening and waterproofing laterite mud floors.
(c) ***Rhizophora*** (Red Mangrove): When some Ashantis of the Gold Coast (with Prempeh I.) were exiled to the Seychelles by the British towards the end of the last century, they saw how the dark-red bark of this small tree (common in the lagoon areas along the coast) was boiled and used for polishing wooden floors. They introduced this practice to Ghana on their return. The bark of this tree contains about 30 % tannin. It is also used in Sierra Leone for dyeing wooden floors dark-red (after burning the bark and mixing the ash with soda).
(d) ***Butyrospermum Parkii*** (Shea Butter tree): From the kernels of the fruits shea butter is being prepared by women in the northern savannah areas of Ghana where this tree is very common. During the butter preparation process an oily brown paste is left over after extraction of the oil and butter. This residual meal is used by the local builders as waterproofing material on the walls, floors and flat mud roofs of their houses.

BAMBOO, THE GIANT GRASS

"Bamboo is all things to some men and some things to all men" (L. Marden: "Bamboo, the Giant Grass", National Geographic, Vol. 158, No. 4, October, 1980). "Bamboo is like a man in a high position and of excellent character. A man like this is capable of bowing down, like bamboo – the taller it grows, the lower it can bow down" (Javanese saying).

In the world there are about a thousand species of bamboo of different genera. Bamboos grow best in Southern Asia. Native bamboo regions occur roughly between the Tropic of Cancer and Tropic of Capricon (Fig. 161). There are giants of 40 m in height and small bamboos the size of ordinary field grass (Fig. 162). The most striking characteristic of bamboo is its fast vertiginous growth – one can literally "see it grow". Catalogues of well over a thousand different uses of the giant grass have been compiled.

In the humid tropics it has been and still is used as a traditional natural building material. In fact the importance of certain species of bamboo as building material has been recognized in many tropical developing countries. The Department of Economic and Social Affairs of the United Nations has published a report in 1972, "The Use of Bamboo and Reeds in Building Construction". One aim of this report is, among others, to provide necessary information about techniques of bamboo and reed construction and also to stimulate research on improving properties of bamboo and reed and on improving traditional methods used for building with bamboo and reed.

Fig. 159: PARKIA CLAPPERTONIANA leaf. The shape of this leaf is a common motif for decoration on the northern compound walls.

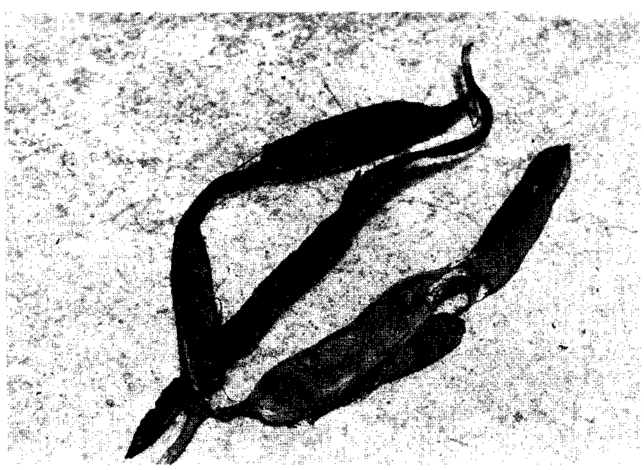


Fig. 160: Boiled-out fruit pod of the same tree.

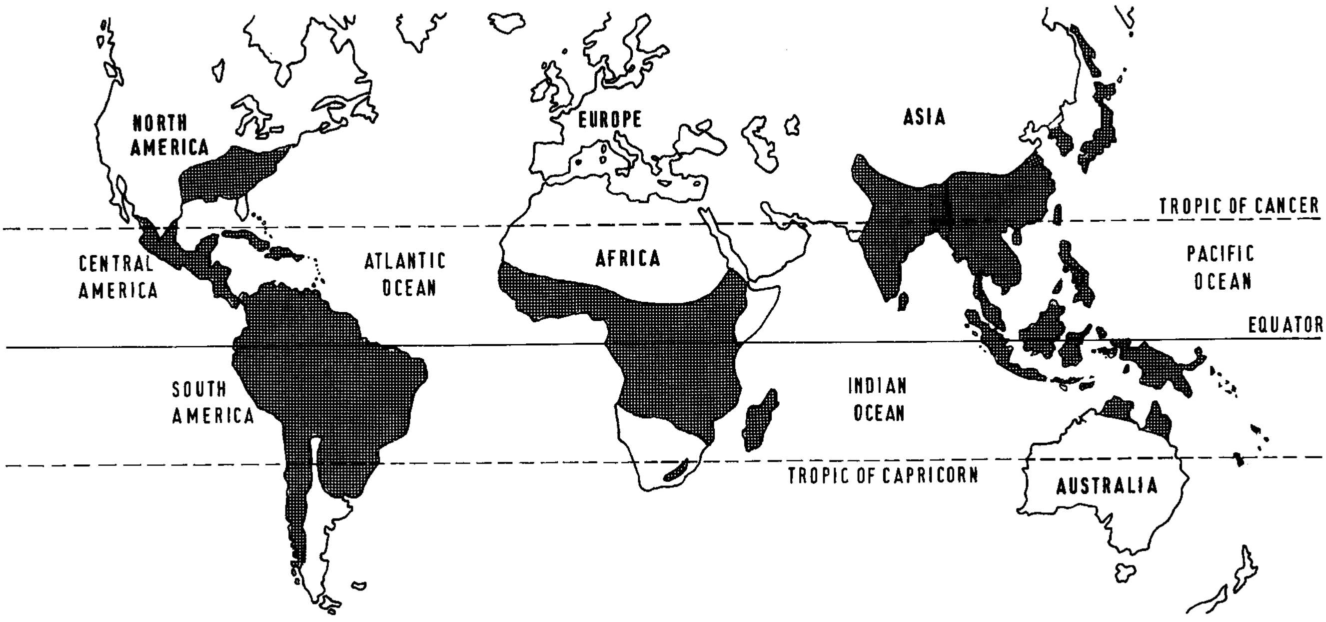


FIG. 161 : SPREAD OF BAMBOO THROUGHOUT THE WORLD
FROM "NATIONAL GEOGRAPHIC", VOL. 158, N° 4 - 10/1980.

All bamboos grow up from rhyzomes, underground stems that send up shoots. They grow in clumps of culms (Fig. 163). These mature in two to six years (large species may take longer).

In Ghana three species are known:

(a) ***Bambusa Vulgaris*** (Yellow and green striped bamboo or plain green): This bamboo ist pantropic in cultivation. It is very fast growing. Its wood is moderately thick and strong; susceptible to attack by *Dinoderus* (the powder post beetle).

(b) ***Dendrocalamus Strictus*** (Male Bamboo – India): This is a green stemmed bamboo forming dense clumps up to 30 m high, stems are 125 mm in diameter about 1 m from the ground. The outer shell of the culms is hard and strong, but elastic. It is the most widely spread and universally used of the Indian bamboos. In South-east Asia this bamboo is used for general building purposes, for scaffolding, fences, furniture, masts etc., when it is about 3 years old. It has been introduced into Ghana and could be very well developed into a cheap but versatile and durable building material.

Fig. 162: Bamboo clumps in the Botanical Garden of U.S.T., Kumasi, 1981.

(c) ***Oxytenanthera Abyssinica*** (Savannah Bamboo): A darkgreen greyish bamboo of 10-15 m in height, growing in dense clumps. The culms are solid and semi-solid, the largest hollow, 100 mm in diameter. This bamboo is widely distributed throughout tropical Africa and quite common in Ghana where the stems are used as rafters for roof building, for roofing and roofing pegs, as fences, furniture, etc. Younger shoots are used as bamboo canes for many domestic and horticultural purposes.

PHYSICAL AND MECHANICAL PROPERTIES OF BAMBOO (Table 2):

I. DIMENSIONS:
As already mentioned before some bamboos grow to a height of around 40 *metres* (*Dendrocalamus Giganteus*), others are no larger than small shrubs.

WEIGHT SPECIFIC GRAVITY	648 kg / cm^2 0·5 TO 0·79, MEDIAN 0·65
STRENGTH MODULUS OF ELASTICITY (MATURE CULMS)	125 000 TO 195 000 kg / cm^2 (AVERAGE: 160000 kg / cm^2)
MODULUS OF RUPTURE	900 TO 1700 kg / cm^2 (AVERAGE: 1300 kg / cm^2)
COMMPRESSIVE STRENGTH PARALLEL TO GRAINS	315 TO 725 kg / cm^2 (AVERAGE: 520 kg / cm^2)
TENSILE STRENGTH PARALLEL TO GRAINS	1400 TO 2800 kg / cm^2

TABLE 2: PROPERTIES OF BAMBOO

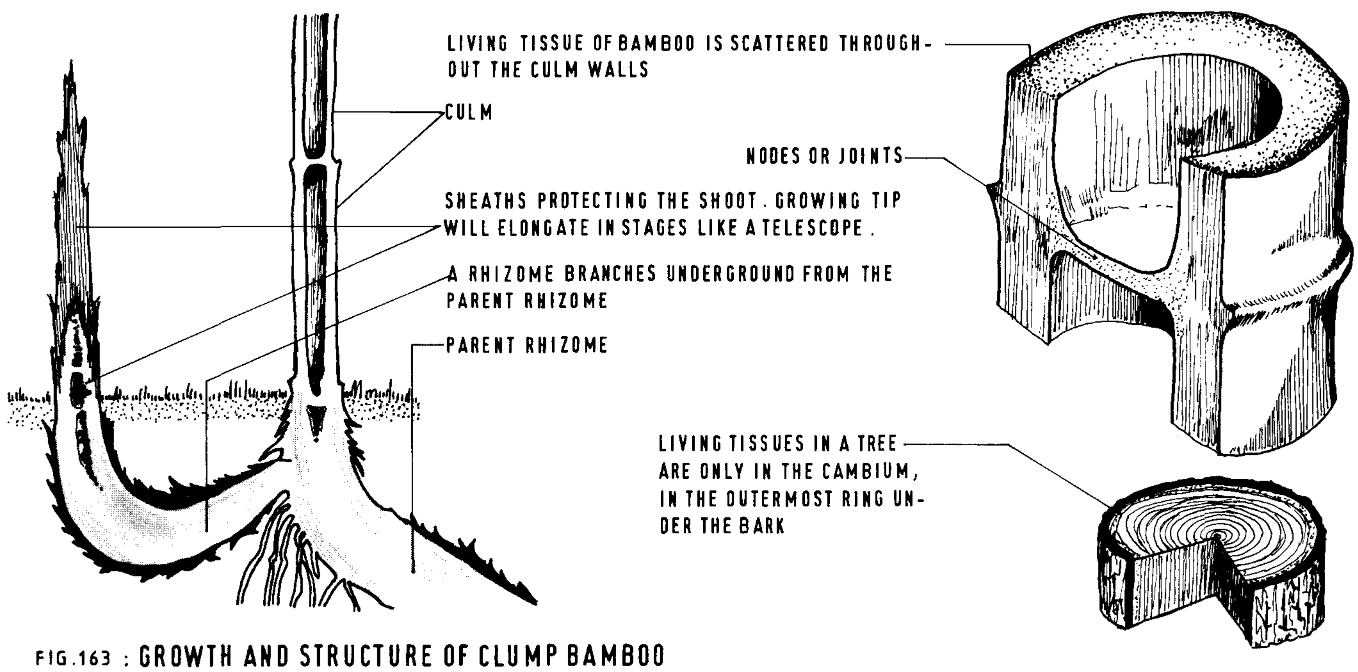


FIG.163 : **GROWTH AND STRUCTURE OF CLUMP BAMBOO**
FROM "NATIONAL GEOGRAPHIC", VOL.158, N°4-10/1980.

The culm diameter varies from 10 to 300 mm. There are 65 species of bamboo from about 10 genera (groups of related species) which are used in construction.

II. WEIGHT:

Bamboos are light in weight compared to structural timber. The specific gravity of bamboo varies between 0.5 to 0.79 (average 0.65), which would make the weight of it 648 kg/m^3.

III. STRENGTH:

Strength of bamboo varies with species, age, conditions of growth, moisture content, disposition of nodes and position along the culms. When designing a structure in bamboo these points should be known.
The culms have a characteristic physical structure that gives them a high strength-weight ratio. Nearly round in cross section, usually hollow, they have rigid cross walls at the inter-nodes which prevent collapse on bending. Near the surface of the culms are concentrated the strong, hard tissues of high tensile strength. This is an ideal position for giving the culm its mechanical strength. Generally the strength of mature air-dried culms is higher than that of green culms. With kiln-drying these properties can be increased (elasticity, tensile and bending strengths). Bamboo tends to split, particularly in the internodes. Joints used in building with bamboo are achieved through lashing (*see* **"Building with Bamboo"**), because the splitting tendency precludes the use of nails or screws. On the other hand the substance and grain of bamboo is such that it can easily be divided by hand into shorter pieces by sawing or chopping or into narrow strips by splitting (for mat walls and screens).

IV. DURABILITY:

Bamboos are highly susceptible to destruction by wood-eating insects and rot-fungi. When dry they also burn easily. Bamboo can, however, be treated

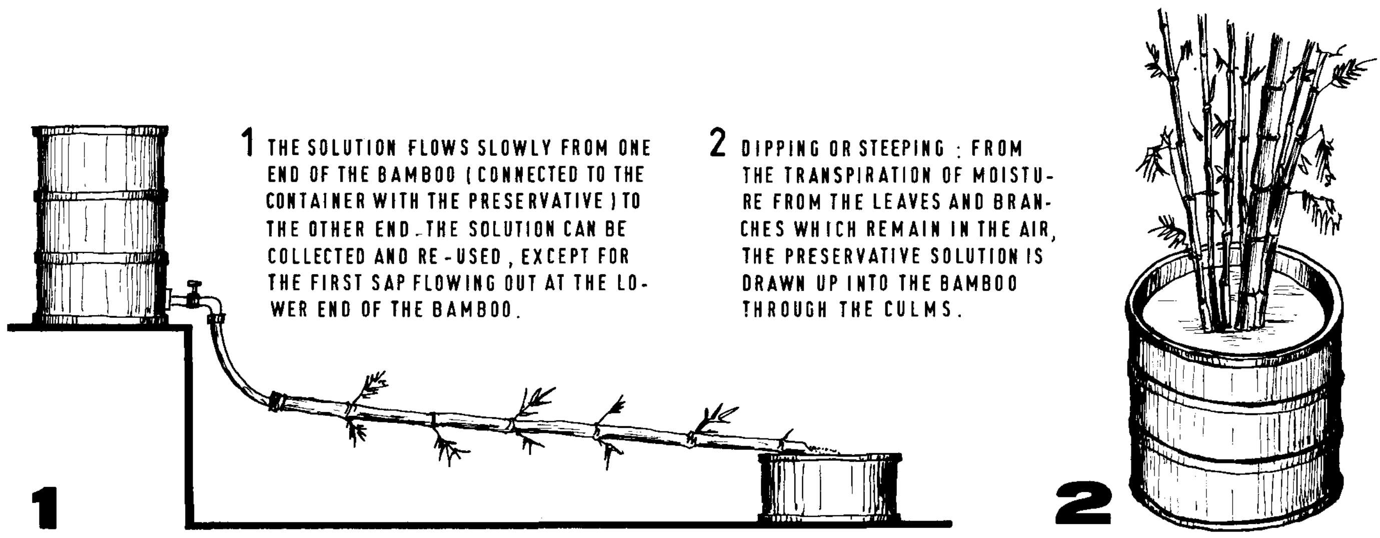


FIG.164 & 165 : **PRESERVATION OF BAMBOO BY BOUCHERIE PROCESS AND BY DIPPING**
(FROM "BAMBOO" BY J. JANSEN, UNIVERSITY OF TECHNOLOGY, EINDHOVEN, THE NETHERLANDS).

NOTE: THE BOUCHERIE PROCESS IS CONSIDERED TO BE THE BEST METHOD.

in different ways with suitable chemicals. Methods used in India where bamboo has been and is being used in construction of village houses and other structures are:

(a) BY STEPPING PROCESS: After removal of branches and leaves the culms are put (standing up) into a container holding the preservative solution, to a depth of 300 to 600 mm into a solution of **Copper-Chrome-Arsenic** composition (or **Copper-Chrome-Acetic Acid**). This process takes some time. It is easier to dip the freshly cut stems into the solution with the branches and leaves still attached (Fig. 164). These help to draw up the preservative solution through transpiration of moisture from the leaves. Treatment lasts about 2 days (depending on length and species of the bamboo and on the prevailing climatic conditions).

(b) BY BOUCHERIE PROCESS: The freshly cut bamboo stem (with branches and leaves attached) is connected with a tube to the container with the preservative solution. The stem is placed at a slight fall away from the container, to allow the solution to flow slowly through the whole bamboo. The solution can be collected at the lower end for re-use. This process has proved to be the most effective (Fig. 165).

(c) BY BOUCHERIE PROCESS WITH PUMP: The reservoir containing the preservative solution is made air-tight. A hand-air-pump is attached to it to increase the rate of flow of the solution through the bamboo. The treatment time is reduced. The normal Boucherie process takes from 1 to 5 days depending on the length of the stem and the species. There are a variety of different chemical solutions which can be used. The durability of bamboo also increases through proper seasoning to reduce the moisture content. The stem should be mature before air- or kiln-drying.
For the preservative treatment the bamboo should be freshly cut and have a high moisture content which improves its treatability.
To treat bamboo with fire retardant chemicals in the same way as structural timber is rather costly for the types of houses built of bamboo. A combination of chemicals suitable for treatment against insects, rot-fungi and for fire-resistance would be appropriate.

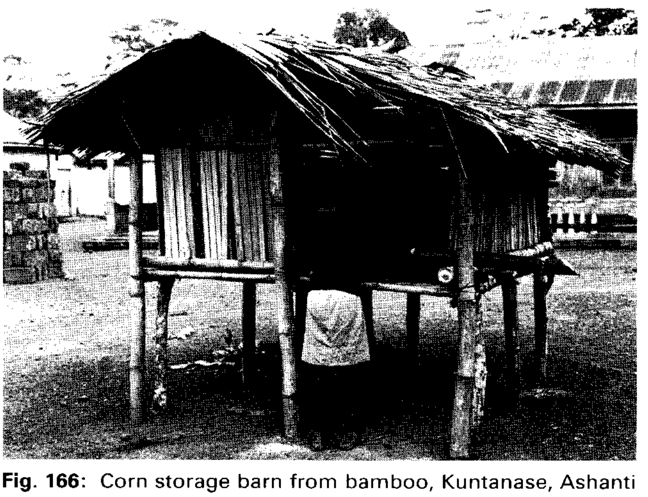


Fig. 166: Corn storage barn from bamboo, Kuntanase, Ashanti Region, 1979.

BUILDING WITH BAMBOO

In Ghana bamboo is being used for the construction of storage barns and cribs, (Fig. 166) as framework for wattle and daub walls, as roof structure, for fence building and for the manufacture of furniture (Fig. 167 *and* 168). It should, however, be possible to cultivate on a large scale species of the *Dendrocalamus* group which

Fig. 167: Bamboo fence in Kpandu, Volta Region, 1980.

Fig. 168: Bamboo chair produced in the Department of Rural Arts, College of Art, U.S.T., Kumasi.

are suitable for building construction, especially Dendrocalamus Strictus and Dendrocalamus Giganteus as well as other Bambusa species, e.g. ***Bambusa Balcoa, Bambusa Polymorpha*** (both common bamboos in India, Bangladesh, Burma and Thailand), or species common in South America as ***Guada Angustifolia*** (Columbia and Ecquador), a bamboo resistant to rot-fungi and wood-eating insects.
It should be a challenge to any architect to design bamboo houses suitable for tropical developing countries which show an awareness of the strength and beauty of bamboo as a building material, its aesthetic qualities and its versatility, as shown in bamboo houses in Japan, Java and Malaysia and in experimental bamboo structures put up at the Forest Research Institute, Dehra Dun in India (Fig. 169).

1. FOUNDATIONS:

Until a reliable and economical treatment of bamboo has been developed for preserving bamboo posts which have been driven directly into the ground (common feature of traditional bamboo structures in many countries) it is advisable to use more durable material than untreated bamboo for the foundations, e.g concrete, stones, brick.

2. FRAMEWORK:

More often the structural framework of a house which has bamboo floors, bamboo board or mat walls and a bamboo roof structure is made of a different material, in most cases from durable hardwood. In earthquake areas a bamboo framework has a superior resiliency than a rigid timber framework.

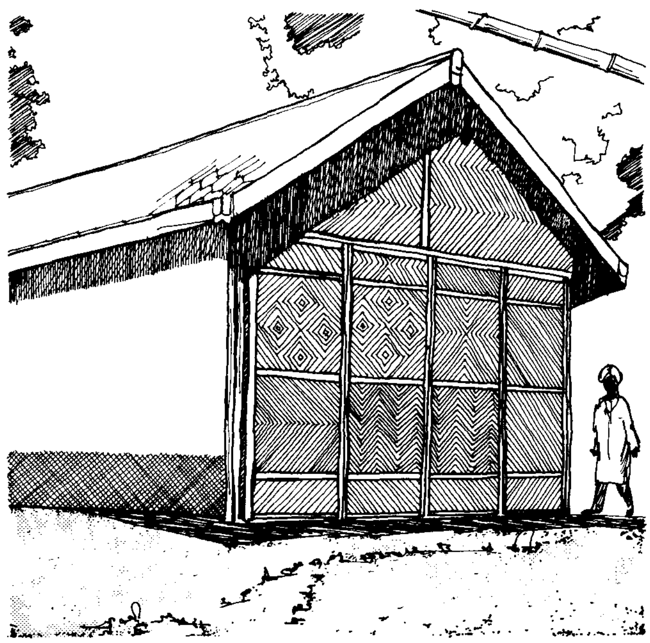


FIG.169 : EXPERIMENTAL STRUCTURE WITH WALLS OF BAMBOO MATTING, BAMBOO AND MUD AT THE FOREST INSTITUTE, DEHRA DUN, INDIA - FROM "THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION", U.N. PUBLICATION ST/SOA/113.

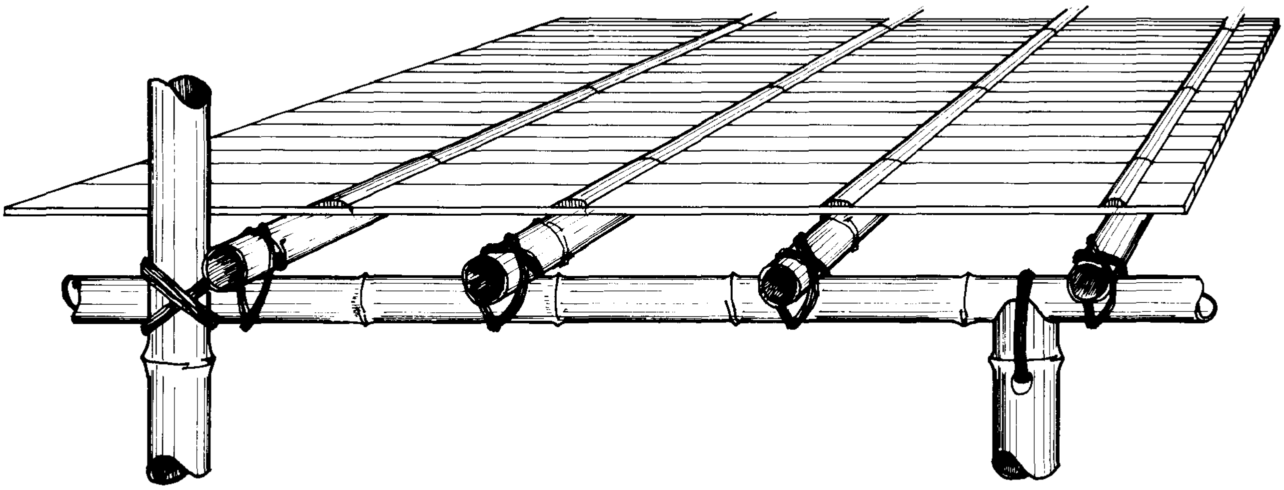


FIG. 170 : FIXING AND SECURING BAMBOO BOARD FLOORS
FLOORS ARE NORMALLY ABOVE THE GROUND WITH USABLE SPACE BELOW. SUPPORTING BAMBOO FRAMEWORK IS LASHED TOGETHER WITH THIN STRIPS OF BAMBOO. FLOOR COVERING CAN BE MADE OF SMALL WHOLE CULMS, STRIPS OR BAMBOO BOARDS MADE BY OPENING AND FLATTENING OUT WHOLE CULMS. (FROM: "THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION", DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, U.N., ST/SOA/113).

3. FLOORING:

To prevent inundation by surface drainage the floors of bamboo houses should be raised above the ground. The sheltered space below the floor can be utilized for different purposes (Fig. 170).

4. WALLS:

In Indonesia a common method of wall construction is with bamboo boards (Fig. 171). The boards are covered on both sides with closely plaited matting on internal walls. External walls are plastered on one or both sides. A fine-weave matting does normally not receive any paint or other finish. If it should be plastered the weave is arranged open (Fig. 172).

In a wattle and daub wall construction bamboo lath is used as the base for the application of mud mixed with clay, organic fibres or cow-dung on both sides. Very often this bamboo lath is eaten away by termites and the walls easily collapse. To avoid this the mud plaster may be mixed with an anti-termite solution as protection.

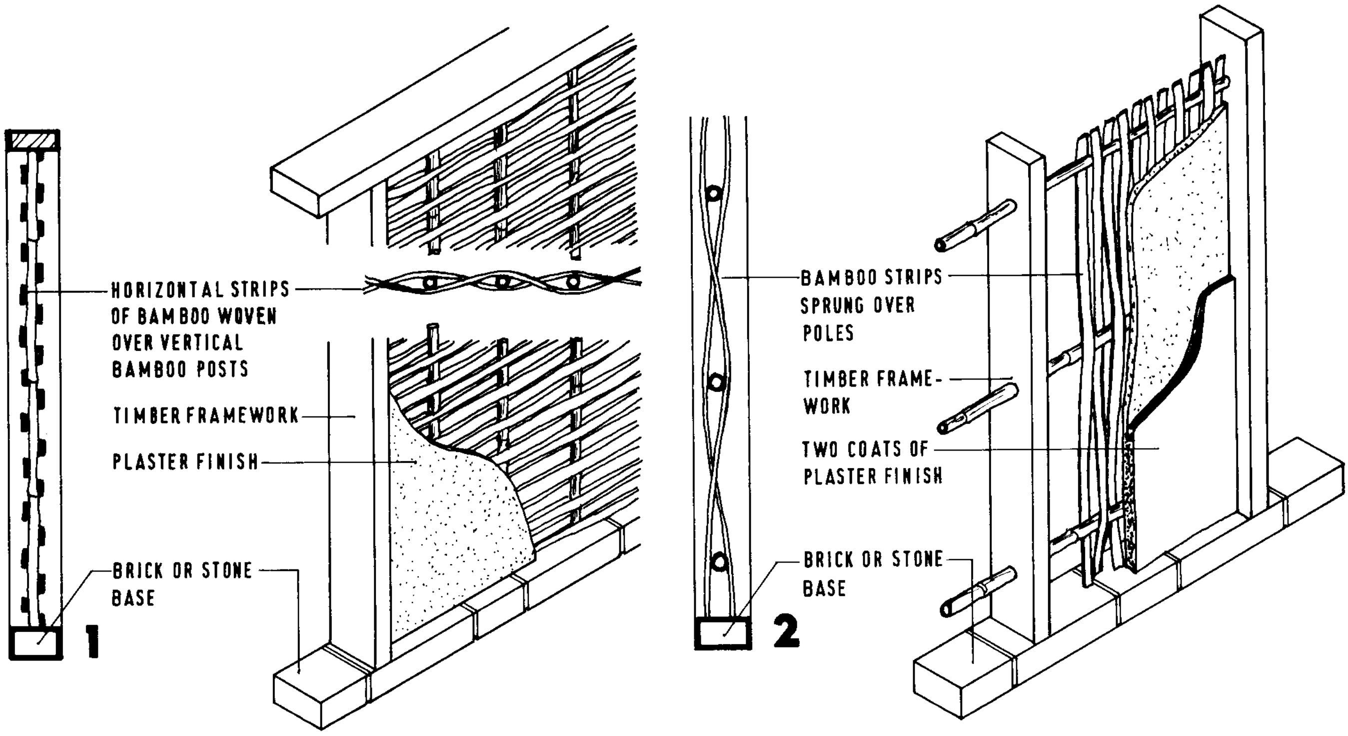


FIG.172 : **WATTLE WALL CONSTRUCTION**

1 - WOVEN BAMBOO STRIPS

2 - SPRUNG STRIP CONSTRUCTION

(FROM :"THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION," U. N. ST / SOA / 113).

Another wall construction is the wattle wall in various different variations. In all these constructions bamboo lath is used as a base for receiving mud plaster that is applied on one or both sides. The mud is mixed with clay, organic fibre or cowdung. As already mentioned it would be advisable to include in the plaster mix a solution of **Dieldrin** or other anti-termite chemicals (16 litres/m^3 of a 0.5 % emulsion).

5. ROOFING:

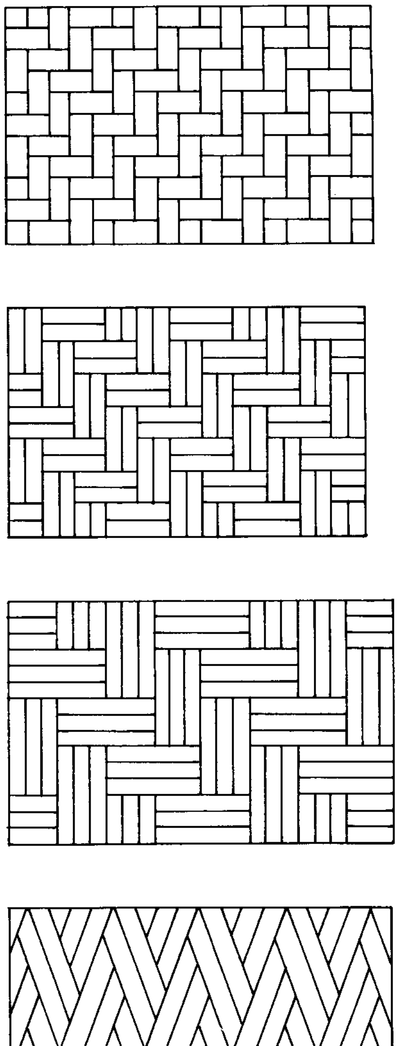
Bamboo ist frequently used for both the roof substructure and the actual roofing:

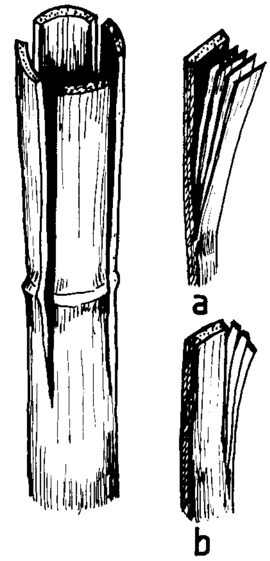
(a) **Bamboo tile roofing:** This is made of halved bamboo stems which run the full length from eaves to the ridge. Culms used for roofing tiles should be well seasoned. Minimum pitch of such **"Roman Pattern"** roof should be 30°.

(b) **Bamboo Shingles:** From very large diameter culms a type of bamboo shingle can be cut to a size of 30 to 40 mm in width and the length equal to the distance between nodes. It is rather a tedious process requiring about 200 such shingles to cover one square metre of roof surface and needing a skilled hand, but the outcome is a completely watertight (pitch ≥ 30°) and beautiful roof (Fig. 173).

6. BAMBOO SCAFFOLDING:

Since ancient times bamboo poles lashed together have been used as scaffolding. Bamboo, because of its strength and resilience is an ideal material for this purpose. In Hongkong the guild of high-rise bamboo scaffold riggers is a rather exclusive craft union. They rig up scaffolds for multi-storey structures up to 30 storeys and more by tying the scaffolding to the external walls of the structure.

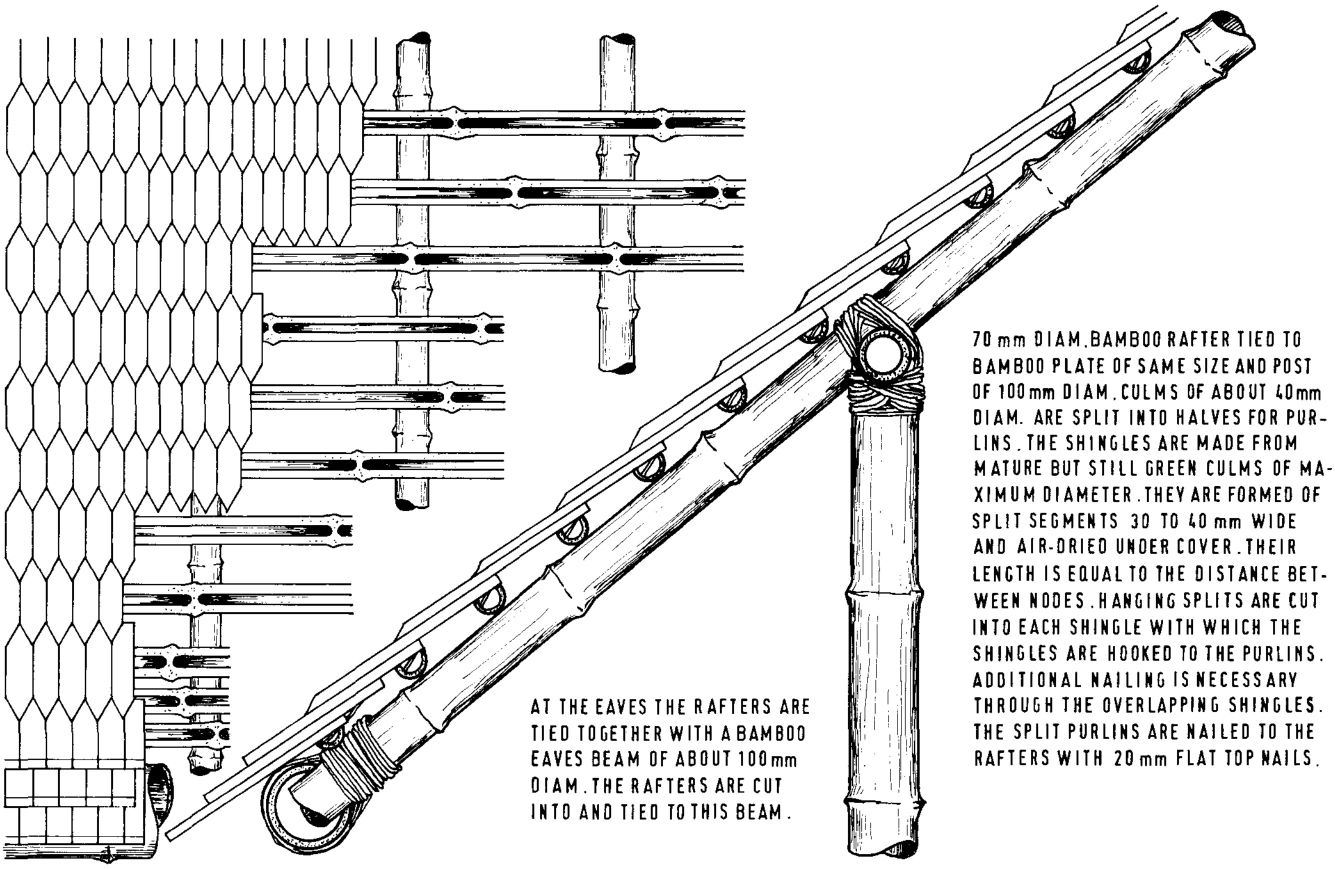




THE FULL CULMS ARE SPLIT OPEN. THE SPLIT PIECES ARE CUT TANGENTIALLY (a) OR RADIALLY (b).

BAMBOO BOARDS AND MATS ARE USED FOR FLOORING AND WALLS. THEY ARE PLAITED FROM SPLIT CULMS BY HAND IN DIFFERENT DESIGNS.

FIG.171: **BAMBOO BOARDS AND MATS** - FROM "THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION", U.N., ST / SOA / 113.



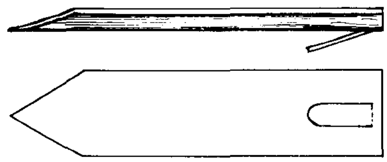


FIG.173 : **BAMBOO SHINGLE ROOF CONSTRUCTION, EAVES DETAIL AND VIEW OF SHINGLE COVER AND SUBSTRUCTURE** - FROM :"THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION", U.N., ST / SOA / 113.

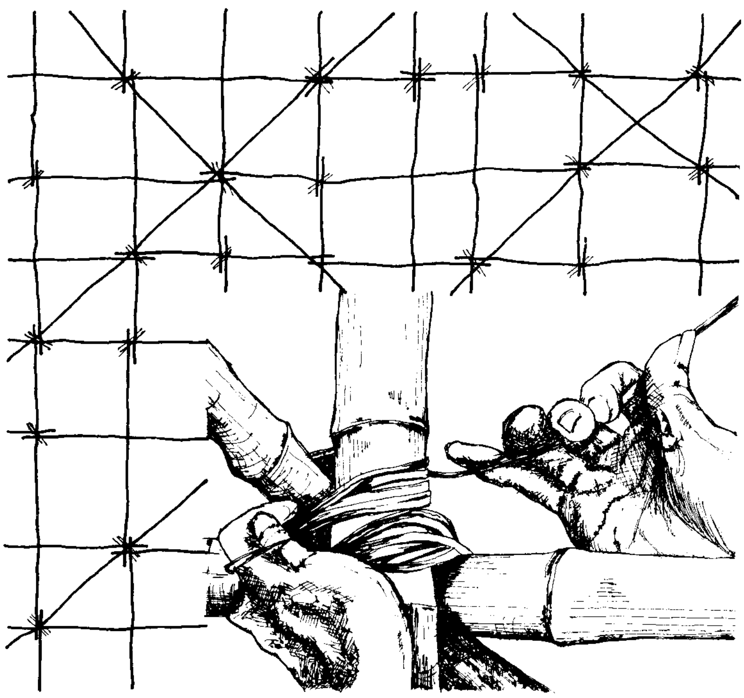


FIG.174 HONGKONG SCAFFOLD RIGGERS ERECT BAMBOO SCAFFOLDING WITH STRUCTURES MORE THAN 30 STOREYS HIGH. THE BAMBOO POLES ARE LASHED TOGETHER WITH STRIPS OF SPLIT BAMBOO. (FROM :"BAMBOO, THE GIANT GRASS" BY L. MARDEN, NATIONAL GEOGRAPHIC, VOL.158, N° 4, OCTOBER 1980).

The bamboo posts and beams of the scaffold are lashed together with strips of split bamboo. These scaffolds have withstood typhoons when tubular steel scaffolding has crumpled (Fig. 174).

7. LAMINATED BAMBOO FRAMEWORK:

A Congress took place in Jakarta, Indonesia (International SUBUD Congress) in 1971, for which 1,500 participants had to be accommodated. It was decided to build bamboo structures for the dormitories, cafeteria, dining hall, information centre etc. The dormitories were built as traditional 2-storey long house type of living quarters. For the construction of these structures a semi-prefabricated system was used in form of laminated bamboos framework.

8. JOINTS:

The different joints used in horizontal and vertical connections of bamboo are explained in Fig. 175 *and* 176. For lashing split bamboo is used in strips of 600-1000 mm length.

9. BAMBOO REINFORCEMENT OF CONCRETE:

As far back as the 1930's several experiments were carried out in Europe (Germany and Italy) and since after World War II also is Asia (China, Japan and the Philippines) to test the performance of bamboo as reinforcement in concrete beams. The most recent and comprehensive information on this subject can be found in a report by Prof. H. E. Glenn: "Bamboo

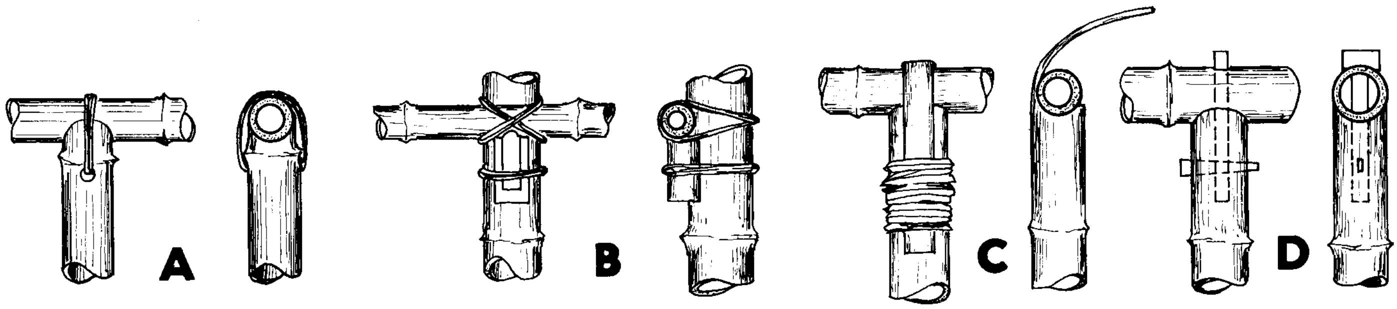


FIG. 175 : **JOINTS IN BUILDING WITH BAMBOO : BUTT, SADDLE AND SEATED JOINT.**

A – SADDLE JOINT BETWEEN A HORIZONTAL AND VERTICAL MEMBER. A HOLE IS DRILLED INTO THE VERTICAL MEMBER TO FACILITATE LASHING.

B – THIS CONNECTION, THE SEATED JOINT, USES THE STUMP AT A NODE OR AN INSET BLOCK FOR SUPPORTING THE HORIZONTAL MEMBER.

C – BUTT JOINT : A TONGUE IS LEFT AT THE END OF ONE MEMBER WHICH IS WRAPPED AROUND THE OTHER MEMBER AND LASHED TO THE FIRST MEMBER.

D – JOINT USING HARDWOOD TENDON AND KEY.

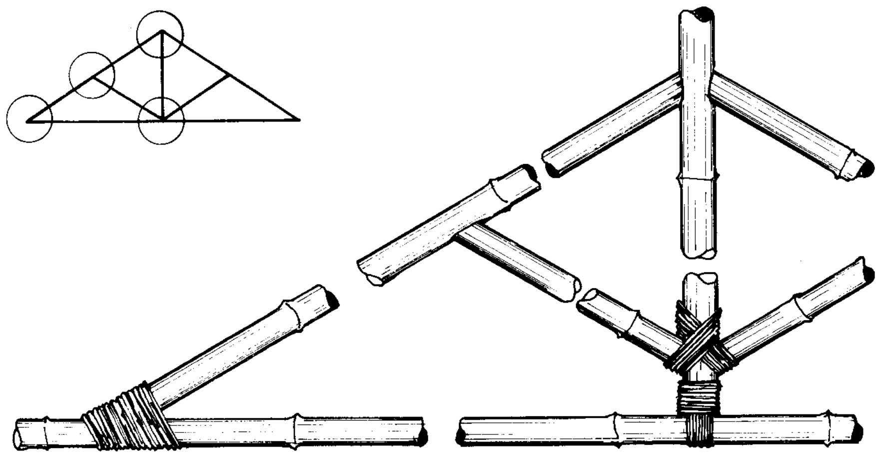


FIG. 176 : **JOINTS USED IN BUILDING A SIMPLE ROOF TRUSS** – FROM :"THE USE OF BAMBOO AND REEDS IN BUILDING CONSTRUCTION", U.N., ST / SOA / 113.

Reinforcement of Portland Cement Concrete Structures" (Clemson College Engineering Experiment Station, Bulletin 4, Clemson, South Carolina 1980 – U.S.A.) A summary of the investigations into the possible use of bamboo as reinforcement of concrete shows that:

(a) Although the ultimate tensile strength of some species of bamboo in direct tension is about the same as that of mild-steel – from 1,400 kg/cm^2 to 2,000 kg/cm^2, it is in practice not possible to make use of the complete tensile strength when it is embedded in concrete, because of the poor bond strength between bamboo and concrete and the low modules of elasticity of bamboo.

(b) Bamboo as reinforcement, even if seasoned, absorbs large amounts of water present in the wet concrete, resulting in initial swelling and subsequent shrinkage as the concrete matures, and ultimately in longitudinal cracks in the concrete and poor bond formation. This can partly be overcome by applying a water-repellent coating to the bamboo reinforcement (asphalt emulsion or coaltar).

(c) Selection, seasoning, preparation and treatment of bamboo for reinforcement should be carefully carried out. Only mature bamboo should be selected. Split (not wider than 20 mm) bamboo has better load capacities than whole culms.

Bamboo is already used as reinforcement in the Phillippines for small building structures, covers for septic tanks, working tables in markets, kitchens etc. But more research is necessary to study the effect of bamboo as a compressive reinforcement, to find more exact data on diagonal tensional reinforcement and on the bond between bamboo and concrete.

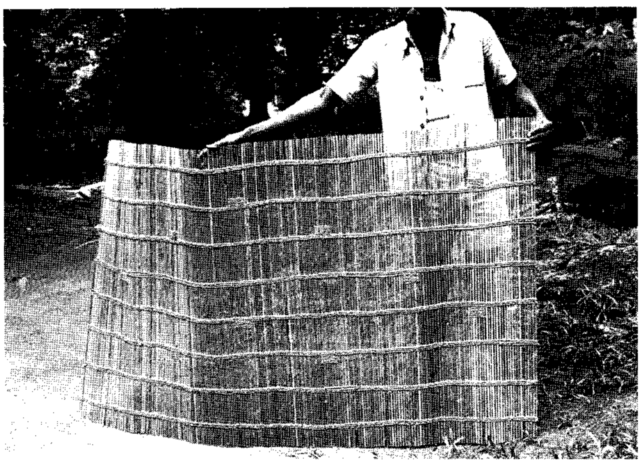


Fig. 177: Floor mat from bamboo, made in Ghana, 1980.

3.2 MAN-MADE MATERIALS

In this section materials developed by man from the raw material stage through a process of extraction, processing, dressing and manufacturing to finished and usable building materials will be described. To a large extent these materials or the raw materials from which they are produced are imported and contribute to the high cost-factor in construction in tropical developing countries (especially when considering the dependency on the price fluctuations on the overseas market for basic materials as well as equipment and construction plant), and also use scarce foreign currency reserves. An attempt will be made to explain the use of possible substitutes for some of these raw materials from local sources in Ghana.

Examples will be described of similar developments in other developing countries with conditions resembling those of Ghana. One part in this section will deal with the production of building materials from agricultural, forestry and industrial wastes.
The importance of establishing building material industries using local materials and available wastes has been recognized by many developing and developed countries. In these countries different areas for development in the building materials industries have been identified. In Ghana these areas are:

(a) Materials for all construction (stabilized soil blocks and bricks, burnt clay bricks, stones);
(b) Materials for the structural framework – foundations, columns, beams, slabs (cement, lime, pozzolana, steel, timber);
(c) Materials for roof construction (burnt clay tiles, aluminium, asbestos-cement and materials from waste).

3.2.1 STABILIZED SOIL BLOCKS

When soils are stabilized with certain stabilizing agents these impart improved properties to the soils which they alone do not possess: Better technical quality, higher mechanical strength, durability, better cohesion and with this better thermal properties.
The principle of stabilizsation is therefore to increase the strength of the soil and to maintain it to a reasonable extend when wet. This is achieved by adding:

(a) Cementitious materials (mostly Portland cement) in quantities which will cement the soil particles together in a similar way as binding of an aggregate in ordinary concrete;
(b) Hydraulic lime and lime pozzolana mixes. Pozzolanic reaction occurs between lime and some clay minerals to form different cement-like compounds which act on the soil as cement. Lime stabilizes the soil against changes in the moisture content;
(c) Bitumen, asphalt and certain resins. These are waterproofing agents which provide a physical barrier against the passage of water.

In most cases the addition of Portland cement is sufficient to help resist moisture movement.
The proper soil for stabilization with cement does not shrink appreciably when dried, is very compactable, should consist of a right mixture of sandy, silty and clayey materials and achieves high strength. The mixture should be prepared and processed in the following way:

1. Mixing of components;
2. Compaction of mixture;
3. Drying and curing.

Before this it is essential to choose a well graded soil. This will contain the correct proportion of different particle sizes. The soil should be completely free of organic matters and soluble salts.
Tests have shown that an addition of 4 % to 8 % cement is sufficient to produce a block which has a compressive strength similar to or even greater than an ordinary fired clay brick.

To determine the correct amount of water for the mixture a simple test should be made: One takes a handful of the prepared mixture and squeezes it inside the hand. If the mixture retains the shape of the hand, does not soil the hand, can be pulled apart without disintegrating and, upon dropping it from a height of about 1.00 m disintegrates into loose material on the ground similar to the original mixture, then the mixture has the correct amount of water.

There are different ways of making blocks. The simplest is with the help of moulds. These are normally made from wood, rigid or from detachable parts and hinged, with a rammer of the same material. More commonly used are mechanical (hand-operated) moulders which have been developed as simple presses. These are:

CINVA-RAM

Originally designed by the Inter-American Housing and Planning Centre (CINVA) in Bogota, Columbia (Fig. 130), this hand-operated press is now manufactured in several countries under licence from the IBEC-Housing Corporation in New York, U.S.A. Block size produced is 290 x 140 x 90 mm, solid or half-hollowed. Manufacturer: CINVA-Ram, Metallibec Ltd., Bogota, Columbia.

TEK-BLOCK PRESS

Designed and manufactured by the Department of Housing and Planning Research, Faculty of Architecture of the University of Science and Technology in Kumasi, Ghana, this press has a lever arm made from timber instead of the 3-piece metal arm used for the Cinva-Ram. The TEK-Block press requires less numbers of operations than the Cinva-Ram (Fig. 131 *to* 135). Block size produced is 290 x 215 x 140 mm. From one bag of cement as stabilizer 60 soil- cement blocks can be produced (4 % cement addition), which are suitable for all structural and external walls. For foundation walls the cement mix should be richer, from 6 % to 8 %, these blocks should also be allowed to dry and cure longer than the blocks for the walls.

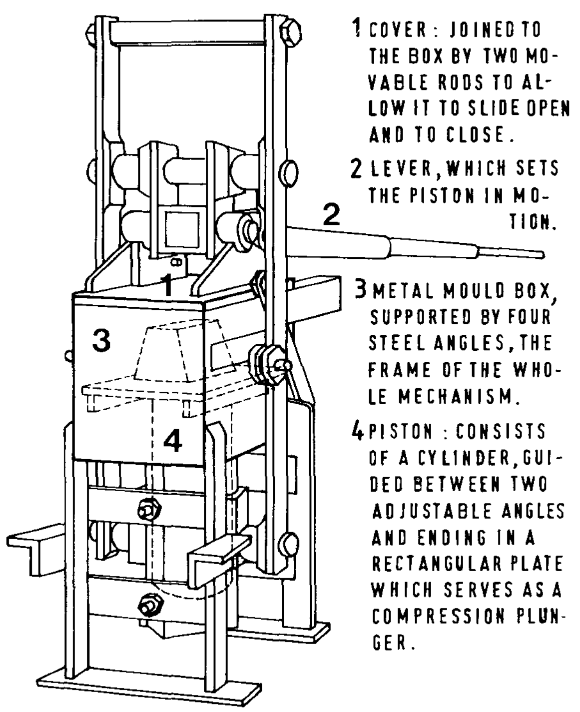


FIG.130 THE CINVA-RAM BLOCK PRESS
(FROM "SOIL-CEMENT, ITS USE IN BUILDING", U.N. DEPARTMENT OF ECONOMIC AFFAIRS, ST/SOA/54.)

THE TEK-BLOCK PRESS FIG. 131

1 FILLING THE MOULD BOX
2 SWINGING THE HANDLE OVER TO THE OTHER SIDE
3 PRESSING THE BLOCK
4 EJECTING AND REMOVING THE BLOCK

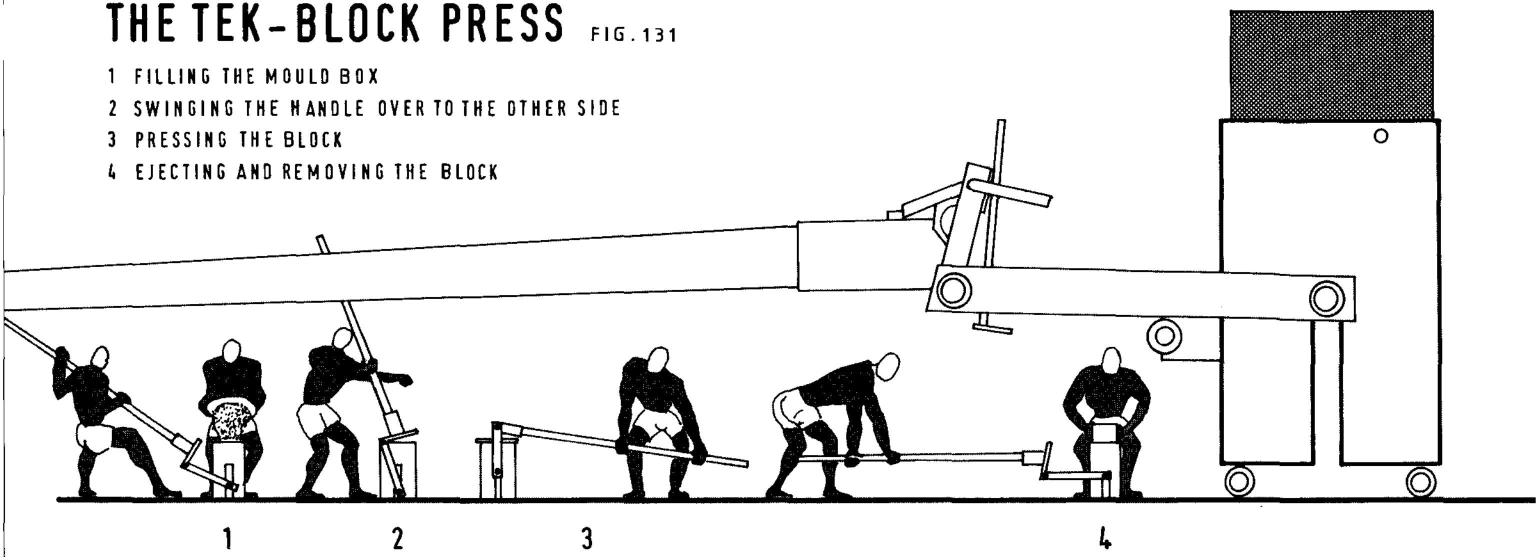


Fig. 132: Blockmaking with the TEK-Block Press, 1979: Filling the mould;

Fig. 133: ...pressing the block;

Fig. 134: ...compressing it further;

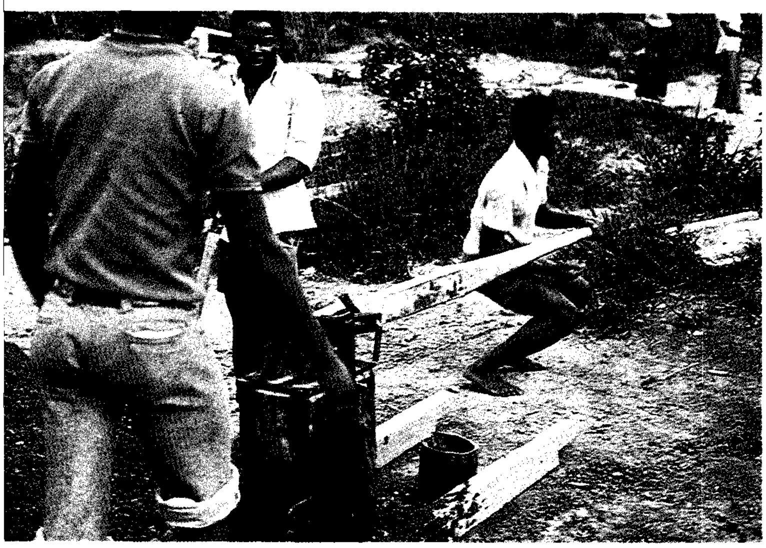


Fig. 135: ...removing the finished block.

EARTH AND LOAM-BLOCK PRESS (CENEEMA)

This is a block press which works on a similar principle as the TEK-Block Press (Fig. 136). It was developed in the Republic of Cameroon and produces stabilized soil blocks to the size of 300 mm x 100 mm (height) x 140 mm (width).

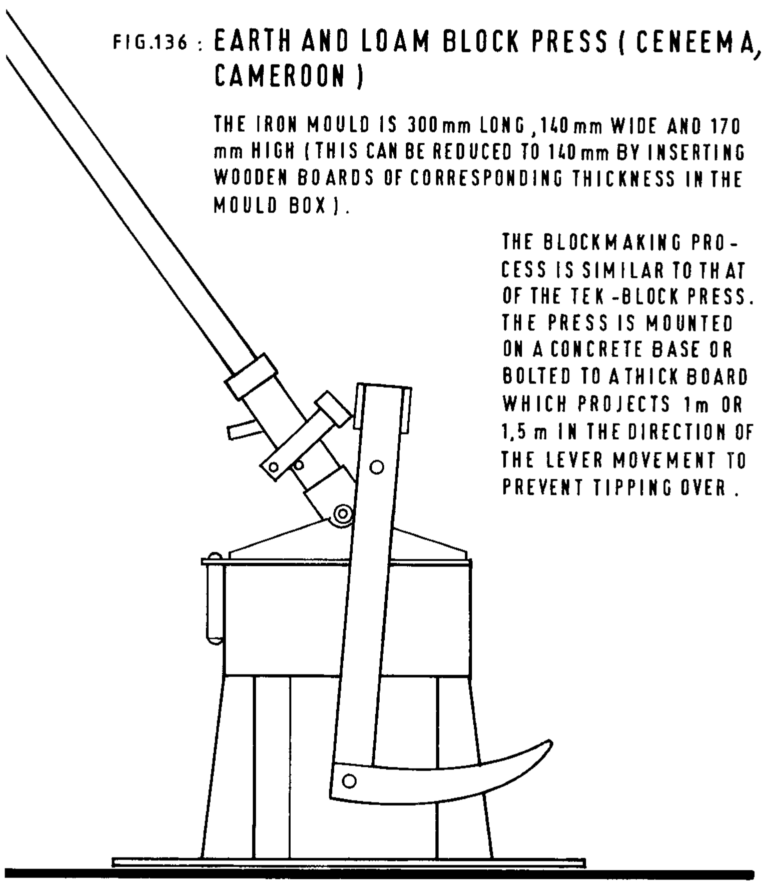


FIG.136 : EARTH AND LOAM BLOCK PRESS (CENEEMA, CAMEROON)

THE IRON MOULD IS 300mm LONG ,140mm WIDE AND 170 mm HIGH (THIS CAN BE REDUCED TO 140mm BY INSERTING WOODEN BOARDS OF CORRESPONDING THICKNESS IN THE MOULD BOX).

THE BLOCKMAKING PROCESS IS SIMILAR TO THAT OF THE TEK -BLOCK PRESS. THE PRESS IS MOUNTED ON A CONCRETE BASE OR BOLTED TO A THICK BOARD WHICH PROJECTS 1m OR 1,5 m IN THE DIRECTION OF THE LEVER MOVEMENT TO PREVENT TIPPING OVER .

ELLSON BLOCKMASTER

Manufactured in South Africa by Ellson PTY., this hand-operated press has as higher lever ratio (500-1) and produces very dense blocks. It is also easier to operate, with the mould approximately 860 mm above the ground compared to the Cinva-Ram and TEK-Block Press which are both 500 mm from the ground to the top of the mould. Blocks are of different sizes, solid or hollow. Manufacturer: Elson Equipments (Pty.) Ltd. Johannesburg, South Africa.

There are a number of power-operated soil-cement presses for high-speed production of soil-cement bricks or lime-stabilized laterite blocks in an industrial process:

SUPERTOR

A Brasilian press powered by a 5 HP electric motor with an operational output of 20,000 soil-cement bricks per 8-hour use. Manufacturer: Torsa Maquinas Equipamentos Ltd., São Paulo, Brasil.

LATOREX

A Danish high speed production plant producing about 12,000 lime-stabilized laterite blocks per day. Size of blocks: 230 x 110 x 55 mm.

A mobile soil brick plant has also been developed by CONSOLID AG. in Switzerland and successfully tested in different tropical developing countries, including Ghana (Fig. 137). Their "CLU-3000" mobile plant has a compaction pressure of 50 kg/cm^2 and produces 350 to 500 bricks per hour in the metric size 250 × 120 × 75 mm or imperial size bricks 5" × 4⅛" × 2⅝" (219 × 105 × 67 mm). The plant is powered by a 13 HP Diesel engine with a fluid pump. A mixer performs the soil treatment (with added chemicals for water-proofing) and filling of the four moulds.

When stabilized soil blocks or bricks have been pressed, they must be allowed to dry and mature with adequate protection against sun and rain (in a drying shed) on a dry and level surface for about three weeks. For the first 24 hours loss of moisture must be strictly controlled. After twenty-four hours the blocks should be regularly watered with a sprinkler (watering can). They can be stacked or piled after three days, but should still be watered for up to one week after casting. They can be used for construction 21 days after they are made.

Fig. 137: Experimental house built with soil bricks produced by a "CONSOLID CLU – 2000 PRESS", at OKPONGLO near Legon, Accra (built in 1978), 1981.

3.2.2 CONCRETE

The word concrete originates from the Latin word Concretus meaning "grown together, compounded". Concrete is a mixture of a cementitious material, aggregates and water.

There are early records of uses of lime as a cementitious material. The use of lime in mortar for bedding stones, bricks, and blocks in wall construction is the most traditional and most widespread. Early examples are the pyramids of Egypt (**Cheops**) 2,560–2,475 B.C., the Great Wall of China, the Temple of Apollo in Greece (around 500 B.C.) and the use of lime concrete by the Etruscans in Italy. The Romans made pozzolanic cement in 75 B.C. from a red volcanic powder found at Pozzuoli near Mount Vesuvius, Naples. They also developed lightweight concrete by introducing crushed pumice as an aggregate.

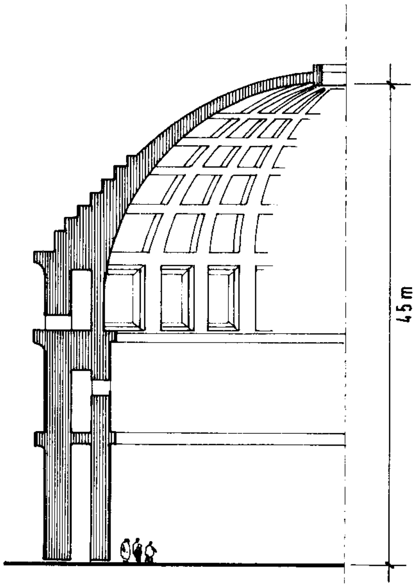


FIG.178: **PANTHEON, ROME**

BUILT UNDER EMPEROR HADRIAN IN A.D.120.

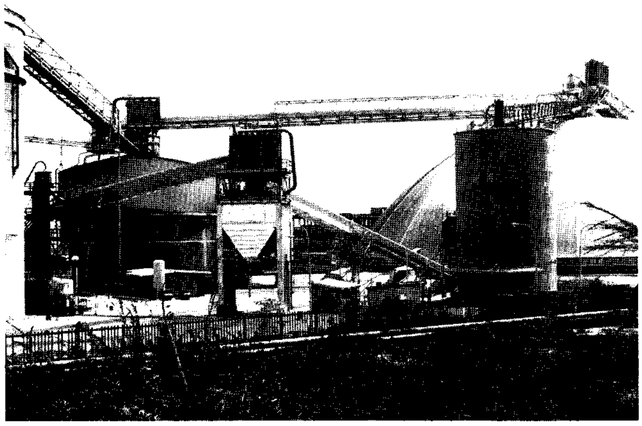


Fig. 179: Part of the Cement Works in Tema, 1981.

The arches of the **Colosseum** and the dome of the **Pantheon** were built with this material (Fig. 178). After the decline of the Roman Empire in the 5th century the next recorded use of concrete is the Norman structure of Reading Abbey in Britain in 1121. In 1824 Joseph Aspdin patented his improvement upon hydraulic lime (produced by burning chalk or limestone which contain clay) in Britain and called the product **Portland cement**, because it resembled Portland stone. It was the beginning of the industrialized production of cements.

CEMENT

Cement can be described as powdered material which, when mixed with water and aggregates (including sand) in the correct proportions can be moulded in the plastic stage und which will set into a hard and durable material which is concrete. Ghana used to import her complete processed cement materials until the early 1960's. From then onwards the greater porportion of it is processed from imported clinker and gypsum which are ground at two factories in Tema (Fig. 179) and Takoradi.

The raw materials used in making all types of cement are substances containing calcium carbonate ($Ca\ CO_3$) such as chalk or limestone and substances containing silica, alumina and iron oxide such as clay or shale. Cement clinker is produced by burning, in a rotary or shaft kiln, intimately blended mixtures of these substances which are carefully proportioned. In the mills the clinker ist subsequently ground to a fine powder. During the grinding a small proportion, 4-7 % of hydrated calcium sulphate (gypsum) is added to control the setting process. In Ghana Portland cement with a medium rate of hardening which is suitable for most types of concrete work etc. and rapid hardening Portland cement are produced.

(Ghana Standard Applicable:
G.S. 22-1970: Ordinary and rapid hardening Portland Cement).

TYPES OF PORTLAND CEMENT

(a) **Ordinary Portland Cement**: Produced as described above. The reaction of minerals present in Portland cement are: Dicalcium Silicate for strength at longer ages; Tricalcium Silicate and Tricalcium Aluminate for setting and early strength characteristics; Complex Ferrite Phase for early strength development.

(b) **Rapid Hardening Portland Cement**: This cement is more finely ground. Its mineral composition may be modified to contain a slightly higher proportion of Tricalcium Silicate resulting in more rapid reaction with water. The ultimate strength value is the same as that of ordinary Portland cement.

(c) **Sulphate Resisting Portland Cement**: This cement is formulated to give a better resistance to attack by sulphates present in the ground or in sea water. This is achieved by adjusting the chemical composition in reducing the proportion of Tricalcium Aluminate by 5 % (the mineral most affected by sulphate salts).

(d) **Low-heat Portland Cement**: The earlier the strength development of Portland cement, the greater the heat produced in the process. This may not be desirable for certain types of concrete work using large masses of poured concrete (eg. dams, large floor slabs etc.). By increasing the proportion of Dicalcium Silicate and reducing that of Tricalcium Silicate and Tricalcium Aluminate the total amount of heat generated when setting is reduced.

(e) **White or Coloured Portland Cement**: White cement requires a choice of special raw materials such as white china clay, white marble or pure chalk to exclude iron oxide which imparts grey colour to the cement. Coloured cements are produced by addition of suitable inorganic pigments to either white or ordinary Portland cement, depending on the depth of colour required.

There are a variety of other cements which are produced by intergrinding with or intimately blending of Portland cement with other materials, e.g. **Granulated Blastfurnace Slag** (achieves slower hardening and an improved sulphate resistance) or **Pozzolanic Materials** (achieve low heat properties, reasonable sulphate resistance, are used for construction in sea water). **High Alumina Cement** (which contains a higher percentage of alumina and less lime and silica, produces a concrete of very early strength, high sulphate resistance and generates more heat on hydration) is **not** recommended for use in tropical conditions for structural works because it looses strength if exposed to maturing temperatures higher than 30° C. There ist an increasing tendency to use chemical products as admixtures to cement mortars and concrete mixed with Portland cement with the objective of improving one or another quality:

- **Workability Aids**: To improve the flow characteristics of the wet concrete, or to reduce the cement: water ratio in order to increase the strength of the concrete;

- **Accelerators** (e.g. Calcium Chloride, Magnesium Chloride and Alkali Carbonates-Carbon Dioxide);

- **Retarders** (e.g. lignosulphonic acids and their salts): I. Sodium or Calcium Lignosulphonate; II. Hydroxylated Carbooxydic acids such as gluconic acid and their Ca, Na or triethanolamine salts; III. Non-ionic agents such as:
  (a) Carbohydrates – sugars, polysaccharides and dextrins;
  (b) Water-soluble derivations of cellulose and of silicones);

- **Damp-proofing and Permeability Reducing Agents**: To shed water from the surface of the concrete, to prevent water movement by capillary action and to reduce permeability of the set concrete (mainly used for concrete roof slabs and on exposed concrete structures).

POZZOLANA-CEMENT

The estimated cement requirements in Ghana are exceeding 1.5 million tons per annum. The output of the two local factories is far less than this figure. The shortage of exportable clinker from the industrialized countries is due to increased fuel costs (cement clinker production involving calcination at temperatures around 1,450° C is an energy-consuming process) which these countries are facing as a result of higher prices for this raw material and is leading to a reduction in the import rather than an increase.
One step to arrest this situation is to utilize Ghana's own limestone and clay deposits for the manufacture of cement clinker. The tendency is to establish small-scale but technically well supervised lime manufacturing plants for the production of lime which can be used for masonry and brick bonding and rendering. The Building and Road Research Institute in Ghana has already carried out extensive research on the production of pozzolana from bauxite-waste from bauxite mining at present undertaken in the country (with proposals to develop other bauxite reserves in the country). This pozzolana could replace 20-50 % of the conventional cement clinker in the local cement production. Its addition to cement would result in the following properties:

- Reduction of heat of hydration and thermal shrinkage;
- Improvement of workability;
- Reduction in porosity of the concrete;
- Increased sulphate and sea water resistance;
- Elimination or reduction of alkali aggregate reaction;
- Lowering the susceptibility to dissolution and leaching;
- Cost reduction. ("Pozzolana from Bauxite – waste" by A. A. Hammond, B.R.R.I., Kumasi Ghana).

The bauxite-waste pozzolana is a substitute material which, when turned into pozzolana-cement is an acceptable alternative for Portland cement. It reacts chemically with calcium hydroxide to form a stable cementitious material. If lime is mixed with it the resulting lime – pozzolana cement can be used for concrete.
In India a pozzolanic material known as **Surkhi** is extensively used in conjunction with lime (which is manufactured in many small-scale plants throughout the rural areas of India). Surkhi is essentially pulverised fired clay or brick-earth produced by disintegrating unterfired, broken or rejected bricks from the brick and tile kilns. Lime and surkhi are natural alternatives for cement in building. However, village produced lime and surkhi is not standardized and therefore varies in quality.

It is essential to organize any small-scale production on a similar level, with set standards for its production, as it is the practice with larger, centralized industrial plants. This will ensure the manufacture of a product of acceptable quality.

AGGREGATES

There are two groups of aggregates used for concrete mixes, dense and lightweight aggregates. Aggregates used for concrete must be clean and free of organic impurities (dust, clay coatings, organic matter etc.), they should be hard and low in absorption of moisture if exposed to weather in the concrete.

I. **Dense or Normal Aggregate**:

Fine aggregates are materials passing a 5 mm sieve e.g. crushed stone sand, crushed gravel sand and natural sand. Coarse aggregate is retained on a 5 mm sieve e.g. natural gravel, crushed gravel and crushed rock (*see* **"Sand"**, **"Gravels"**). All-in-aggregate is a material composed of the two foregoing. Dense aggregate is used in Ghana for concrete mix and cement-sand (fine aggregate) mortar and plaster mix. There are other types of dense aggregates:

- **Blastfurnace Slag**: Air-cooled blast furnace slag is a by-product in the manufacture of pig iron. It is suitable as coarse aggregate for concrete.
- **Broken Brick**: Good quality crushed brick can be used as aggregate for mass concrete work where a high degree of permeability is not required. The brick used should be free of adhering pieces of mortar, plaster and dust.
- **Heavy Aggregates**: Iron shot, magnetite, barytes. These are used for providing a very high density concrete needed for radiation shielding (X-ray rooms etc.) and for high sound insulation. With iron shot, the heaviest concrete density has been obtained with up to 5,250 kg/m^3

II. **Lightweight Aggregates**:

These aggregates include natural aggregates such as **Pumice**, by-product materials such as **Furnace Clinker** or processed aggregates such as **Foamed Slag, Sintered Fly Ash, Expanded Clay, Expanded Vermiculite** (a micaceous mineral, which exfoliates on heating) and **Perlite** (Obsidean or other vitreous rock in form of enamel-like globules). These lightweight aggregates help produce a light or very light concrete which is used mainly as insulating concrete.

In Ghana crushed mineral aggregates used as dense or normal aggregate are mostly obtained from rocks. River shingle and gravels are also used for concrete work for smaller buildings. Artificial aggregates derived from metallurgial and other processes (as mentioned above) are not available in Ghana. The mechanical properties of an aggregate are less important in concrete work than its **grading** and **shape**.

TYPES OF CONCRETE

(a) **Dense or Plain Concrete**

Throughout the world the concrete used most for all normal structural concrete work is dense or plain concrete. It is composed of proportions of cement, sand, coarse aggregate and water. These are thoroughly mixed. The proportions should make it possible:

- to achieve a low water: cement ratio for strength and durability;
- to achieve a satisfactory workability in order to be easily compacted to give a dense and homogenous product with a clean surface;
- to achieve as lean a mix as possible, having minimum shrinkage and creep.

High density in concrete is associated with high strength, hardness, durability and imperviousness.
Nominal concrete mixes vary. General practice has been to specify nominal mix proportions by volume such as 1:2:4 (1 part cement to two parts sand to 4 parts coarse aggregate respectively). Specifications include minimum compressive strength requirements. For structural concrete work the cement: aggregate proportions vary between 1:2.5 and 1:12 (all-in) with an acceptable water: cement ratio $\left[\frac{\text{total weight of water}}{\text{weight of cement}}\right]$ of not higher than 0.7 (for reinforced concrete under tropical conditions). Acceptable compressive strength limits at 28 days for most of the structural concretes range between 10 N/mm^2 to 70 N/mm^2. For testing concrete mixes on site 7 days strenghts are taken. In tropical climates 7 days strengths of concrete mix are generally 75 % of the 28 days strenghts in the case of good quality concrete. Dense concrete made with ordinary Portland cement has strength properties which increases with age (with a maximum to be reached at about 12 months). The density of well compacted plain concrete will vary between 2,150 kg/m^3 and 2,500 kg/m^3 (Fig. 180). Dense concrete can be designed to have additional specific characteristics which will be achieved through certain chemical admixtures. Some of these characteristics are:

- Colour;
- Low permeability;
- Low abrasion;
- Chemical resistance;
- Suitability for casting against special forms or for subsequent tooling.

The normal practice in building is to mix the concrete on the site (Fig. 181). But delivery to the site of ready-mixed concrete is particularly useful where space for storage of materials and for mixing is restricted. Ready-mixed concrete can make high quality concrete and special mixes available, especially on small urban sites.

(b) **Lightweight Concretes**

These are concretes which weigh less than 1920 kg/m^3 and are made in densities down to 150 kg/m^3.
There are advantages in using lightweight concretes:

- Lower costs of hauling and handling materials;
- Reduction of dead loads;
- Superior thermal insulation and fire resistance;
- Superior sound absorption;
- Faster building rate.

Lightweight concrete is produced in three different ways: By omitting the fine aggregate ("No-fines concretes"), by using lightweight aggregate instead of the usual dense crushed gravel or rock ("Lightweight aggregate concretes") and by incorporating air or gas bubbles into a matrix of cement ("Aerated concretes") (Fig. 182).

Fig. 180: Concreting dense concrete with a vibrator. First floor slab of the Members' Lobbies at the Parliament House extensions in Accra. Architect: HANNAH SCHRECKENBACH, 1970/71.

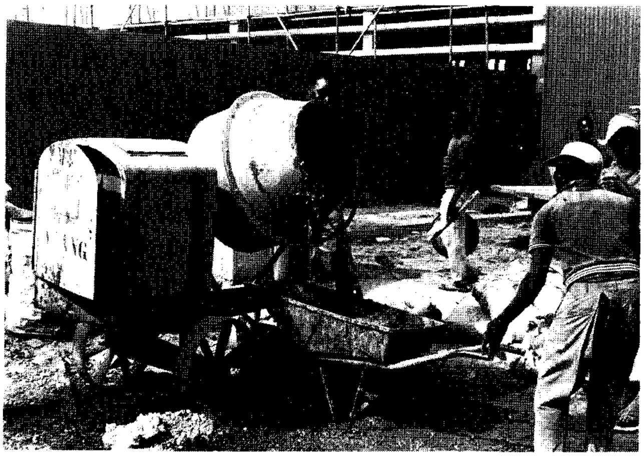


Fig. 181: An end-over tumble concrete mixer at the Parliament House site.

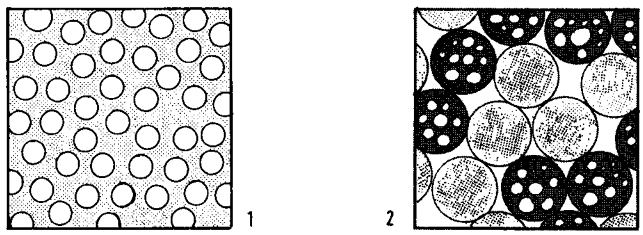


FIG. 182 LIGHTWEIGHT CONCRETE
1 AERATED CONCRETE - VOIDS IN MATRIX
2 LIGHTWEIGHT AGGREGATE CONCRETE WITH VOIDS IN THE AGGREGATE
FROM :"MATERIALS" BY A.EVERETT, BT BATSFORD LTD., LONDON.

I. **No-Fines Concrete:**

These concretes contain only single size aggregate of 10 to 20 mm with sufficient cement (cement: aggregate ratio 1:16 to 1:10 by volume) to join the particles while leaving voids between them. These pores effectively prevent capillary action. The lean mix and the fact that the aggregate particles are in point contact, result in a very small drying shrinkage and moisture movement. No-fines concrete is almost always cast in situ and used for loadbearing and non-loadbearing walls.

II. **Lightweight Aggregate Concretes:**

Aggregates used for these concretes are clinker, foamed blastfurnace slag, expanded clay or shale, sintered pulverized fuel ash, pumice, exfoliated vermiculite, expanded perlite. The lightest concretes (800 to 1500 kg/m^3) are used for thermal insulation screed. They have very low strength properties. Intermediate densities are suitable for building blocks.
Structural (reinforced) lightweight aggregate concrete needs full compaction to achieve a good bond between steel and the concrete. If the structure is in an exposed position, concrete cover over the reinforcement should not be less than 50 mm, the maximum aggregate size should not exceed 13 mm.

III. **Aerated Concretes:**

These concretes have the lowest densities, strengths and thermal conductivities. There are two ways of effecting aeration:

- Gas is generated within the mix during its plastic condition by the chemical reaction between aluminium powder and a calcerous binder. This method is used for making pre-cast units which are subsequently autoclaved to have reasonable strength and low drying shrinkage.

- Air bubbles are introduced into the mix either by adding a prepared foam to a cement-sand slurry and mixing it in a concrete mixer or by using a foaming agent with a cement-sand mix in a special mixer to produce a fine foam. The air bubbles are retained when the concrete is set. Density of aerated concrete is 400 to 1000 kg/m^3.

Both lightweight aggregate concretes and aerated concretes are not produced in Ghana.

(c) **Reinforced Concrete**

Concrete has a very much higher strength when it is under compression, than when it is subjected to tension. Its tensile strength is only about 1/10 of its compressive strength. The purpose of reinforcing concrete is to provide a material with a high tensile strength, which can be embedded in the concrete in such a way that it is able to take the tensile and shear stresses and at the same time allows full advantage to be taken of the high compressive strength of concrete. Reinforcement may also be needed at times to supplement the compressive strength of concrete or to control cracks.

The material which is suitable as reinforcement is **Mild Steel** or **High Tensile Steel** (*see* Table 3). Mild steel bars which are normally used as reinforcement material:

- have tensile strength;
- are capable of developing this tensile strength with comparatively small strain on elongation;
- have a surface which will bond well with concrete when this is cast all round it;
- have the same coefficient of thermal expansion as concrete.

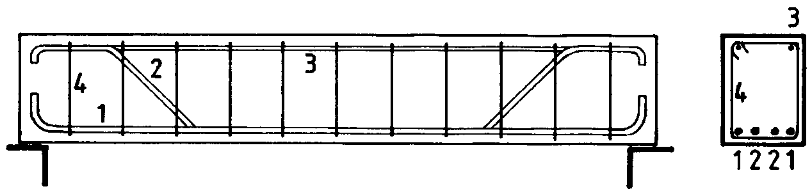
High tensile steel is used for prestressed concrete work.

In the Steelworks in Tema, Ghana manufactures reinforcement steel bars and a limited range of structural steel sections, such as angles and flats from scrap iron (Fig. 183).

The following types of reinforcements are necessary in structural concrete work:

- **Tension Reinforcement:**

  Tension reinforcement will be placed near the bottom face of simple supported structural members and in central positions of continuous members and near the upper face of cantilevers and continuous members as they pass over their supports (Fig. 184).



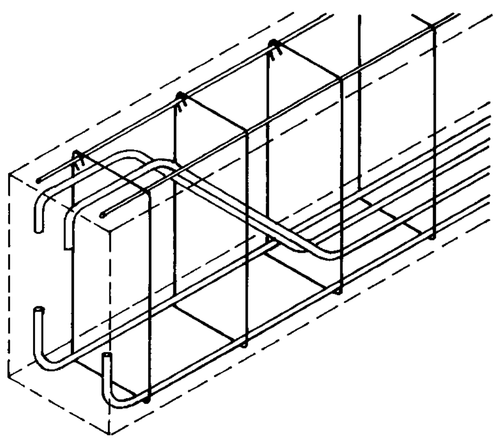
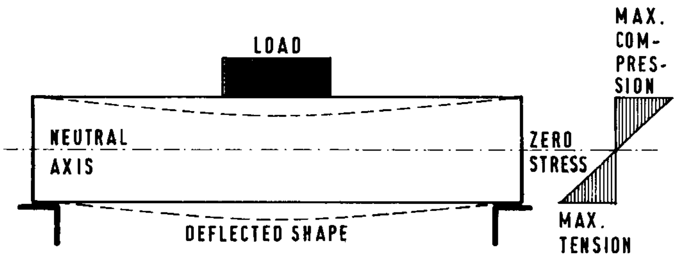
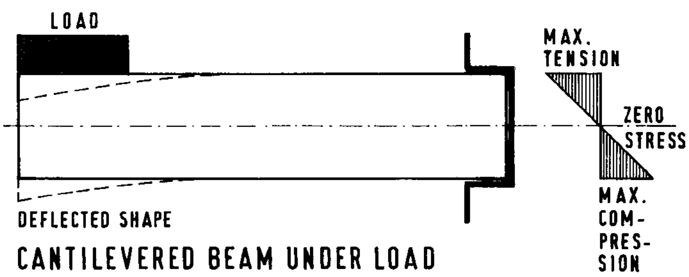


FIG. 184 TENSION AND SHEAR STRESS REINFORCEMENT IN A NORMAL SUPPORTED BEAM UNDER LOAD

1 STRAIGHT TENSION BARS
2 BENT-UP TENSION BARS
3 NOMINAL BARS FOR HOLDING UP TOP OF STIRRUPS
4 VERTICAL STIRRUPS



SIMPLE BEAM UNDER LOAD



CANTILEVERED BEAM UNDER LOAD

METALS	DENSITY kg / m³	PROOF STRESS 0·1 PER CENT N / mm²	TENSILE STRENGTH⁺ N / mm²	ELONGATION ON 50mm PER CENT	MODULUS OF ELASTICITY E N/mm²	THERMAL CONDUCTIVITY W/m deg C	MELTING POINT °C
COPPER (Cu) 99·2 - 99·9 % PURE	8940	46 - 371	216 - 355	8 - 65	96 600 - 132 000	400	1083
BRASS 60%Cu : 40% Zn	8380	108 : HOT-ROLLED 386 : COLD-ROLLED 124 : COLD-ROLLED & ANNEALED	371 : HOT-ROLLED 541 : COLD-ROLLED 386 : COLD-ROLLED & ANNEALED	40 : HOT-ROLLED 5 : COLD-ROLLED 45 : COLD-ROLLED & ANNEALED	103 300	129	904
MILD (STRUCTURAL) STEEL	7850	-	423 - 510	22	207 000	52 - 63	1900
HIGH STRENGTH STEEL	7850	350 - 430	495 - 617	19	207 000	52 - 63	1900
STAINLESS STEELS Fe : Cr : Ni : (Mo)	7850	210	510 = 18 Cr : 10 Ni 540 = 17 Cr : 11 Ni : 2·5 Mo	50	207 000	15	1490 1430
WROUGHT IRON	7850	-	355	25 - 40	207 000	-	-
GREY CAST IRONS×	7150 = AVERAGE VALUES	100 - 200	155 - 310	0·5 - 1·0	120 000 = AVERAGE VALUES	45 - 50	1150 - 1350
ZINC (Zn) 99·99 % PURE	7140	-	139 : PARALLEL TO DIRECTION OF ROLLING 216 : PERPENDICULAR TO DIRECTION OF ROLLING	: 25 : 10	96500	113	419
ALUMINIUM ALLOY HE 30 TF	2700	270 : BARS AND SECTIONS	315 : BARS AND SECTIONS	18	69 950	184 - 206 VARIOUS ALLOYS	570 - 660
ALUMINIUM (Al) 99·0 % PURE	2650	-	70 - 140	2 - 20	68 300 - 72 400	214	660
99·99 % PURE		-	80 - 100	3 - 45		244	

× RANGES GIVEN RELATE TO METHODS OF FORMING AND CONDITION.

⁺ RANGES, EXCEPT FOR MELTING POINT, ARE FOR LOW-HIGH STRENGTH IRONS.

TABLE 3 : **PROPERTIES OF SOME METALS** - FROM : "MATERIALS" BY A.EVERETT, MITCHELL'S BUILDING CONSTRUCTION, B.T. BATSFORD LTD., LONDON.

– **Compression Reinforcement:**
Placed around near the face of columns this reinforcement considerably increases their load-bearing capacity (Fig. 185).

– **Shear Crack Reinforcement:**

Shear cracks are in fact caused by tension and are controlled by the same type of reinforcement as that used for bending tension (bent-up bars and vertical stirrups). Vertical stirrups in beams are the most common form of shear reinforcement. They make a solid

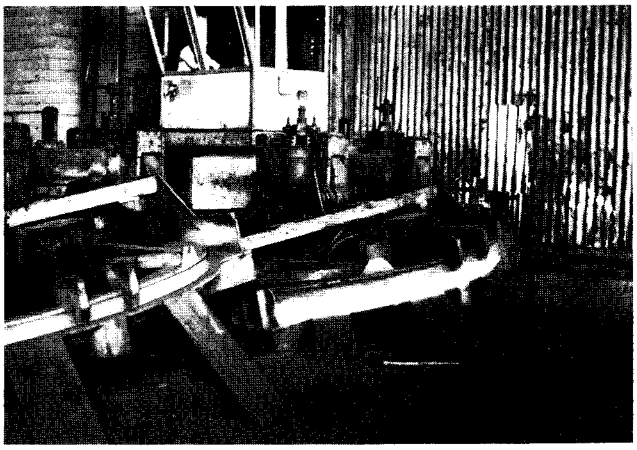


Fig. 183: Production of reinforcement steel bars at the Tema Steelworks, 1981.

cage of the beam reinforcement and provide adequate strength against diagonal tension failure (Fig. 186).

For large concrete areas (floors, walls) an additional reinforcement is needed to arrest cracking (Fig. 187). It is placed at right angles to the tension reinforcement in reinforced slabs to distribute isolated loads and to counteract effects of temperature and shrinkage. In normal slabs mild steel building mesh placed near the surface is sufficient. The same is used near exposed surfaces of concrete walls.

For all reinforced concrete works adequate cover of the steel is essential. Much of the deterioration of reinforced concrete structures is due to insufficient cover of concrete of the bars. **Minimum cover should not be less than the diameter of the specified reinforcement bars whichever is smaller** (Fig. 188). For all external concrete work (in exposed conditions), concrete structures against earth faces (retaining walls) and internal concrete structures in corrosive conditions a cover of the bars of not less than 40 mm is recommended.

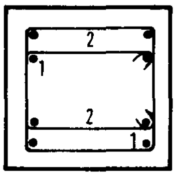
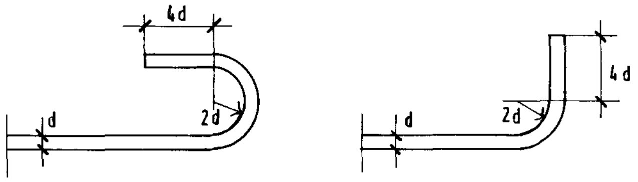


FIG. 185 **COMPRESSION REINFORCEMENT IN A COLUMN**

1 STRAIGHT BARS
2 HORIZONTAL STIRRUPS



U-AND/OR L-HOOKS AT END OF BARS

1. FOR EACH END OF REINFORCING BAR, NOT LESS THAN 25 mm OR MIN. TWICE DIAMETER OF BAR.
2. FOR A LONGITUDINAL REINFORCING BAR IN A COLUMN, NOT LESS THAN 25 mm OR MIN. BAR DIAMETER, IF GREATER.
3. FOR TENSILE, COMPRESSIVE, SHEAR OR OTHER REINFORCEMENT IN A SLAB NOT LESS THAN 15 mm.
4. FOR ALL REINFORCEMENT IN EXPOSED CONDITIONS AND FOR INTERNAL WORK IN CORROSIVE CONDITIONS, NOT LESS THAN 40, FOR FOUNDATIONS 50 mm.

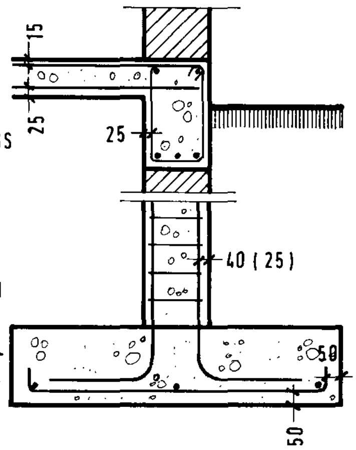


FIG. 188 : **CONCRETE COVER FOR STEEL REINFORCEMENT**
(EXCLUSIVE OF PLASTER AND OTHER DECORATIVE FINISHES)

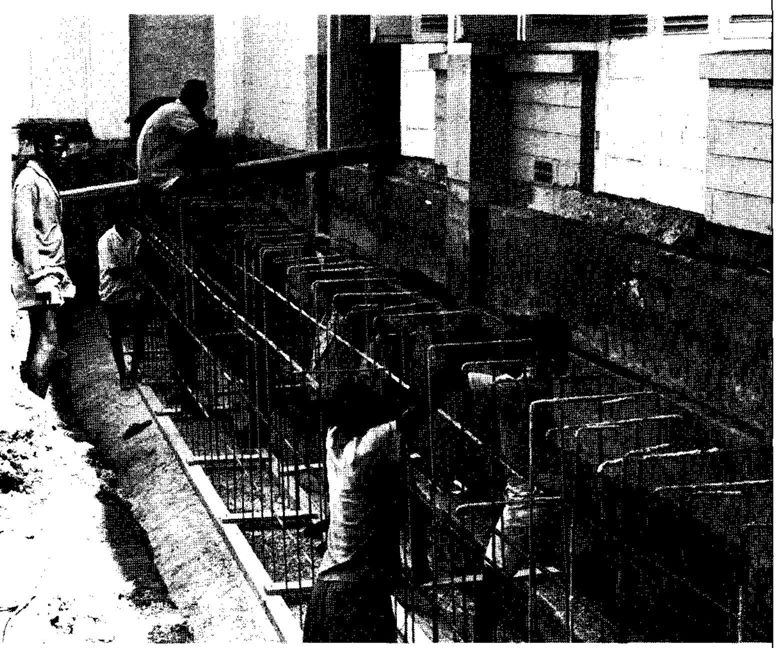


Fig. 186: Vertical stirrup irons in the new foundation wall at the Parliament House extensions.

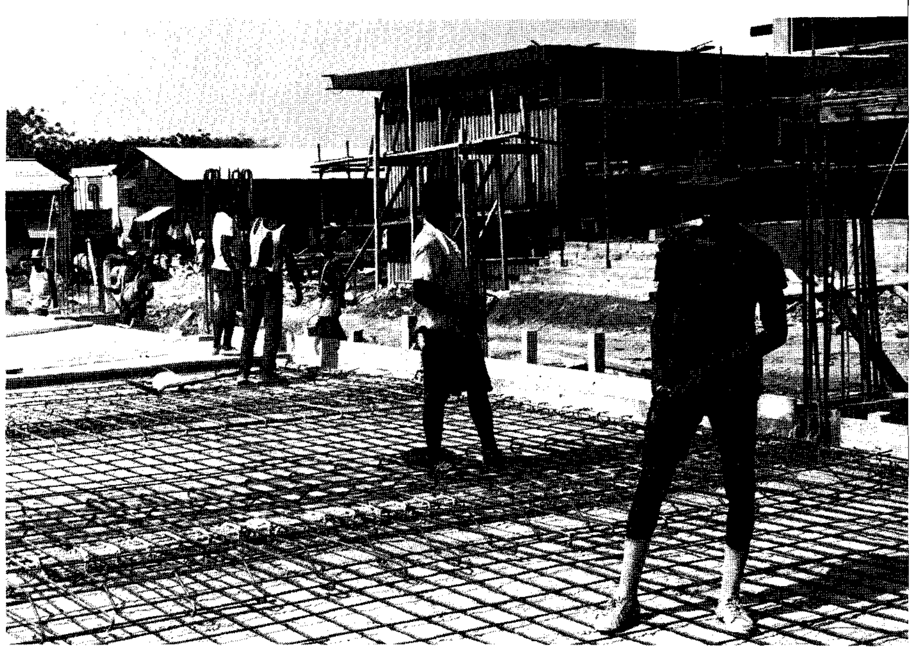


Fig. 187: Ground floor stab reinforcement of an office block at the Parliament House site, Accra.

IRON ORE

MIXED TOGETHER WITH — COKE, LIMESTONE, OTHER MATERIAL

HEATING AT 1100 °C IN A
BLASTFURNACE
(REACTION OF HOT AIR WITH COKE TO MELT IRON)

PIG IRON

(CARBON CONTENT 3 TO 4 %.)

••• BY-PRODUCTS

- BLASTFURNACE SLAG — FOR CONCRETE AGGREGATE, ROAD METAL AND USE IN CEMENT MANUFACTURE.
- FOAMED OR FORMED SLAG — MADE BY BLOWING WATER INTO THE MOLTEN SLAG, FOR LIGHTWEIGHT CONCRETE AGGREGATE.
- SLAG WOOL — FOR THERMAL INSULATION.

CAST IRON

(PRODUCED BY RE-MELTING PIG IRON TOGETHER WITH STEEL AND CAST IRON SCRAP, ALSO BY RE-CARBONISING STEEL CHARGES)

A CONSTRUCTION MATERIAL OF LONG STANDING. GREY CAST IRON WAS USED FOR THE FIRST IRON STRUCTURE IN 1799 - FOR THE BRIDGE AT IRONBRIDGE IN SHROPSHIRE, ENGLAND. GREY CAST IRON COLUMNS AND ARCHES WERE USED FOR THE CRYSTAL PALACE IN LONDON, WROUGHT IRON WAS USED ON THE PALACE FOR MEMBERS IN TENSION IN 1851.

CAST IRON IS USED FOR SERVICE PIPES AND FITTINGS, MANHOLE COVERS, ROAD AND DRAINAGE CASTINGS, BOILERS, RADIATORS, GENERAL IRONMONGERY, TUNNEL SEGMENTS ETC.

- GREY CAST IRON — MAJOR PART OF CARBON CONTENT IS IN A CHEMICALLY UNCOMBINED STATE - GRAPHITE. MAJOR ENGINEERING MATERIAL.
- MALLEABLE CAST IRONS — IMPROVED TO ADDITIONAL STRENGTH AND DUCTILITY.
- DUCTILE CAST IRON — A CAST IRON WITH HIGH STRENGTH, DUCTILITY AND SHOCK RESISTANCE.

WROUGHT IRON

(PIG IRON, TOGETHER WITH IRON OXIDE, IS MELTED IN A SMALL PUDDLING FURNACE. CARBON AND IMPURITIES REACT WITH IRON OXIDE AND FORM SLAG. THIS IS, EXCEPT FOR ABOUT 1 %, EXPELLED THROUGH HAMMERING AND ROLLING.)

WROUGHT IRON IS A LOW CARBON (0.02 TO 0.03 %) FERROUS METAL, OF WHICH ONLY VERY SMALL QUANTITIES ARE PRODUCED TODAY. THE EIFFEL TOWER IN PARIS - 1889 - IS ONE OF THE LAST LARGE WROUGHT IRON STRUCTURES.

THE BLACKSMITH WITH FORGE AND ANVIL PRODUCES WROUGHT IRON AND TURNS IT INTO GENERAL IRONMONGERY, TOOLS, ORNAMENTAL WORKS, FENCING, GATES ETC.

STEELS

(CARBON, SILICON, PHOSPHOROUS AND OTHER ELEMENTS IN PIG IRON ARE REDUCED IN QUANTITY BY OXIDATION.)

- CONVERTER (BESSEMER) PROCESS
- OPEN HEARTH FURNACE
- ELECTRIC FURNACES
- SPRAY STEEL MAKING (ATOMIZING MOLTEN PIG IRON WITH BLAST OF OXYGEN)

STEEL INGOTS

- LOW CARBON STEELS — (UP TO 0.15 % CARBON) - SOFT, SUITABLE FOR IRON WIRE AND THIN SHEET FOR TIN PLATE.
- MILD STEELS — (0.15 TO 0.25 % CARBON) - STRONG, DUCTILE, SUITABLE FOR ROLLING INTO SECTIONS, STRIP AND SHEET.
- MEDIUM CARBON STEELS — (0.20 TO 0.50 % CARBON) - SUITABLE FOR FORGINGS AND GENERAL ENGINEERING PURPOSES.
- HIGH CARBON STEELS — (0.50 TO 1.50 % CARBON) - FOR FILES, CUTTING TOOLS, FOR CASTINGS, E.G. HEAVY MACHINE FRAMES.

STRUCTURAL STEEL	SHEET STEEL	ALLOY STEEL
SECTIONS, BEAMS, COLUMNS, TUBES, PLATE, REINFORCEMENT BARS, STEEL WIRE	SHEET, STRIP, CORRUGATED SHEETS, GALVANIZED MILD STEEL PIPES AND CONDUITS	STAINLESS STEEL STRIP, SHEET, TUBES, BASINS, SINKS, SECTIONS

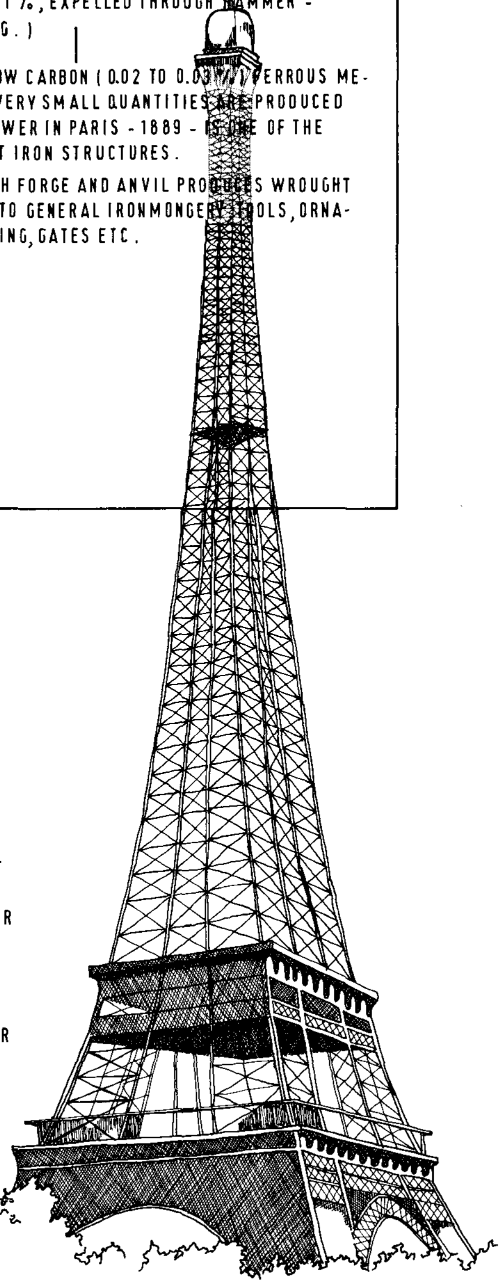


TABLE N°4 : **PRODUCTION OF FERROUS METALS**

3.2.3 METALS

It would go beyond the scope of this book to describe in detail the origin, production process and properties of all metals. Only those metals which are important for construction will be listed, especially if they can be or are already processed and manufactured from raw materials which are found in different tropical developing countries and where this process contributes to a growing economic development in these countries (Table 3).

There are two main groups of metals:

- **Ferrous Metals:** Iron and steels.
- **Non-Ferrous Metals:** Nickel (Ni), Zinc (Zn), Copper (Cu), Tin (Sn), Aluminium (Al), Silicon (Si), Manganese (Mn), Magnesium (Mg), Chromium (Cr), Cadmium (Cd), Lead (Pb), Silver (Ag) and Gold (Au) – the two last being precious metals.

FERROUS METALS

Table 4 explains schematically the origin and making of ferrous metals.

STEEL

Steel is one of the most important construction materials used for structural framework, reinforcement bars for reinforced concrete, galvanized steel pipes, conduits, corrugated roofing sheets, high tensile alloy steel bars for prestressed concrete, steel window and door frames etc.

Structural steel sections are described as **Universal Sections** (Fig. 189) up to 350 x 400 mm. Steel tubes for mechanical, structural and general engineering purposes are from 25 mm to 455 mm in diameter. Rectangular hollow sections for the same purposes are from 25 x 50 mm to 406 x 305 mm. Steel plate, sheet and strip describe plates from 3 mm thickness upwards, which can be welded to form a wide range of structures, e.g. heavy box columns and I-beams larger than the universal sections (Fig. 190). Sheet steel is made by hot or cold rolling steel plate, sheet and strip and passing through a galvanizing process (a metal coating by electrolysis or a zinc or iron coating without electricity). Sheet is either flat or corrugated, and used for cisterns, tanks, cylinders, roofing sheets, pressed steel gutters, rainwater pipes, fittings and accessories. Corrugated roofing sheets are produced in Ghana from imported flat steel sheets (Fig. 191). Size: 2.45 m x 0.76 m using 34, 36 gauges with 0.063 mm of zinc coating.

(Ghana Standards Applicable:

G.S. 22-1970 – Galvanized corrugated steel sheets for general purposes.
G.S. 152-1976 – Galvanized mild steel cisterns and covers, tanks and cylinders.
G.S. 163-1976 – Galvanized wire netting).

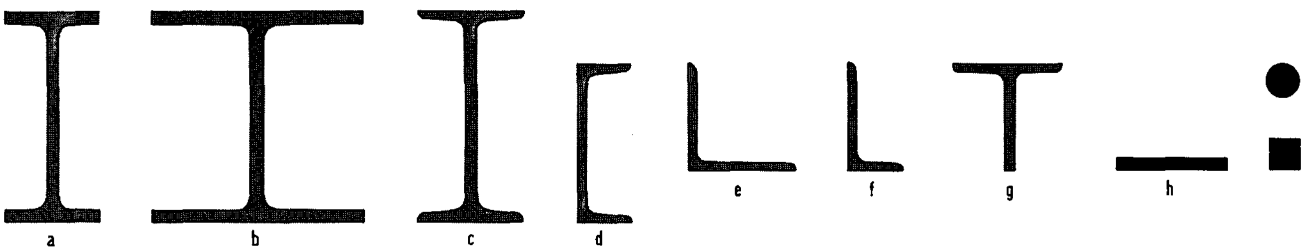
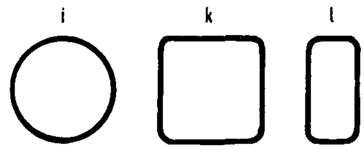


FIG.189: TRADITIONAL HOT-ROLLED SECTIONS AND HOLLOW SECTIONS

a UNIVERSAL BEAM; b UNIVERSAL COLUMN; c JOIST OR I-BEAM; d CHANNEL; e EQUAL ANGLE; f UNEQUAL ANGLE; g T-BAR; h FLAT, SQUARE, ROUND SECTIONS; i CIRCULAR HOLLOW; k SQUARE HOLLOW; l RECTANGULAR HOLLOW SECTIONS



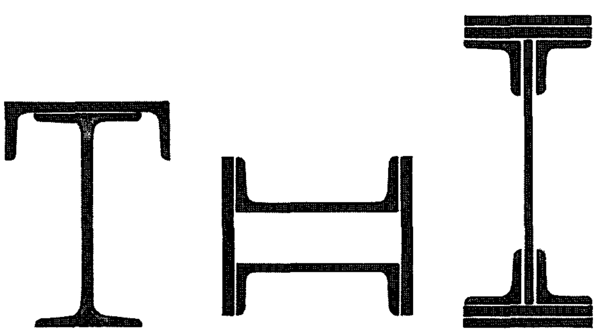


FIG.190: MADE-UP SECTIONS

a GANTRY GIRDER; b COMPOUND STANCHION; c PLATE GIRDER

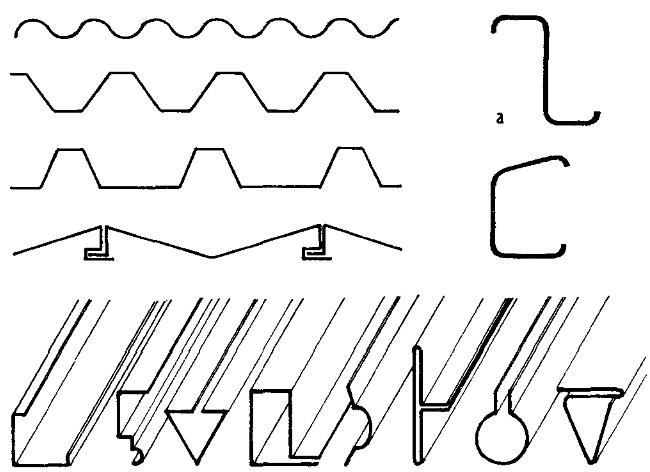


FIG.191: COLD-FORMED SECTIONS AND SHEETS

COLD-FORMED STEEL PRODUCTS ARE GENERALLY SHEET AND CLADDING MATERIALS IN MANY DIFFERENT SHAPES. a Z-PURLIN

Alloy steel contains more than 5 % of alloying elements to provide special properties such as ultra high strength, corrosion and heat resistance. Stainless steel is about 8-12 times more expensive as say, one kg of mild steel. Yet it is increasingly used in building, especially in sheet form as stainless steel basins and bowls in hospitals, laboratories and kitchens, where its use is especially hygienic, since the hard, smooth, corrosion-free surface does not hold dirt readily.

Corrosion Prevention: Untreated steel corrodes and also looks ungainly. There are three methods by which protection is achieved:

- **Vitreous Enamel Coating:** This provides a tough, glossy, highly corrosion resistant surface which can be easily cleaned.
- **Plastics Coatings:** These are P.V.C., acrylic, epoxide or phenolic coatings which are applied as liquids or laminates. For external and corrosive conditions it is advisable to choose:
- **Metal Coatings:** Zinc (the most common), aluminium, cadmium and tin can be applied. Although zinc is much more resistant to corrosion than mild steel, in exposed positions an additional protection with paint is necessary. Metal coating can be applied by:

- Electroplating;
- Cladding;
- Spraying;
- Hot-dipping (usually for zinc coatings),
- Sherardizing (nuts, bolts and small steel objects are put into a cylinder containing zinc dust which is rotated and heated and an alloy of zinc and iron is formed on the surfaces).

NON-FERROUS METALS

These metals have superior working properties and better resistance to corrosion than the ordinary ferrous metals. Most non-ferrous metals are used as alloys in building (Table 5).

NICKEL, TIN, CADMIUM, CHROMIUM and ZINC are mainly used as coatings on steel sheet and steel components or electro-plating the same for resistance to corrosion. Nickel, tin and zinc are used in different alloys. Zinc is also used in sheet or strip form for roof coverings, wall cladding, gutters and flashings but nowadays replaced with aluminium sheet where this is available because aluminium has longer life in exposed conditions.

LEAD (normally pure) is the densest, softest, weakest and one of the most durable metals commonly used in building. But lead pipes are rapidly being replaced nowadays with P.V.C. pipes for internal supply pipes, waste pipes and rain water pipes. Lead is still being used for radiation shielding from X-rays, reactors and radioactive appliances and as sealing compound. Lead compounds (white, red lead) are also used as paint pigments.

COPPER

Copper is a very ductile and malleable metal, which can be made into sheets as thin as 0.051 mm and drawn into wire of 0.025 mm diameter. Three grades of copper are used in building:

- **Deoxidized copper:** Oxygen has been removed by means of phosphorus. This copper can easily be welded and is used for plumbing pipes and general engineering purposes.
- **Fire refined tough pitch copper:** This contains oxygen and is a metal with high thermal and electrical conductivity. It is used for roof coverings. Exposed to the atmosphere copper develops a typical green-white patina which acts like a protective film.
- **Electrolytic tough pitch high conductivity copper:** This is used for electrical and heat conductors.

COPPER-BASED ALLOYS of which the brasses and bronzes are the most known have high resistance to corrosion and have high thermal and electrical conductivity.

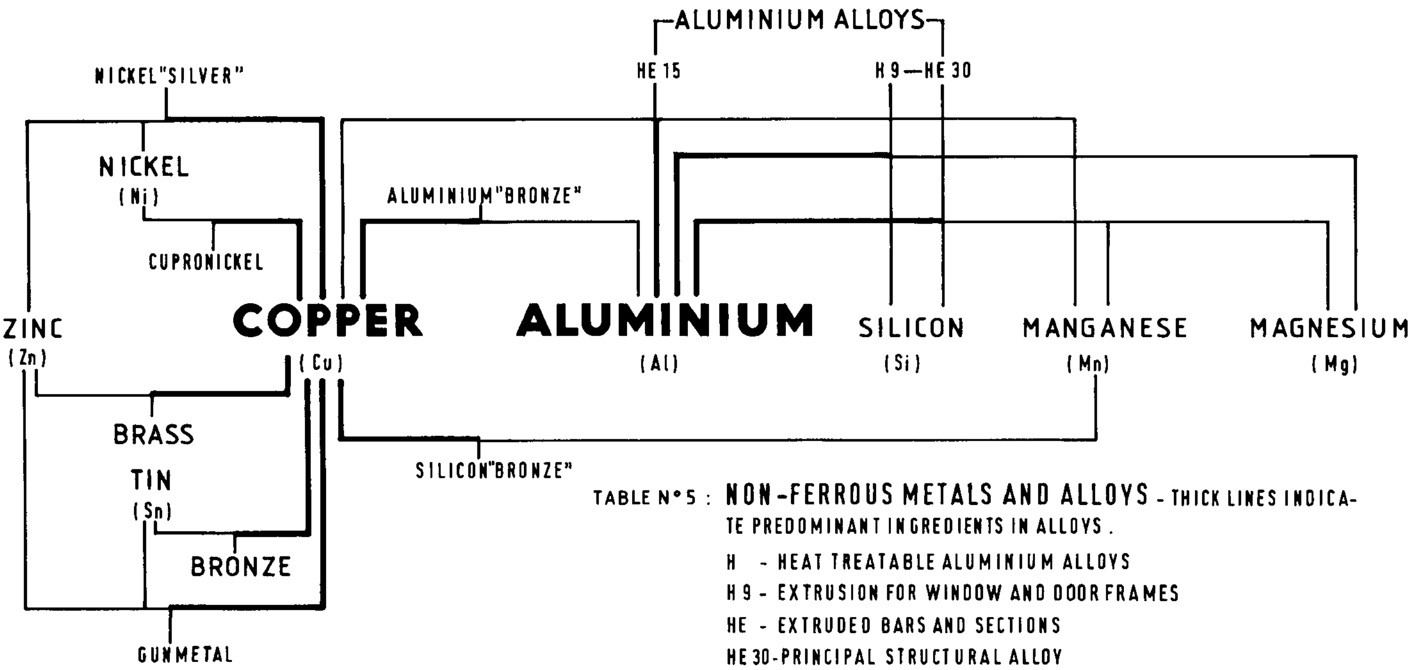


TABLE N°5 : NON-FERROUS METALS AND ALLOYS - THICK LINES INDICATE PREDOMINANT INGREDIENTS IN ALLOYS.

H - HEAT TREATABLE ALUMINIUM ALLOYS
H 9 - EXTRUSION FOR WINDOW AND DOOR FRAMES
HE - EXTRUDED BARS AND SECTIONS
HE 30 - PRINCIPAL STRUCTURAL ALLOY

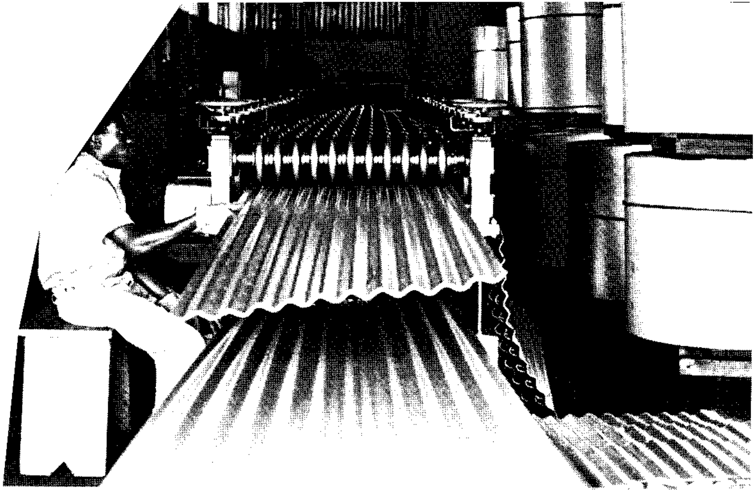


Fig. 192: Production of corrugated aluminium, roofing sheets at Ghana Aluminium Products Limited, Tema, 1976.

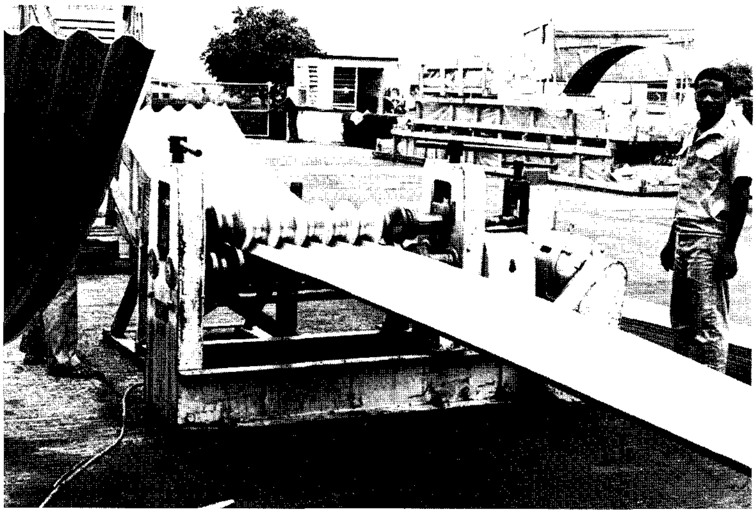


Fig. 193 and 194: Production of self-supporting industrial deep-trough aluminium arches in the same factory.

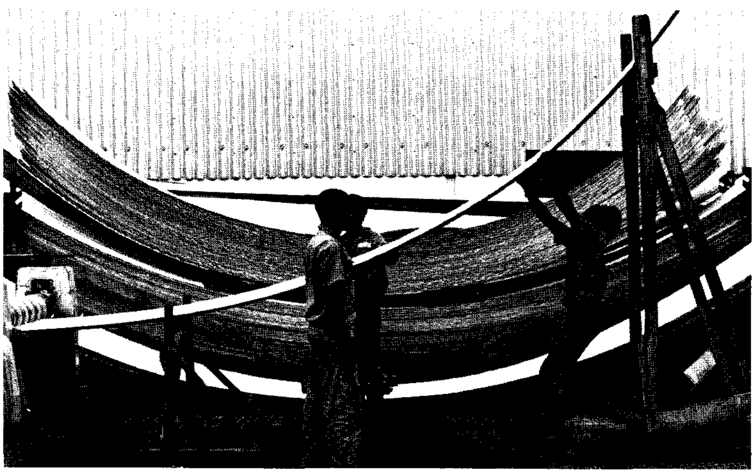
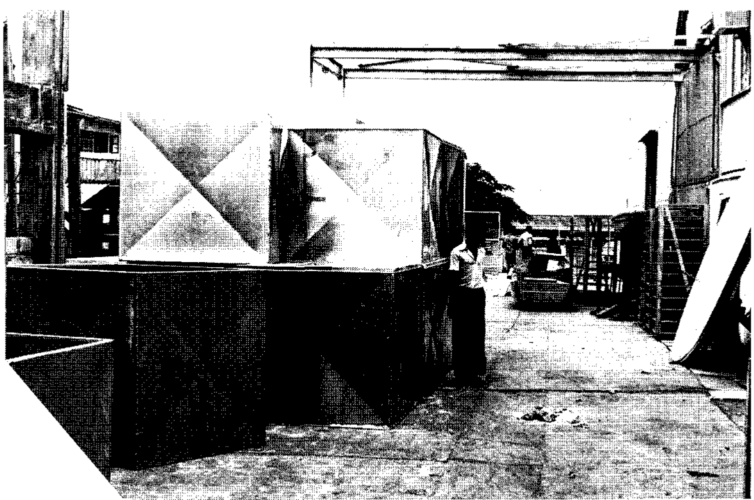


Fig. 195: Plain aluminium sheet water tanks, made in the same factory.



BRASSES: Alloys of copper and zinc. There are three classes of brasses:

- **Alpha brasses:** From 0.37 % to 37 % zinc. These brasses have a relatively high tensile strength and are ductile. They are used for door furniture, caps of electric light bulbs, headlamp reflectors, cartridge and shell cases.
- **Alpha-beta brasses:** With 37 % to 45 % zinc. These are high tensile brasses used for propellers, pumps, valves, non-sparking tools (for gas, oil and explosives industries);
- **Beta brasses:** 45 % to 50 % zinc. These brasses are too brittle for most engineering works.

BRONZES: Bronzes are alloys of copper and tin and other elements. They are harder and stronger than brasses but less ductile. They are often employed for "prestige" work, ornamental door furniture etc. Bronze, though costly, still is a favourable sculpture material.

ALUMINIUM

This is, next to steel, one of the most important metals used in building construction. Its properties have especially been found useful in construction in tropical countries although it is a costly metal which needs a great amount of electricity for its production. For 1 ton of produced aluminium 4 tons of bauxite clay and about 17.000 kilowatt hours of electricity are needed. 4 kg of high grade bauxite are processed to 2 kg of pure aluminium oxide (alumina). This is reduced to 1 kg of aluminium by electrolysis.

Ghana has large deposits of bauxite, but does not manufacture aluminium from own resources. The large aluminium smelter which was built in Tema and uses hydroelectric power from the harnessed Volta river at Akosombo since the early 1960's imports alumina for the manufacture of aluminium ingots. Preparatory work for the promotion, organization and development of an aluminium industry is nearly completed.
Mineral bauxite is being exported from Ghana. The uses of bauxite waste have already been drecribed in the **"Cement"** section and will be further detailed in **"Building Materials from Agricultural, Forestry and Industrial Wastes"**.

To provide improved strength aluminium is alloyed with other elements. For building purposes, the alloys most commonly used contain magnesium, manganese and silicon. Of these the heat-treatable (H– or HE–) aluminium-magnesium-silicon group alloys have very high strengths, are corrosion resistant and widely used for strucutural and building works. Aluminium wire is also rapidly replacing copper wire for electrical wiring and conductors.

Wrought Alloys: These are aluminium alloys suitable for rolling, pressing and extrusions and are either heat-treatable (prefix H) or non-heat-treatable (prefix N). The heat-treatable alloys, as already mentioned before, are largely used in building (H9 – for extrusions for window frames, H30 – for structural works). The non-heat-treatable alloys gain strength by cold working, they are mainly in sheet form (e.g. N3, the simplest alloy) and used for corrugated and industrial trough roof sheeting, flashings, etc. (Fig. 192 *to* 195).

Casting Alloys: These alloys are used mainly as door and window furniture.

Pure aluminium and its alloys are used in building construction in form of:

Sheets;
Structural Sections;
Wire;
Castings.

Maintenance of aluminium sections, etc. is required frequently to remove atmospheric deposits. Cleaning should be done with soapy water.
The light weight of aluminium products is one of their most valuable characteristics.

Finishes to Aluminium:

A process called **"Anodizing"** (electro-chemical process which applies only to aluminium) is used to thicken the natural oxide film on exposure of aluminium. Anodizing enhances the appearance of suitable aluminium products and forms an integral coating with the parent metal. Aluminium roofing sheets produced in Ghana are normally "silver" (matt) or "green" anodized. These finishes greatly reduce the glare of untreated aluminium roofing sheets. Aluminium surfaces can also receive other finishes:

- Mechanical bright polishing (mirror-like);
- Sand-blasted finish (matt finish);
- Vitreous enamelled finish;
- Lacquered finish.

A few precautions must be taken when fixing aluminium sections, sheets etc. against other materials:

- **Contact with Concrete**: When aluminium sections are fixed against concrete surfaces before the concrete has completely set (fresh plastering, mortar joints etc.), some light attack occurs when free lime is released. It shows in a form of etching on the metallic surface, but does not adversely affect the structural properties of the metal. An embedded portion should however be painted with a bituminous paint. In general it is advisable to paint aluminium surfaces where these are in contact with concrete with bituminous paint. Aluminium window and door frames should be fixed in a timber subframe and not directly against cement/sand/lime mortar or plaster surfaces (*see* **"Construction: Windows"**).
- **Contact** with **Stone, Block and Brickwork**: Direct contact with aluminium can, in wet conditions, cause corrosion. Aluminium framing should be separated from masonary with spacers (which can be treated with bituminous paint), with strips of bituminous roofing felt or with a timber subframe.
- **Contact with Copper and Copper Alloys**: All direct contact with copper and copper alloys must be avoided in conditions where water may run off copper surfaces on to aluminium (copper over-head cables etc.).
- **Contact with Zinc**: Aluminium is not corroded by zinc. It is rather zinc which must be treated in aggressive atmospheres.
- **Contact with Lead**: Aluminium is only corroded on contact with lead in most aggressive marine atmospheric conditions, where both surfaces can be treated.
- **Contact with Wood**: In tropical conditions where rain and sun expansion and contraction of a corrugated aluminium roof can cause a considerable noise-nuisance a simple lining over the timber purlins to which the sheets are fixed reduces the sound transmission. In addition a suspended ceiling or a ceiling lining will normally be fixed to reduce solar heat transmission (*see* **"Construction: Roof Structures and Roof Finisher"**).

(Ghana Standards Applicable:
G.S. 30-1970: Aluminium roofing sheets.
G.S. 136-1975: The structural use of aluminium).

3.2.4 ASBESTOS-CEMENT

Asbestos-cement is composed of asbestos fibres (about 10 to 15 % by weight) and Portland cement. The incombustible mineral is quarried from the rock, crushed, fibred and graded in shaking screens, and formed in open moulds by hand or in a mechanical process (**Hatschek-process**). The common variety for general use is **White Asbestos** (compound of magnesia and silica). **Blue Asbestos** is composed of iron and silica and is more suitable for use in positions where a great resistance to acids is required. Asbestos in general is incombustible. Its very low conductivity of heat and electricity makes it an essential insulator in many industrial processes.

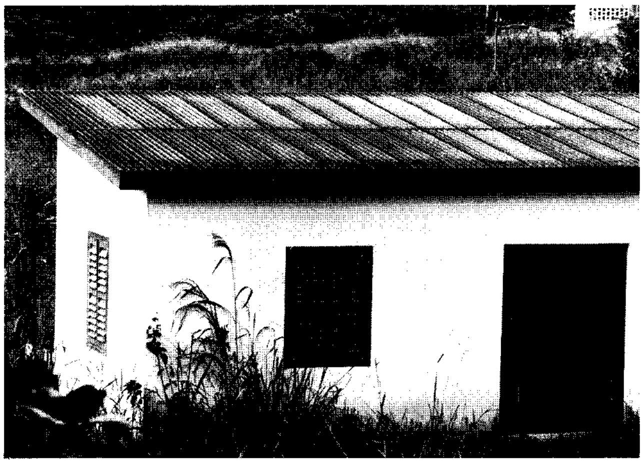


Fig. 196: Corrugated asbestos cement sheets.

Asbestos-cement sheets used in building construction are built up in rolling mills from layers of cement and uniformly distributed asbestos fibres (Fig. 196). Asbestos-cement increases in strength with age, but intends to grow brittle. During the production of asbestos-cement sheets various colour and embossed finishes can be applied to the product. Common colour for such application is terracotta for roofing sheets. Corrugated cement-asbestos roofing sheets and flat sheets are produced (also in Ghana) in a wide range with a great number of accessories and fixing accessories (*see* **"Construction: Roof Structures and Roof Finishes"**). Asbestos-cement pressure pipes are used for water and sewerage pumping mains and similar applications. The pipes are produced from 50 to 914 mm in diameter and up to 5 m in length.

(Ghana Standards Applicable:
G.S. 177-1978: Sampling and inspection of asbestos-cement products.
G.S. 178-1978: Asbestos-cement pipe fittings for building and sanitary purposes.
G.S. 181-1978: Guide to the use of ISO recommendation R. 390 "Sampling and Inspection of Asbestos-Cement Products."
G.S. 193-1978: Building and sanitary pipes in asbestos-cement.
G.S. 204-1978: Asbestos-cement pipes, joints and fittings for sewerage and drainage.
G.S. 212-1978: Asbestos-cement pressure pipes).

3.2.5 BITUMINOUS PRODUCTS

These are three products: Bitumen (natural or derivative), coaltar and pitch.

Bituminous materials resist the passage of water and water vapour. They are, in general, resistant to acids and alkalis.

Bituminous products are softened by heat and by sunlight. Their uses in building construction are many:

- BITUMEN: Natural bitumen is extracted from mineral matter called **Lake Asphalt** (Lake Trinidad, West Indies) or from **Rock Ashalt** (limestones which contain bitumen) in France, Switzerland, Germany and Sicily. Derivative bitumens are distilled from petroleum.

  Bitumen has many uses, mainly in road building. Mastic asphalt (produced from crushed limestone or crushed rock asphalt, asphaltic cement and fillers and fluxing oils) is used for special floorings (*see* **"Floors and Floor Finishes"**) and for damp proof courses.

  In building construction bitumen is used as damp-proof membranes, adhesives to wood-block flooring, insulating linings and felts, as a saturant for roofing felts and different water-proof building papers and joint fillers.

  During the petroleum distillation process certain by-products are available which are used in Ghana (produced by the Shell Company of Ghana) in road construction and road maintenance: **Medium Curing Cutback** (MC2) and **Quick Breaking** (or rapid setting) **Emulsion** (also called **Colas**). The Building and Road Research Institute in Ghana has successfully conducted experiments with MC2 as a stabilizer and water-proofing material for soil-sand plasters and mud walls (see **"Walls and Wall Finishes"**). It has been found that a mixture of 5 % bitumen cutback (medium curing) or of slow setting emulsion (**Terolas,** which is not available in Ghana) produce very satisfactory results with the plaster retaining a good appearance and only showing minute cracks on drying which can be removed with a final trowelling.

- COALTAR: Softens at lower temperatures than bitumen and oxidizes more easily. Its uses are similar to bitumen, except for heavy duty uses in road construction.
- PITCH: This is the residue after distilling tar from coal (fluxed back with some of the by-products). Its important use in building construction is as an impregnant for pitch-fibre drain pipes. In the age of plastics changes have also occurred here with P.V.C. being used more and more as water, rainwater and drain pipes and replacing some of the "traditional" materials.

3.2.6 GLASS

In building construction glass is mainly used as flat glass (for glazing). Glass fibres and foamed (cellular) glass are also used. Another use is as vitreous enamel coating on metals.

The following raw materials are needed for the production of sheet glass:

(a) **High Quality Quartzite Sand**: 71-78 % of the total volume of the raw materials;
(b) **Limestone** and/or **Oyster Shell**: (a) and (b) are the materials which give glass mechanical strength and increase its stability;
(c) **Feldspar**: Reduces the coefficient of expansion and allows the glass to be worked;
(d) **Dolomite**: Is added for colour (from magnesium). This is useful for reducing light and solar heat penetration;
(e) **Soda Ash**: Is a fluxing agent and reduces the melting point from 1710° C to 1440° C (and introduces a fuel saving factor in the process). It also gives transparency to the glass;
(f) **Borax**: Gives physical and chemical stability to the glass and increases its mechanical stability;
(g) **Potash**: Imparts oxygen into the glass during the production process. The large bubbles which are formed by the released oxygen rise through the glass and sweep out smaller bubbles and "seeds" (impurities).

The establishment of a glass-producing industry in a tropical developing country, where the majority of the raw materials needed for glass-manufacture are available, is an economic and feasible undertaking, because in such countries bottles, jars and containers are needed for other industries (fruit juices, drinks, beer, preservatives, vegetable pastes, oils etc.). For example, high quality quartzite and deposits are not only found as alluvial sands in Ghana in the incipient stages of streams draining certain sandstone formations, but could be obtained from angular quartz sands from the vast quantities of sands available in the dumps of the country's gold mines. These sands can be used after undesirable impurities (e.g. iron ore) have been removed. For the production of soda ash sea salt can be used. In the case of Ghana where a glass producing factory has been set up the only raw materials which need to be imported are potash and borax.

Sheet glass used for glazing in building is produced as transparent or translucent glass.

TRANSPARENT GLASS:

This glass is transparent to infra-red rays and relatively opaque to ultraviolet rays. It tends to accumulate heat within the glazed area. The ordinary type of sheet glass (drawn sheet) has fire-finished surfaces. Because the two surfaces are never perfectly flat and parallel, there is always a certain degree of distortian of vision.

In 1923 Pilkington Brothers Ltd. (England) developed a continuous process of grinding and polishing rough cast glass on both sides to form plate glass. In 1959 they developed the **Float Glass** – process by which most clear glass is produced today.

Glass produced this way is 3, 4, 5 and 6 mm thick. It provides clear and undistorted vision and reflection. Polished glass moreover has a lustrous and brilliant finish.

Green, grey and bronze float glasses can be produced for controlling solar radiation by the use of suitably shaped electrodes which introduce the colour into the glass producing process.
Transparent clear plate glass is used for window glazing in domestic, public, commercial buildings, schools and

hospitals, where a clear and undistorted view is required. In the humid tropics glass-louvered windows (allowing unobstructed passage of cross-ventilation) are used with 5 mm thick clear (or obscured) glass blades (Fig. 197).

TRANSLUCENT GLASS:

These glasses have one flat surface and the other with a texture or pattern. The pattern obscures vision in varying degrees. In general, light transmission decreases as the degree of obscuration and diffusion increases. Thicknesses are from 3 to 6 mm, with 4 to 6 mm most commonly used.
Translucent glass is used in places where direct vision is not required or desired (Fig. 198).

Wire mesh, electrically welded at the intersections, can be embedded centrally in the thickness of rough cast glass during rolling. It is valuable as an efficient fire retardant and is normally used for roof lights.

There are different **Special Glasses** which may be specified and used for special purposes:

- **Toughened Glass**: This glass is made by subjecting ordinary clear plate or float glass to a process of heating and sudden cooling which results in an increased mechanical strength and higher resistance to impact. When it breaks it disintegrates into small pieces which do not have the dangerous cutting edges of ordinary glass. Thickness: 5, 6, 10, 12, 15, and 19 mm.
- **Solar Control Glasses**: These are specially manufactured glasses which reduce solar heat gain by absorption and re-radiation (by reflection). They are produced in several types, but all have a tinted effect. The extra costs of these glasses are easily compensated in tropical conditions by the improved comfort conditions for the occupants and by the savings in costs of air-conditioning buildings (Fig. 199).
- **X-Ray Resistant Glass**: This is usually a polished plate glass containing a large proportion of lead oxide (which has a high degree of radiation shielding).
- **Antique Glass**: This is made by traditional means in the handblown process and therefore costly. Antique glasses are used for decorative and ornamental work.
- **Glass Mosaic**: Molten glass mixed with alkaline and metal oxide is poured into moulds and pressed in 20 x 20 x 3 mm sizes. Glass mosaic is used for wall finishes, in swimming pools, for decorative purposes.
- **Glass Blocks**: These are hollow pressed glass units in clear glass, colours or various patterns for the construction of translucent nonload-bearing walls.

Useful information on all aspects of glazing in building and patent glazing may be gained from the publications of Pilkington Brothers, St. Helens, Merseyside, England.

GLASS-FIBRE PRODUCTS:

The modern glass-fibre products are classified as glass wools and glass fibre reinforcement. These products are used for thermal, sound and electrical insulation. Glass-fibre-reinforced polyester (GRP) is used in the production of corrugated plastic translucent sheets for rooflights, cladding panels and many other purposes. Glass-fibre reinforced cement (GRC) is used as permanent formwork with superior resistance to abrasion and chemicals than the in-situ concrete it encases. Glass-fibre-reinforced gypsum (GRG) is produced in panel form and used as internal partitions and floor units.

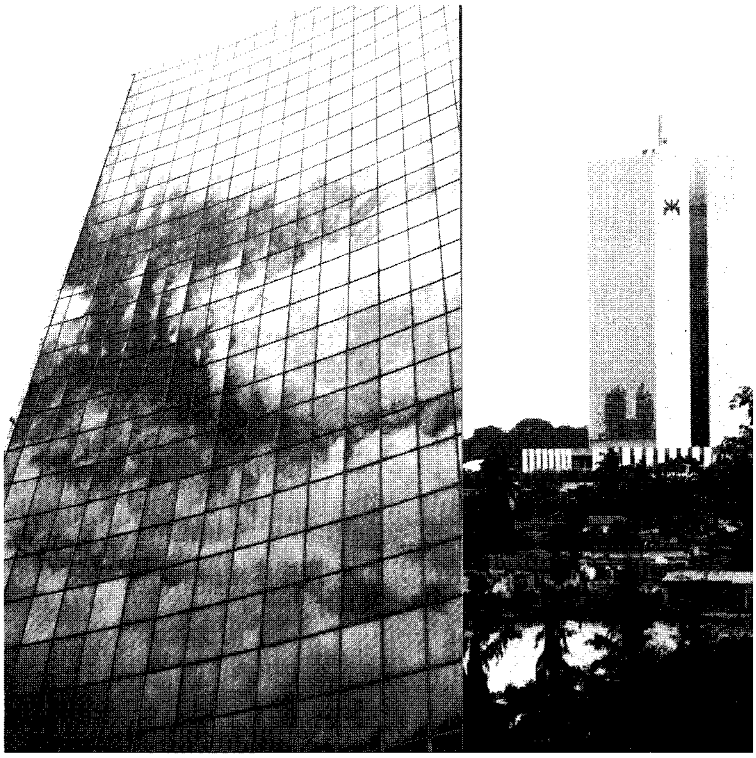


Fig. 199: Solar-control reflective glass facade at the 2nd February Hotel in Lome, Togo, 1981.

Fig. 197: Clear glass louvre blades in Naco-louvre blades.

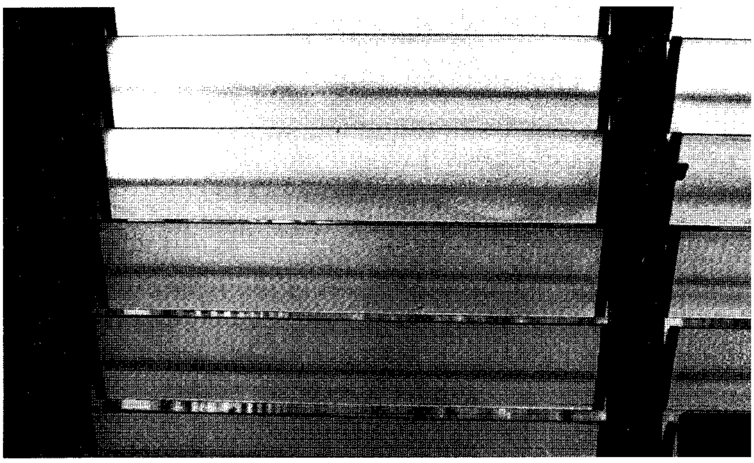


Fig. 198: Obscured glass louvre blades.

3.2.7 PLASTICS

Plastics have, since a few decades, become steadily assimilated into building usage. Plastic materials have in some cases nearly replaced the traditional materials in the production of rainwater, water, waste and drainage pipes.

The expanding use and market of plastics received a set-back when oil prices were drastically increased in 1973 and have been increased ever since. Fossil fuel form the basis of plastic materials used in building construction. With the steadily rising price of oil the industrialized countries are looking for and experimenting with alternative energy sources. Plastics are today entering a new period, where they must compete with the traditional materials on much more equal grounds. It is therefore important for developed and developing countries to channel the use of plastics into those areas where their undoubted unique properties can be utilized with greatest advantage.

All plastics are **"Polymers"**, their molecular structure comprises long chains of molecules loosely tangled together. This explains the lightweight of plastics.

Two types of plastics are distinguished. One kind – **Thermoplastics** – softens when it is heated and hardens again on cooling. The other kind – **Thermosetting Plastics** – passes through a chemical change during moulding and becomes permanently and inalterably a new, inert material after curing and cannot be re-softened again by heat.

Like all other organic materials plastics are combustible and have to be treated with caution. Some are highly flammable (**Polyurethane Foams** – used for mattress-making), others are difficult to burn (**Polyvinyl Chloride**).

Below are listed some of the most important plastics, their properties and uses in building:

3.2.7.1 THERMOPLASTICS

- **Polythene:** Low and high density (they differ in their basic physical properties, high density polythene being harder and more rigid than the lower density polythene). It is a tough, resilient material, unaffected by action of water and a number of corrosive elements but melts and burns like wax. Polythene film is used for damp proof courses and damp proof membranes. If exposed to sunshine it will quickly degrade.
- **Polymethyl Methacrylate (Acrylic Resins):** This plastic material has been used as clear and translucent corrugated roofing sheets (**Perspex**) where it has shown good resistance to weather. It is a light, tough material which can easily be bent or shaped, but melts and burns readily.
- **Polyvinyl Chloride:** It is produced as flexible (plasticized) PVC or rigid (unplasticized) PVC. PVC is one of the cheapest and more generally known plastic materials. It is remarkable for its versatility. Rigid PVC is used for rainwater goods, cold water pipes, soil and waste pipes (with temperatures of waste water not higher than 65° C). Depending on the nature and proportion of fillers, stabilizers, plasticizers and colourants in the compound PVC can be produced as very resilient and durable floor and wall coverings and tiles. PVC melts but burns only with great difficulty (depending on the plasticizer used). By postchlorination (of rigid, unplasticized PVC) PVC can be used for higher temperatures, up to 120° C, to make it suitable for hot water pipes.
- **Polyvinyl Acetate:** In emulsion form this plastic is the base for emulsion paints and adhesives.
- **Polyvinyl Fluoride:** Polyvinyl fluoride film is being used for lamination to the surfaces of other materials, such as aluminium, plywood, asbestos-cement and other plastics. Weathering properties of these films are very good, requiring low maintenance of the covered materials.

3.2.7.2 THERMOSETTING PLASTICS

- **Phenolic Resins:** Phenolic resin-bonded laminates are of dark colour. They are used in a variety of industrial and domestic appliances (W.C. seats, electrical fittings, etc.).
- **Melamine Resins:** These are decorative laminates in light colours, used for wall and ceiling linings, table and counter tops, mouldings in light colour etc. Phenolic and melamine resins are highly resistant to ignition.
- **Polyester Resins:** Polyester resins are used mainly with glass fibre reinforcement. They harden without heat and pressure.
- **Epoxide Resins:** They are extremely tough and stable, have excellent electrical properties and good resistance to chemicals (especially to acid and alkaline solutions). They are used in in-situ floorings, clear finishes, glass-fibre reinforced plastics and adhesives.

3.2.7.3 CELLULAR PLASTICS (FOAMED AND EXPANDED PLASTICS)

- **Polystyrene:** This is normally produced in form of boards. Although ultra-violet light gradually embrittles the surfaces, these can be painted with water-based and emulsion paints or they can be plastered. Used as suspended ceiling boards or for thermal insulation purposes.

(Ghana Standards Applicable:

G.S. 45-1972: Polystyrene moulding materials.
G.S. 46-1972: Phenolic moulding materials.
G.S. 49-1972: Glossary of terms used in the plastics industry.
G.S. 50-1972: Low and intermediate density polythene sheets for general purposes.
G.S. 66-1972: Thick PVC sheeting (calendered flexible, unsupported).
G.S. 74-1972: Expanded polystyrene tiles and profiles.
G.S. 85-1972: Thin PVC sheeting (calendered flexible, unsupported).
G.S. 89-1972: Unplasticized PVC pipe for cold water service.
G.S. 94-1972: Unplasticized PVC pipe for industrial purposes.
G.S. 95-1972: Methods of testing plastics.
G.S. 108-1973: Polystyrene tiles for walls and ceilings.
G.S. 177-1972: Unbacked flexible PVC flooring.
G.S. 182-1978: W.C. seats (plastics)).

3.2.8 PAINTS

Paint is a viscous substance made by suspending finely ground pigments in a liquid medium (oil or emulsified oil). When this is applied to a surface it solidifies. The functions of paints are:

- To protect the painted surface;
- To create a decorative effect;
- To create a healthy atmosphere in the painted area.

Functions of the constituents of paint:

- **Pigment**: This is the solid matter in paint which gives it body, colour and obscuring power. Pigments used are: Zinc Oxide, Titanium Oxide, Red Lead, White Lead and Aluminium Powder.
- **Medium**: This is the liquid component of the paint. It should improve its cohesive properties and at the same time promote adhesion to the painted surface. Mediums used are: Tung Oil, Soyabean Oil, Raw Linseed Oil, Boiled Linseed Oil.
- **Drier**: These help to speed up the drying process of the applied paint by hastening absorption of oxygen. They are only required in very small quantities and are composed of Leads, Manganese and Cobalt.
- **Thinner**: This is a clear, colourless, volatile liquid which is used in the adjustment of paint to a workable consistency. It should, on application of the paint, evaporate completely and form no part of the dried paint film.

There are different types of paint used in buildings:

(a) **Oil-Based Paints**: These paints consist of a drying oil or an oil varnish as a binder and dry by oxidation or polymerization of the binder. Paint finish is flat (matt), glossy or eggshell (in between flat and glossy).

(b) **Water-Based Paints**: These are paints in which the binder is an emulsified oil in water and dries initially by evaporation.

(c) **Alkali-Resisting Primer**: This is a medium made up of soils which resist alkali attack.

(d) **Aluminium Primer**: This is a medium applied on wood (which must be seasoned and dry) before other paints are used.

(e) **Anti-Corrosive Primer**: With red lead, zinc and zinc oxide pigments, this primer is applied to steel surfaces before their final finish with Aluminium, Red Lead paints or Alkyd Resin paints.

(Ghana Standards Applicable:

G.S. 221-1978: Paints and varnishes – sampling).

3.3 BUILDING MATERIALS FROM AGRICULTURAL, FORESTRY AND INDUSTRIAL WASTES

Imported building materials can account for 15-40 % and more of the construction costs in developing countries. In many emerging countries an industrialization process has started and industries have been set up which are producing some of these building materials. These countries have realized that it is essential to develop an efficient domestic building materials industry in order to save (in most cases scarce) foreign exchange. Equally important is it to develop at the same time their own industries for the supply of local raw materials needed in the building material producing industries. And in this respect developing countries are also beginning to realise that they cannot longer continue to depend on some of the "conventional" raw materials used. For example products from the petro-chemical industry used as adhesives and binders in the production of a large number of building materials are becoming so expensive with the steadily rising price of oil that they are too costly. This is equally affecting developed countries (which are not "oil-owners"). Facing the same limitations caused by the continuing rising cost of oil research has been and is being undertaken into the use of the large quantities of agricultural, forestry, industrial and consumer (household waste, municipal waste, refuse etc.) wastes available for the production of building materials. The following section of the book attempts to record the most useful researches and successful attempts to utilize wastes in different tropical developing countries and in Ghana.

3.3.1 AGRICULTURAL WASTES

3.3.1.1 RICE HUSK

Every ton of paddy rice yields 200 kg of husk. This husk contains about 40 % cellulose, 30 % lignin and 20 % ash. Rice husk therefore comprises nearly 20 % of the weight of the dried and harvested rice crop and is the largest by-product in the rice-milling industry. Husk is not suitable for use as animal feed due to its abrasive character and almost negligible digestible protein content. For the manufacture of paper rice husk is also unsuitable because of its high ash and lignin content. Throughout the world the annual rice production of about 300 million tonnes yield approximately 60 million tonnes of husk. The bulk of this husk is disposed of by burning.

Research into the use of husk ash has been conducted for a long time, especially in the major rice-producing countries in Southeast-Asia, where the production of rice is more than half of the entire world production.

I. RICE-HUSK-ASH CEMENT:

The material presented in this section has been compiled from "Rice Husk-Ash Cement" (Proceedings of a joint workshop sponsored by UNIDO-United Nations Industrial Development Organisation – in Peshawa, Pakistan, 1979) by courtesy of the Regional Centre for Technology Transfer, Bangalore 560052, India.

It has been estimated that 40 to 60 per cent of ordinary Portland cement used in developing countries goes into foundations, flooring, mortars for block and brick laying and plastering. The demand for cement is increasing. If cheap but good quality housing is to be provided in the urban and rural areas of tropical developing countries, where cement is very costly and also mostly not available, rice-husk-ash cement is an appropriate substitute in rice growing areas.

To obtain cementitious material from rice husk ash both the heating value and the silica content of the rice husk is utilized.

Chemical analysis of rice husk ash:

	Content in %
SiO_2 (Silicon Oxide)	93.2
Al_2O_3 (Aluminium Oxide)	0.59
Fe_2O_3 (Ferrum Oxide)	0.22
CaO (Calcium Oxide)	0.51
MgO (Magnesium Oxide)	0.41
Na_2O (Sodium Oxide)	0.05
K_2O (Potassium Oxide)	2.93
Loss on Ignition	2.09

(Cental Building Research Institute, Roorkee, India).

High reactive silica can either be obtained by controlled burning of the husk in a range from 450 to 700° C or by extensive grinding of the ash obtained from burning the rice husk in a wider temperature range. Controlled burning is necessary to reach complete combustion of the rice husk, so that all carbon is burnt off. The controlled burning produces a silica that is amorphous in form and highly reactive. If the combustion temperature is too high, more crystalline forms of silica are produced which are less reactive. Complete combustion produces 40 kg of ash from every ton of rice produced. (P. Kumar Mehta, Department of Civil Engineering, University of California, U.S.A.).

There are about six classifications of cementitious materials utilizing reactive silica:

(1) Blended lime-rice husk ash mixtures;
(2) Interground lime-rice husk ash mixtures;
(3) Limestone-rice husk mixtures which are fired together and ground after calcination and ash production (temperatures required for calcination converts the silica in the rice husk ash to the less reactive crystalline phase);
(4) Blended lime-rice husk ash mixtures which are mixed with certain bauxitic clays;
(5) Blended Portland cement-rice husk mixture;
(6) Interground Portland cement-rice husk mixtures.

Of these (3) ist producing lower strength than (1) and (2). Mixtures (5) and (6) produce the highest strengths. Even with 70 % cement replacement by ash the strength at 90 days was acceptable (Mehta). This means that substantial cement replacement can be made without any significant effect on long term strengths properties. Moreover Mehta's research has shown that concretes made with rice husk ash have improved durability particularly in acid environments.

Technologies developed to date can provide cementitious materials based on rice husk ash to suit different needs ranging from plastering materials to structural concretes. The particular strength properties depend on the raw materials (e.g. the form of lime, whether it is limestone to be calcined, partially slaked or unslaked lime, lime sludge etc.), the temperature of ash conversion, the degree of grinding (hence fineness), the mix proportions and the curing conditions. More research is still going on to establish a satisfactory understanding of the material for a commercial production. Further research is necessary to study the influence of the carbon on reactivity and the long term behaviour of materials made from rice husk ash.

Some processes of producing rice husk ash cement are described:

(a) **Rice Husk Burning under Controlled Conditions:**

Ash is produced under controlled conditions (temperatures between 500 to 700° C) in a suitably designed kiln (Fig. 200 shows an incinerator designed by the Pakistan Council for Scientific and Industrial research laboratories in Peshawar). The ash is ball milled, then mixed with hydrated lime or cement. With a 20 to 30 % addition of hydrated lime to rice husk ash a suitable cement can be produced.

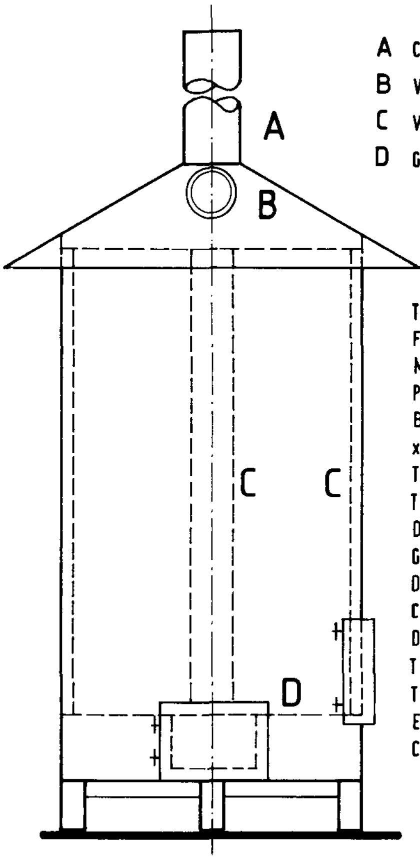


FIG. 200: **INCINERATOR FOR RICE HUSK ASH PRODUCTION** - DESIGNED BY THE PAKISTAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH LABORATORIES IN PESHAWAR.

(b) **Rice Husk-Clay Pozzolana:**

This is a process developed by the Central Building Research Institute in Roorkee, India. An intimate mixture of rice husk and clay is made by using equal amounts of the ingredients by weight, moistened with water and shaped into balls. These are sun-dried and then fired in an open clamp. Due to the rice husk content the balls are self-burning, no extra fuel is required except for the igniting. To make this pozzolana any soil or clay which contains more than 20 % clay fraction can be used. The fired balls are ground to a fine powder in a ball mill. The result is a reactive pozzolana which can be mixed with hydrated lime in the ratio of 2:1 by volume to give a cementitious material which is suitable for mortar and plaster

mixes. The pozzolana can also be used as an admixture with Portland cement (to the extent of 20 to 30 %) to make Portland-pozzolana cement.
It has, however been found in Ghana that it would be better to prepare and burn the rice husk and clay separately, since they are activated at different temperatures. This process produces a highly reactive pozzolana after mixture of the two.

(c) **Rice Husk-Waste Lime Sludge Binder:**

This is the second process developed by the CBRI in Roorkee, India: The rice husk-lime sludge binder is made in the same way as the rice husk-clay pozzolana described above. Clay is, however, replaced by waste lime which is available from the sugar or paper industry or from the production of acetylene gas. Here also, no extra fuel is added and the heat of combustion of the rice husk converts the calcium carbonate (from the lime sludge) to lime. The obtained ash is ground to the desired fineness in a ball mill and possesses hydraulic properties without further addition of lime. The product can be used for mortar and plaster (binder-sand mortar or plaster in 1:3 composition by volume) or for making lean concrete for foundations and base concrete for floors. It can be used as a soil-stabilizer in the production of stabilized soil blocks or bricks (mixed with the soil to the extent of 10-15 % by weight) for improved rural housing suitable in areas where burnt bricks cannot be manufactured due to fuel shortage, but rice is produced and lime sludge is available.

(d) **Ashmoh-Process:**

Developed in the Indian Institute of Technology, Kampur, India, by Dr. P. C. Kapur, this process really caters for the requirements in the rural areas. It is essentially the production of rice husk ash which has not been burnt under controlled conditions in heap or boiler burning. The inert ash contains high percentage of crystalline silica, but can be ball-milled with hydrated lime to produce a hydraulic cement. Important (as well as to all other processes) is a suitable ball mill. In India research is continuing in this field. A pilot plant has been established with a ball mill where the ash can be ball-milled to a (**Blaine**) fineness of between 10,000 and 20,000 cm^2/g.

It is apparent that cement made from rice husk ash can work out to be 30 to 50 % cheaper than ordinary Portland cement. The production of rice husk ash cement would also require far less capital investment than that required for the production of conventional cement. When produced under controlled conditions rice husk ash is an excellent pozzolana.

Although complete figures of rice production in Ghana are not available, it is interesting to note the amount of cement which could be produced from the waste of just one rice mill in the North of Ghana. In 1978/79 the Government Rice Mill in Tamale processed 58,609 bags of paddy rice, with a bag weighing 80 kg. This would work out to approximately 4,700 tonnes of rice. With Mehta's conversion this would mean a possible production (with controlled burning in an incinerator similar to the PCSIR-Peshawar kiln) of about 200 tonnes of ash from the 940 tonnes of rice husk which were the waste product left after processing the paddy. Adding to the ash 30 % of hydrated lime (by weight) 265 tonnes of suitable cement can be produced after the intergrinding process. This would amount to about 5830 bags of 50 kg cement. If the transportation of suitable lime from the deposits at Buipe and Bongo-Da (about 90 km from Tamale) is too expensive clay which can be used instead is readily available near Tamale. The production of rice husk ash cement in this area would be a feasible and economic undertaking.

II. SAND-LIME BRICKS (replacing $\frac{1}{3}$ of the sand with active silica obtained from rice husk ash):

The Building and Road Research Institute in Kumasi, Ghana, has produced sand-lime bricks without autoclaving by replacing about one third of the sand with active silica obtained from burnt rice husk. This was mixed with hydrated lime, moulded under pressure and allowed to cure. The bricks have been tested and have sufficient strength for ordinary use. Such bricks could be produced in the country's northern regions where rice husk and limestone are available, but firewood for use in kilns for burnt clay brick production is scarce.

3.3.1.2 BANANA AND PLANTAIN STALKS AND LEAVES

In the transitional forest and forest areas of Ghana where banana and plantain are cultivated a thick liquid is produced from boiling the stalks and leaves. This liquid is used as a water-proofing agent which is applied as a wash on the plastered mud walls. The presence of fibres controls the formation of cracks during drying.

The process of producing the water proofing agent is very simple. After the stalks and leaves are removed from the plant they are cut into very small pieces. A 40-gallon (180 litres) drum is filled up with two thirds of these cut-up pieces and one third of water. The mixture is boiled, the ingredients mashed from time to time. When the liquid thickens, remaining heavy material is screened out. After application of this liquid good protection of the rendered walls is achieved for about three years before re-application becomes necessary.

3.3.1.3 JUTE STALKS

The Barnagore Jute factory near Calcutta in India is producing chipboards from jute stalks for a number of years. The boards are actually soft boards in various thicknesses, densities and different colours. They are also manufactured in laminated form. The boards are used for thermal insulation. A plant producing rigid boards is planned. These will be manufactured by applying heat and pressure techniques. Chipboards from jute stalk are also produced in Bangladesh since 1969.

3.3.1.4 SUGAR CANE WASTES

During the sugar cane processing a waste by-product, **Bagasse**, is considered in many developing countries as one of the most promising ligno-cellulosic raw materials.

I. BAGASSE-REINFORCED COMPOSITE ROOFING:

The Agency for International Development, United States Department of State, Washington, sponsored a 4-year research project from 1973–1978, with the aim to develop low-cost roofing from indigenous materials in three developing countries (Philippines, Jamaica and Ghana).

Four composite panel roofing material systems were developed which utilize major percentages of indigenous bagasse filler and minor amounts of phenolic or other resin binders. Three of the systems developed use an intensive (**Branbury**) mixer, all four have compression moulding as a final process step in panel fabrication. (Report: "Development of Low-Cost Roofing, from indigenous materials in developing countries" – Agency for International Development, U.S.A., Washington, 1978). Two of the systems which were found to be feasible for Ghana are explained below.

In Ghana it has long been recognized that roofing is one of the key and most costly elements of construction (the roof can account for up to 15 % of the total costs of the building) and that due to the shortage of cement and suitable roofing materials a meaningful housing programme cannot be realized. The programme aimed at producing a roofing material which consisted of composites of low cost indigenous fillers and polymeric binders and required only a minimal foreign currency component. The production process should moreover utilize abundant local manpower and locally available facilities.
The material should successfully pass performance and durability tests and prove to have acceptable resistance to:

- Static loading,
- Impact,
- Solar radiation,
- Heat,
- Rain,
- Humidity,
- Wind,
- Fire,
- Sound transmission,
- Insects, pests and fungus,

and should be of an acceptable appearance.

The tests with two of the composite systems were supervised in Ghana by the Building and Road Research Institute at Kumasi (M. K. Obeng) and manufacturing was undertaken by Ghana Rubber Products Ltd., Accra.

(a) **Bagasse – reinforced Phenolic Composite Roofing Material (BRP):**

This system consists of fibrillating the bagasse (in a Branbury intensive mixer) and dry blending it with resin binder in an end-over tumbler, e.g. concrete mixer (Table 6). The material is then compression-moulded for 3–7 minutes at 135° C. The result is a rigid, strong, durable, moisture resistant, red pigmented panel product.

This system was found to be the one involving the lowest costs from all four system.

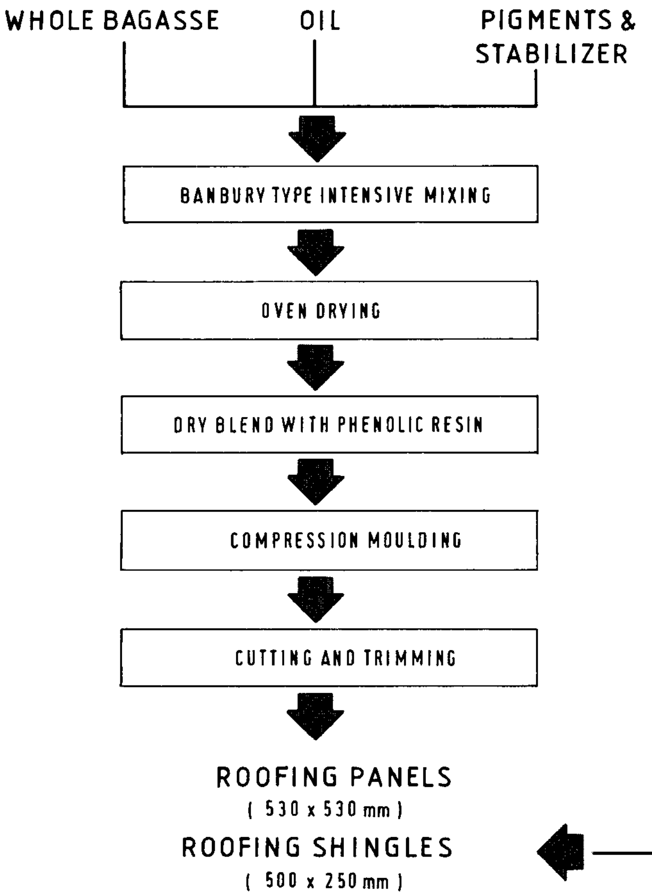


TABLE 6 : PRODUCTION PROCESS OF BAGASSE-REINFORCED PHENOLIC COMPOSITE ROOFING MATERIALS - BRP.

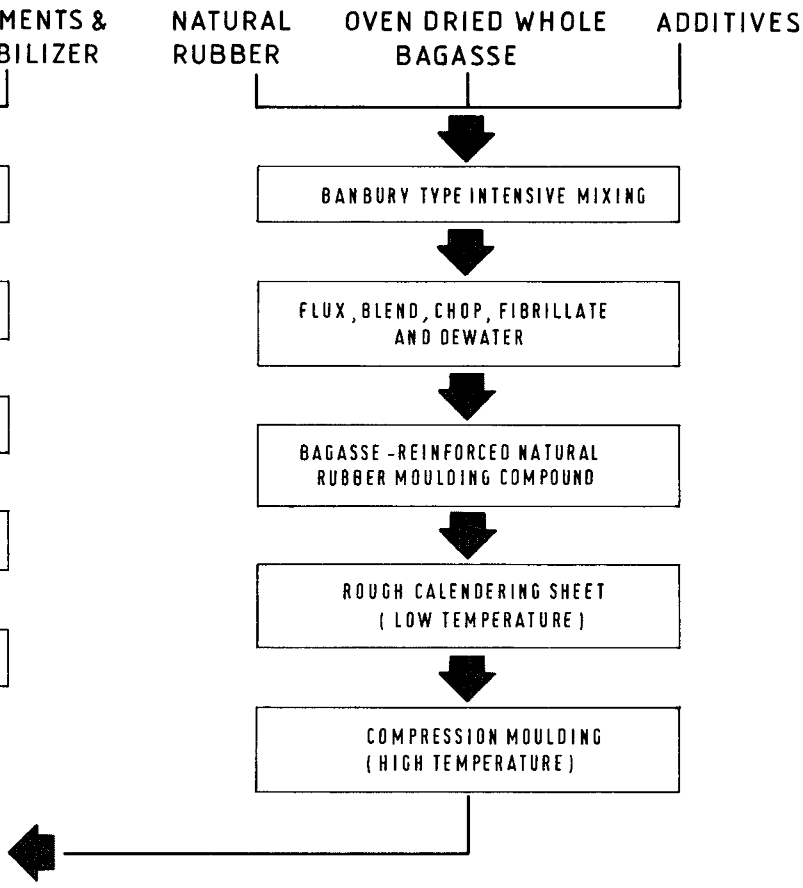


TABLE 7 : PRODUCTION PROCESS OF BAGASSE-REINFORCED HARD RUBBER COMPOSITE ROOFING MATERIALS - BRR.

Composition of raw materials:

	Weight
– Phenolic Binders (Phenol Formaldehyde resin) for strength rigidity and fire resistance)	30 %
– Whole Bagasse (reinforcing filler)	61 %
– Iron Oxide pigment	5 %
– Oil	4 %
– Preservative	0.05 %

In Ghana, besides bagasse, the filler, constituting the largest volume of raw materials needed, process oil, pigments and phenolic powder are available.
On the exposure site it was found that a very thin top surface layer which is rich in resin binder was degraded after the first two months, changing the surface from glossy to a dull finish which is acceptable for the appearance. After a number of years the roofing material is still in good condition (Fig. 201).

(b) **Bagasse – reinforced hard Rubber-Composite Roofing Material (BRR):**

This system has a more complicated process of production using different ingredients. Ghana is a rubber-producing country. The availability of the major raw materials (weight) would make the large-scale production of BRR – roofing shingles or panels an economic venture if a press can be developed for the compression-moulding which works with higher temperatures than that used for the commercial rubber processing.

Composition of raw materials:

	Weight
– Components of a hard rubber matrix material (natural rubber, chlorinated paraffin, sulphur, stearic acid zinc, oxide, stabilizer and accelerator)	45.26 %
– Constituents needed to introduce a level of fire resistance	0.54 %
– Fillers, dry whole bagasse	52.20 %

A low-cost version has been tested in which the chlorinated paraffin oil was substituted with rubber processing oil. This material had a poorer fire resistance. The production process is explained in Table 7.
On the exposure site it was found that the very thin top surface layer which is rich in natural rubber resin binder degraded and eroded, changing the glossy to a dull finish similar to the BRP sheets. Tensile retension of 97 % was graded excellent after two years.
BRR-shingles are tough. They can be nailed with flat top nails. The material can be bent when heated (up to 65° C) around large radius simple curves (which would, in use, minimize sealing problems).

The other two processes, bagasse-reinforced thermoplastic composite roofing (BRT) and phenolic bonded, oriented bagasse fibre composite roofing (BOB) were not tried in Ghana. They also proved to be good materials where they were tried (Philippines, Jamaica).

In a tropical developing country which is self-sufficient in sugar through sugar cane production excess bagasse would be available in sufficient quantities. At present Ghana uses all the bagasse for firing in the two existing sugar mills. "Mini-sugar mills" would offer a solution. If the equipment for the production of the composite roofing material is availsble as well as suitable phenolic resin or hard rubber binders, this roofing material would be a good alternative to the costly conventional roofing materials which in many of these countries have to be imported.

Fig. 201: Experimental bagasse – reinforced phenolic composite roofing shingles on a kiosk at the Council for Scientific and Industrial Research headoffice in Accra, 1981.

II. SUGAR PRESS-MUD:

Sulphitation and carbonation sugar mills have a waste material in the sugar production process, sugar press-mud or lime sludge. From the sulphitation mills this is used as fertilizer. The sludge left from the carbonation sugar mills consists mainly of calcium carbonate and has no use. In India this press-mud has been used as building lime, which was found to be cheaper than to make lime from limestone.

3.3.1.5 COCONUT WASTES

Coconut husk and coir fibre have been used in the production of building boards and corrugated roofing sheets combined with Portland cement in the Central Building Research Institute of Roorkee, India. The boards can be used for partitions and walling, or for thermal insulation. The corrugated roofing sheets have to receive a protective treatment on the exterior surface (a coating based on cashew nut-shell liquid resin or an aluminium foil 10–15 microns thick have shown good-reults against weathering and solar radiation).

3.3.2 FORESTRY WASTE

With the policy adopted in many tropical developing countries to export semi or fully processed timber products rather than the complete logs of commercial tropical hardwood species the processing saw mills, ply and veneer mills, produce waste in form of saw dust, timber off-cuts and shavings (Fig. 202). It has been found that different building materials can be made from wood wastes.

3.3.2.1 SAWDUST

I. PYROLYTIC CONVERSION TO FUEL:

In Ghana a pyrolytic converter has been built (as already mentioned in **"Natural Materials, Clays and Clay Products"**) which converts wood wastes into oil and char. This process was developed by the Engineering Experiment Station (EES) at the Georgia Institute of Technology, U.S.A., through pilot plant studies. The process is applicable to almost any type of carbonaceous waste and ligno-cellulosic materials that are available in sufficient quantities in most of the tropical developing countries. One ton of waste produces the fuel equivalent of about one barrel of oil.

II. BRICK AND FLOORING FROM SAWDUST:

Sawdust is used in the production of porous clay bricks. Sawdust and clay are mixed and hand-moulded. When the bricks are burnt in a kiln the burnt sawdust leaves pores in the structure of the brick, producing a brick of good thermal properties. Magnesium oxychloride floorings are also manufactured containing 28–30 % sawdust.

3.3.2.2 WOODCHIPS, STRANDS, SHAVINGS, WOOD-BASED FIBRE MATERIALS

Timber offal is used for the manufacture of different types of panels. The products manufactured with these particle and wood-base fibre materials include insulating boards, hardboards, particle boards and woodwool slabs. Wood off-cuts can be engineered to an optimum particle size and shape for the product that is to be made. These panel materials are all reconstituted wood. The end products, different types of boards, vary in thickness, density, weight and properties. The raw material used in the production of these boards are coarse residues from logging operations, saw mills and furniture workshops. In addition suitable binders are used. Whereas the forestry wastes used from mills etc. are normally from primary wood species, lesser known or non-commercial species are also a good source of raw materials.

I. FIBRE BOARDS:

The wood materials are converted into fibres and then interfelted together. Lignin acts as bonding agent. Natural and synthetic resins can also be used as binding agents including preservative and fire-resistant chemicals as additives. These will increase the strength of the boards, the resistance to decay, fire and insects.

II. PARTICLE BOARDS:

In the production of particle boards wood chips are bound with synthetic resin (Urea-Formaldehyde, in some cases Phenolic Resins). Special machines are needed to cut the chips and press the boards in the presence of heat. The resins used as binding agents are thermosetting resins with other chemical additives to improve the properties of the boards.

In Ghana rigid particle boards are produced by Novotex at Nkawkaw (Fig. 203). The size of these boards is 2.43 m x 1.22 m x 6 mm (Imperial size 8′–0′ x 4′–0′ x ¼″).

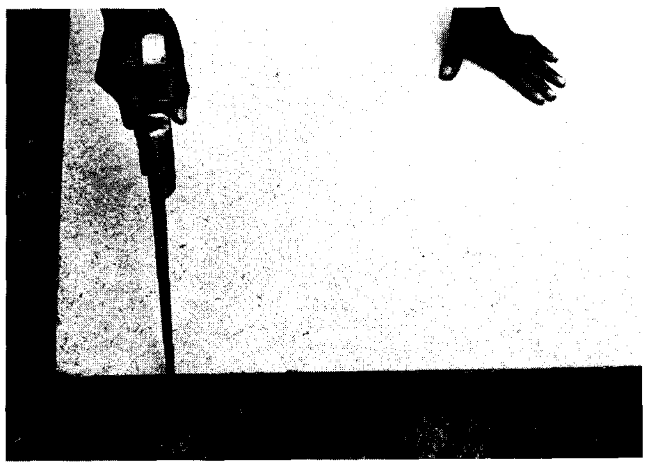


Fig. 203: Particle board made by NOVOTEX, Nkawkaw, 1981.

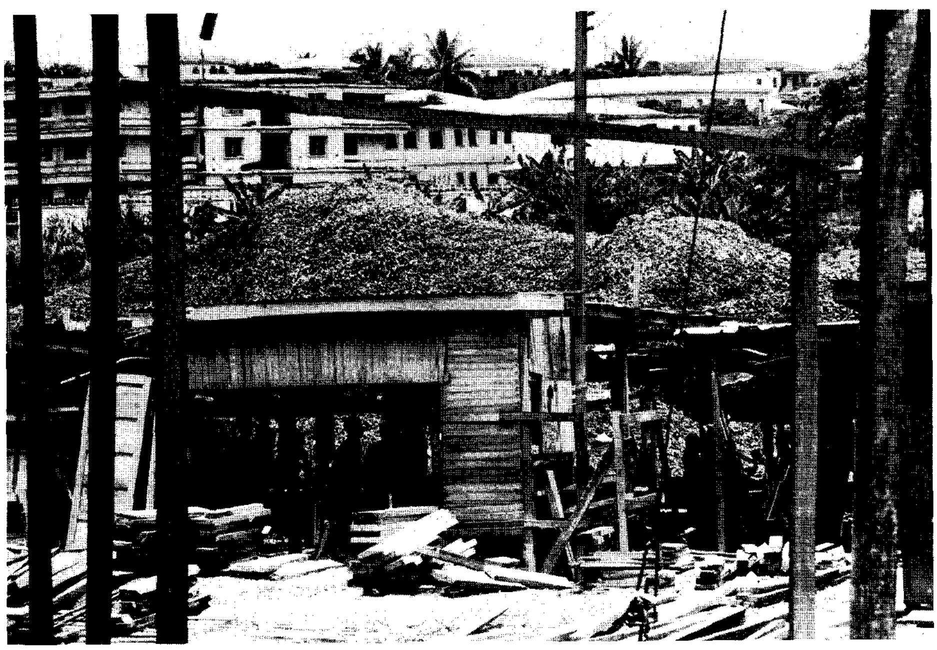


Fig. 202: Timber waste heaps behind carpenter workshops at Anloga, Kumasi, 1981.

III. WOODWOOL BUILDING BOARDS:

Woodwool is manufactured from special wood shavings and mineral binding agents, normally Portland cement, magnesite and gypsum. Wood used for the shavings should be of no commercial value. The Forest Products Research Institute (F.P.R.I.) at Kumasi, Ghana, has tested a number of different local timber species for their suitability in the manufacture of cement-bound woodwool slabs. Not all tropical wood species are suitable for this purpose. Species with too high tannin and/or sugar content (of the ligno-cellulosic material) cannot be used, the setting of the cement would be adversely affected.
Of the suitable species ***Celtis*** sp. and ***Chrysophyllum*** sp. are abundant in the moist semi-deciduous forests of Ghana and neither are commercial species. Woodwool slabs manufactured with shavings of these species have furthermore been tested by the Building and Road Research Institute (B.R.R.I.) at Kumasi, against termite attack and were found to have the lowest termite damage after 16 months exposure on the surface of the ground and in the ground sandwiched between bait wood, compared to other species.
Woodwool slabs are also produced with shavings from other non-economic species like ***Musanga Cecropioides*** (Umbrella Tree).

Woodwool slabs produced in Ghana are 2.00 m x 0.50 m x 25,50,75, or 100 mm thick (first commercial production of woodwool slabs was recorded in Austria in 1928). The density of the boards decreases with increasing thickness. The shavings are mixed by volume: 1 volume of woodwool to two volumes of cement and one part of water. Before mixing, the shavings have been soaked in a 3 % solution of calcium chloride (or magnesium chloride) for 5 minutes. The main binder is cement, but successful tests have also been made to use pozzolanic cement from bauxite waste instead. The mixture is placed in wooden moulds, kept under pressure (with cramps) for maximum 24 hours. The slabs are then stacked on top of battens to allow free air circulation and left to cure for 28 days (Fig. 204 *to* 206).

Fig. 205: Using a clamp to press down ready-mixed woodwool shavings in moulds.

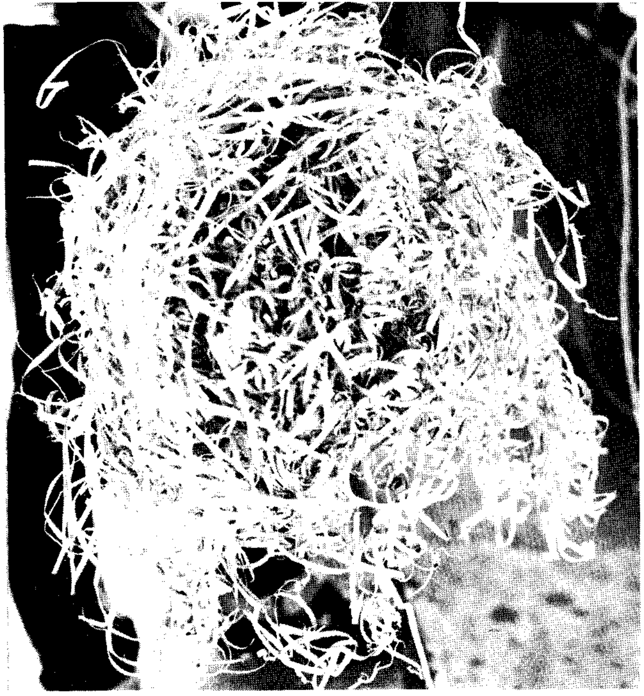


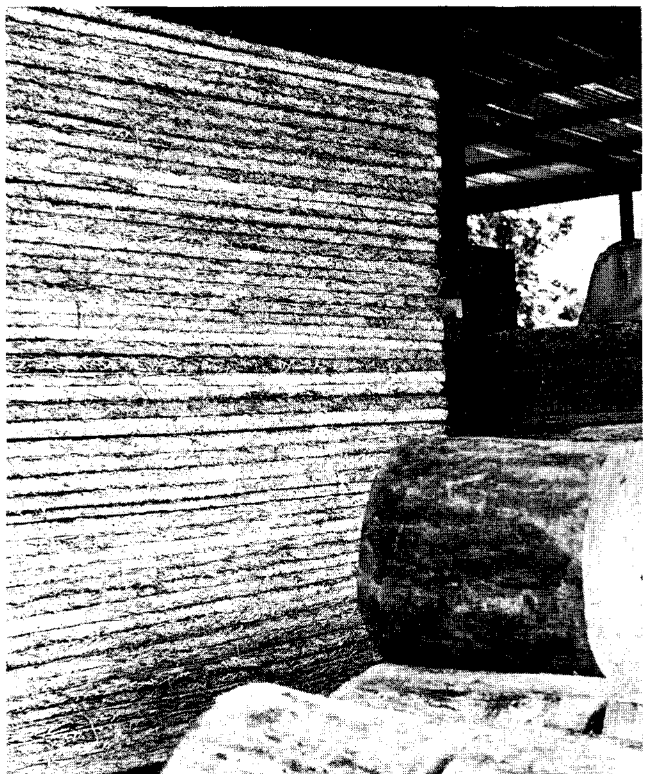
Fig. 204: Shredded timber used for the production of wood wool slabs at the Forest Products Research Institute, U.S.T., Kumasi, 1981.

Woodwool slabs are normally used as non-loadbearing building slabs for thermal insulation, partitions, plaster boards, ceiling boards. They have high accoustical and insulative properties. They can be nailed, sawn and plastered. By adding appropriate chemicals during the manufacture, they can be made resistant to fire and rot. Woodwool slabs are normally used in the interior of buildings where it is less likely that they are attacked by subterranean termites. Woodwool slabs should not be used in a damp and wet environment.

3.3.2.3 TANNIN-BASED ADHESIVES FROM MANGROVE BARK

The bark of ***Rhizophora*** (Red mangrove) contains up to 40% tannin. In Indonesia work has been done on using tannin-based adhesives from this bark in the production of particle boards. The resins (a thermosetting condensation product from the reaction of para-formaldehyde with mangrove bark extract) are the bonding agents in the manufacture of particle board.

Fig. 206: Matured woodwool slabs. Wood used for shredding in the foreground.



3.3.3 INDUSTRIAL WASTES

3.3.3.1 POZZOLANA FROM BAUXITE WASTE

Much work has been done by the Building and Road Research Institute at Kumasi, Ghana, on the production of pozzolana from bauxite waste that can be used, mixed with lime and sand as mortar or plaster or mixed with up to 40 % of Portland cement as pozzolana cement for structural concrete. Some details are also listed in **"Man-Made Materials, Pozzolana-Cement"**.

Bauxite waste in Ghana is produced through washing of bauxite ore for export. These washings, containing 25 % of solids, are collected as ponds. During the dry season from December to February the ponds dry out leaving a red plastic mud. A vast amount of this mud has accumulated to more than a million tonnes at Awaso (British Aluminium Company) mine over the years. This red mud is, after excavation, sun-dried, calcined at controlled temperatures between 600 to 800° C for a suitable period, after which it is ground to cement fineness. In this state it is used with lime and sand as mortar or plaster and has shown satisfactory compressive strengths properties. The ground pozzolana can also be blended with cement in different proportions. Intergrinding the pozzolana with cement clinker in proportions as high as 50 % yields a pozzolanic cement with long-term strenghts equivalent to that of ordinary Portland cement.

Preliminary cost estimates for the commercial production of the pozzolana have indicated that with the availability of bauxite waste (with more waste available if other bauxite reserves are to be developed as proposed) the cost of cement may be reduced by a considerable amount. Bauxite is also being mined in Sierra Leone, Guinea, Zaire, Jamaica, Guyana.

Tables 8 and 9 show compression tests of blended cement – pozzolana mortar and concrete ("Pozzolana from Bauxite Waste" by A. A. Hammond, B.R.R.I., Kumasi).

MIXTURE	MORTAR		CONCRETE 1:2:4	
	7 DAYS	28 DAYS	7 DAYS	28 DAYS
100 % CEMENT	284·35	342·96	214·44	305·84
80 % CEMENT/ 20 % POZZOLANA	267·04	319·19	228·50	316·40
70 % CEMENT/ 30 % POZZOLANA	254·51	284·12	211·62	300·21
60 % CEMENT/ 40 % POZZOLANA	248·17	267·38	140·00	224·28

TABLE 8 **COMPRESSION TESTS OF CEMENT-POZZOLANA MORTAR AND CONCRETE** (kg/cm²)

SAMPLE	7 DAYS	28 DAYS	60 DAYS	90 DAYS
LIME : POZZOLANA : SAND 1:2:9	111·67	120·92	127·95	137·79

TABLE 9 **COMPRESSION TEST OF LIME-POZZOLANA-SAND MORTAR** (kg/cm²)

3.3.3.2 BLAST FURNACE SLAG: SLAG CEMENT

Integrated steel works produce large quantities of blast furnace slag as a waste product. Slag is discharged from the blast furnace as a hot liquid. After it cools in the air (or water) its composition is similar to that of clinker used for cement manufacture, except that its lime content is very low. Blast furnace slag can be used for inter-grinding with clinker to produce conventional slag cement. Other uses for blast furnace slag have already been mentioned in **"Man-Made Materials: Concrete, Aggregates"**.

3.3.3.3 FLY ASH

Fly ash which is a waste by-product of the combustion of pulverized coal in thermal utility plants, is increasingly being used as a pozzolanic material to partly replace ordinary Portland cement. In developing countries which are using thermal power stations the disposal of fly ash and its use as a good quality cementitious material is of ecnomic advantage. The quality of the fly-ash used depends on the quality and fineness of the pulverized coal and the method of burning it. Good quality fly-ash increases the workability, strength and durability of the produced cementitious material.

The Central Building Research Institute of India has developed a process of using fly-ash obtained from India's thermal power stations in the brick industry. The addition of fly ash to the clay results in less firing costs. The bricks are lighter and better burnt. Addition of fly ash has also resulted in a reduction of drying shrinkage of the bricks. The C.B.R.I. has also developed a process for the use of fly ash in combination with clay and coal for the production of light-weight aggregates with bulk density of 650 to 700 kg/m³. The fly ash is fed (together with clay and pulverized coal in suitable proportions) into a pan pelletizer. The pellets are then fed into a sintering machine. The sintered products are allowed to cool, then crushed in a jawcrusher and sieved into three fractions. One ton of aggregate requires a little more than one ton of fly ash.

3.3.3.4 LIME SLUDGE

Large quantities of waste lime sludge in form of finely precipitated calcium carbonate are available from:

- Carbonation process, sugar factories;
- Sulphate and soda process, paper mills;
- Tanneries;
- Calcium carbide based acetylene industries (Fig. 207).

Fig. 207: Lime sludge waste at the AIR LIQUID factory in Tema, 1981.

Much research work has been done in different developing countries into the use of lime sludge by intergrinding this waste material with Portland cement to produce a specially formulated masonry cement. It is necessary, however, to examine lime sludges before they are used as raw materials for the manufacture of cement, since calcium carbonate and lime sludge are likely to contain impurities such as sulphates, phosphates and alkalis.

3.3.3.5 ASBESTOS CEMENT FACTORY WASTE

During the production of asbestos cement waste in form of asbestos cement sludge and recuperator waste is produced. The Regional Research Laboratory in Jorhat, India, has developed a simple process for making durable floor tiles from this waste. Even with a low moulding pressure of 50 kg/cm^2, the value of transverse breaking load and the percentage of water absorption satisfy the specification requirements. Tile sizes are 200 x 200 mm x 20 mm thick and they can be produced in different colours. The raw materials required are: asbestos cement sludge and recuperator waste, ordinary Portland cement, white cement, marble dust and chips and pigment. The main items of the equipment for the production are: pulverizer, ball mill, concrete mixers, hydraulic press with necessary moulds for tile making, grinding machine, curing and water tanks. With sufficient raw materials available 2000 tiles could be produced in a working day.

3.3.3.6 ASPHALTIC CORRUGATED ROOFING SHEETS

Bitumen, a by-product of the petroleum-refining industry is already being used together with paper felt in the manufacture of asphaltic corrugated roofing sheets in India, Brazil and some African countries. The production process (as described by DR. A. V.R. Rao from the Indian National Building Organization in Appropriate Technology, Vol. 1, No. 4, "Roofing with Low-cost Corrugated Asphalt Sheets") is simply to reduce the basic raw material: waste paper, rejected asbestos fibre and rags or other cellular fibres, cocosnut fibres, etc. to a wet pulp of the required fineness successively in coarse and fine hammer mills and forming the pulp into sheets, in felt or board forming machines. The boards are dried in the sun or in a drying oven under controlled conditions and trimmed. They are then impregnated in an asphaltic bath, cured for a short time and finally dip painted (aluminium paint). The impregnation medium is a standard paving asphalt.

Asphaltic corrugated sheets could satisfactorily replace conventional and more expensive roofing materials such as corrugated iron and aluminium sheets especially where these have to be imported and waste raw materials for the production of asphaltic corrugated sheets are available.

It is recommended to use asphaltic corrugated roofing sheets in temperatures not exceeding 44 °C in the shade. India is already producing these sheets with an average annual capacity of 20 million square metres (1976) and plans to establish more plants. Asphaltic corrugated roofing sheets are completely waterproof, having excellent thermal insulation properties, are flexible, non-conducting, fungus and termite proof and not susceptible to corrosion (and consequent leakages, as so often happens with galvanized iron sheets). Being light the sheets require a lighter substructure. They can be nailed directly on to the supporting structure even by unskilled labour without special fixing equipment. In India these roofing sheets are used in areas of heavy rainfall, for low-cost urban housing and for rural housing.

3.3.4 CONCLUSION

From the foregoing it can be seen that the conversion of various types of agricultural, forestry and industrial wastes into building materials is no longer just a research pursuit but in many cases an already established technological achievement, especially in many of the developed countries. There the industries established to manufacture building materials from wastes have the advantage of vast amounts of low cost raw materials. At the same time these new industries help solve pollution and socio-economic problems. With rapid agricultural development and industrialization in the developing countries large quantities of agricultural, forestry and industrial wastes are now available. Their conversion into building materials will supplement conventional building materials, will reduce shortages of building materials and will enable developing countries to implement their necessary construction programmes.

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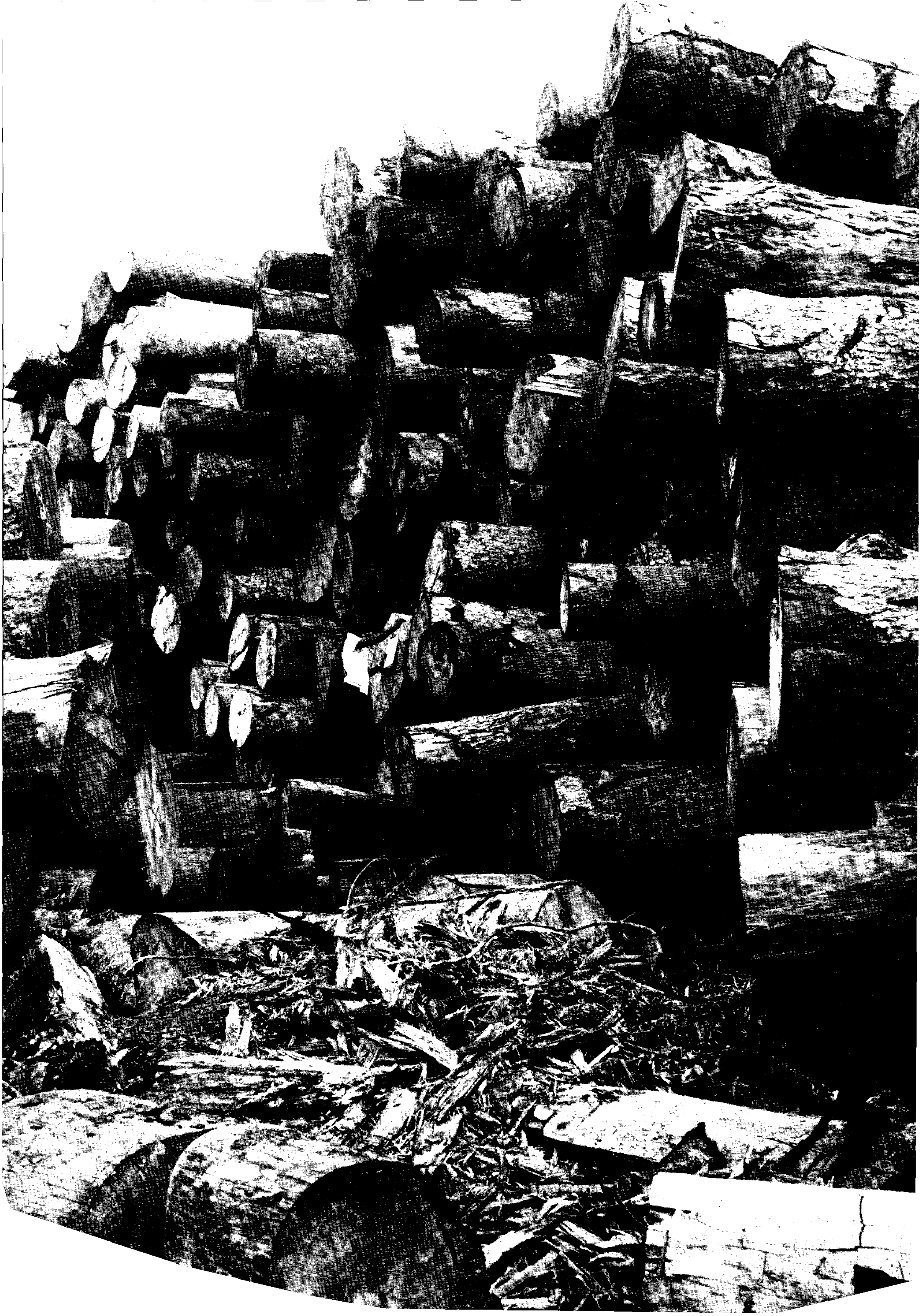


4 TIMBER AND TIMBER FRAME CONSTRUCTION

For the present housing need in developing countries where the population grows at a much higher rate than in the developed countries the uses of all available local building materials must be fully explored.

As already mentioned before the tendency in Ghana has been to use cement-sand block construction for wall building in the fast growing urban areas. With the beginning stagnation and decline of the economy the call went out for low-cost housing schemes. As about 60 % of the costs of a building account for materials used in the construction it is in the national interest of developing countries which are rich in different tropical hardwoods to use timber to a greater extent in building.

The advantages of timber will be discussed in the following sections on the physical and mechanical properties of timber. The disadvantages are always over-emphasized, whenever there is a discussion about the use of timber for construction of houses. The first reason for rejecting timber is "that it burns". It is true that timber is a combustible material, but in larger sections (which are those normally used in frame construction) it has a greater resistance to fire than for example steel and aluminium, because metals distort, bend and collapse in a short time when burning, while timber sections stand fires for a longer period without failure. It is perhaps interesting to note here that during World War II and the bombing damages to European, especially English and German towns, structural timber in many medieval and other buildings survived the fires (the framework was burnt and smouldered away on the outside, the core of the sections was untouched and sound), yet buildings with reinforced concrete frames and slabs had collapsed. In its natural state timber already satisfies general fire resistance requirements of building codes. With additional treatment it can be rendered incombustible. Fire hazard is therefore not a setback in the use of timber for building.

Treatment of timber can also improve its resistance to fungi and termites, as will be explained further on. Coupled with these measures should be a careful selection of the right timber species for construction and specific design details which help to prevent possible fungus and termite attack.

As with mud houses a change of mentality is necessary to understand that timber houses have qualities equal and better than houses built with cement-sand blocks and reinforced concrete frames. Wood is easily worked and shaped. It has high strength compared to its weight. It is flexible for component design, that is for prefabricated panel system building, which makes erection and dismantling of timber structures easy. Industrialized building methods with timber components and structural timber are common practice in the Scandinavian countries. This practice is spreading throughout North America, Canada and Britain where timber is becoming, next to bricks the principal material in one, two and three-storey housing construction. The same is true of Australia and New Zealand. Some tropical developing countries such as Papua New Guinea, India, Kenya and Malasia are also putting a larger emphasis on the use of wood for housing.

Overleaf: Logs at a sawmill in Kumasi, 1982.

Timber houses are durable, comfortable and also more resistant to earthquakes. The feeling of comfort in a house is being enhanced by wood panelling on walls, by a timber floor and timber strip ceiling. The wealth of textures and colours of different tropical timber species and their natural beauty cannot be matched by any other material (Fig. 208). Wood has excellent insulating properties and a low thermal conductivity. It is resilient. In concert halls timber panels of different kinds are most valuable tools in tuning of these halls or in sound studios (wood is used there for accoustic applications). Timber frame windows and doors have proved to be more economical than steel or aluminium-framed windows and doors in tropical developing countries.

There are no less than about 250 species of timber available in Ghana, out of which about 100 species are usable for construction (see **"Timber Catalogue"**, Appendix II). Of these about 40 are so-called "commercial" species (of which 12 are used primarily for export). Some of these species are soft and light; some are as hard as iron and very heavy. Some of them have similar properties. So that, if one particular species, e.g. Odum (***Chlorophora Excelsa***) is not locally available in one area, other timber species may be there which have properties similar to Odum.

4.1 TREE GROWTH (Fig. 209)

Wood is made up of individual units, called cells. When cells of the same type are together and perform the same function, their formation is described as tissue (there are the storage tissue, the conducting tissue, the strengthening tissue). The growth of a tree is the result of the living process of cell formations. Growth is restricted to those regions in which cell forming tissue occurs and this is entirely in the **Cambium**-sheath (Fig. 210). Tropical timbers, unlike timbers from temperate climates, do not obey climatic changes and so do not often exhibit growth rings. The effect of wide rings, if any, is a lower density of the wood and consequent decrease in structural strength. Narrow rings point to a strong wood of high density. If both wide and narrow rings occur in one piece, typical seasoning defects may appear on drying, which will be explained further on.

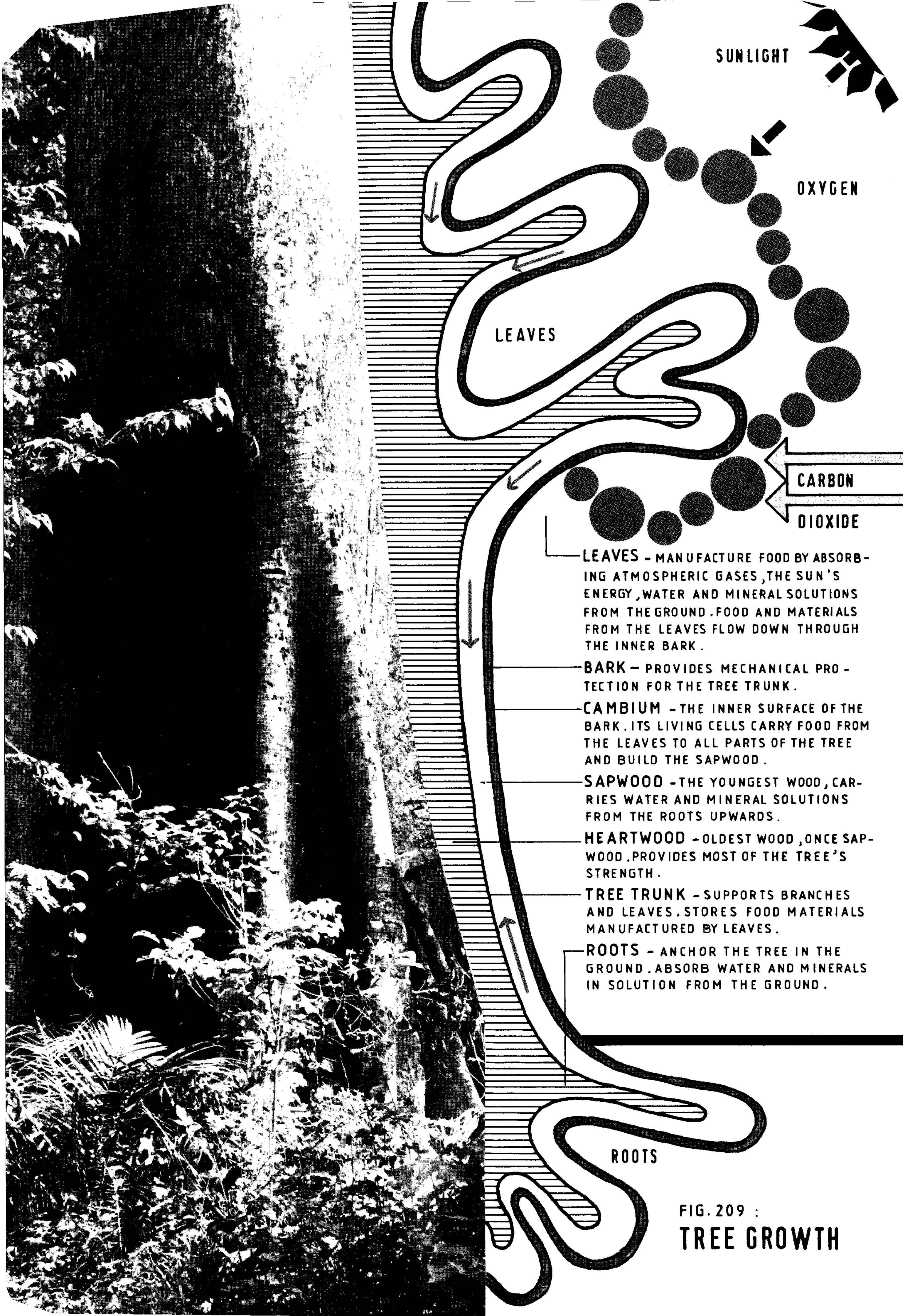


FIG. 209 :
TREE GROWTH

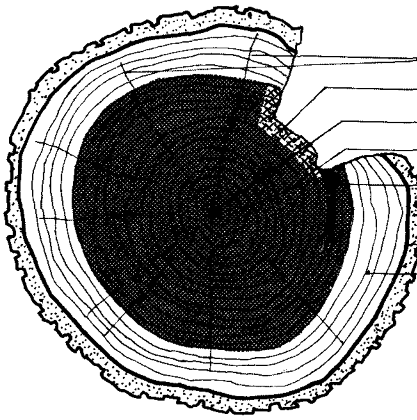


FIG.210 SECTION THROUGH A TREE TRUNK

Under normal conditions the growth of a tree is more or less erect. Wood for building construction should be cut from straight logs and should be free of defects, such as knots (which cause the grain fibres to run obliquely to their former course in their vicinity).

The grain of wood is the direction or arrangements of fibres or cells. It is also describing the structural features of timber (or the plane of the outer surface of the timber – end grain, side grain). The strength of timber varies with the angle of inclination of the applied stress to the direction of the grain. The greater the inclination or slope, the weaker the timber is in strength; for example knots disturb the direction of grain causing localized cross grain with steep slopes.

4.2 CONVERSION AND GRADING OF TIMBER

4.2.1 CONVERSION

A proper conversion of timber (cutting up of a log into sawn timber) is important, because the value of the wood is being influenced by the correct methods used for the different requirements of the sawn timber.

A survey on timber conversion at some of the sawmills in Kumasi showed that generally two methods of conversion are being used (Fig. 211). The type of conversion used depends on the user's specifications.

FLAT SAWN:

Also described as through and through sawn or slash-sawn refers to cutting tangential to the growth rings right through the log.

QUARTER CUT:

Or rift-sawn refers to cutting radially to the growth rings. Quarter-sawn timber shows less tendency to curl across the width and shrinks less than flat sawn timber. It is the best method of cutting floor boards.

4.2.2 GRADING

Grading of timber means sorting or classifying it into quality groups for particular uses. The basis for grading may be the determination of defects (by visual means) which affect appearance and/or strength or the determination of strength by mechanical means. In some sawmills the following grading system is being used (in the absence of a uniform system of grading) in Ghana:

1st grade = free from all defects;
2nd grade = some round knots and small defects;
3rd grade = a larger number of knots and small defects;
4th grade = definitely knotty (with dead knots) and waney edges.

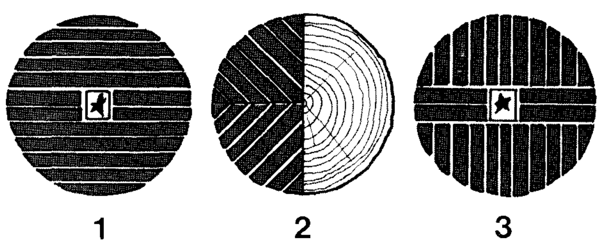
Since it is seldom possible to find a perfect log, most sawn timber will have a certain number of imperfections, defects and blemishes. A defective piece of timber cannot be used where it is necessary to use a faultless piece. On the other hand it would not be economical to use a faultless piece of timber where pieces with some defects could be tolerated. The basis for a grading system therefore is the identification and description of limiting defects (in the case of strength grading) or limiting blemishes (in the case of appearance grading). In addition the user's specification will be another basis ("usage grading").

Grading for strength is more technical. As already mentioned before, different defects have variable influences on strength properties of timber. Principal defects which cause a decrease in the strength of timber are:

1. Slope of grain;
2. Knots and holes;
3. Wane (decrease in size);
4. Gum pockets.

Grading rules are formulated which specify limitations for the defects which affect the strength of timber ("Stress-grading" = accurate and reliable grading for strength). In recent years mechanical grading has received considerable attention. It is based on the relationship between deflection and flexural strength.

In Ghana work on grading by the Building and Road Research Institute (B.R.R.I.), the Forest Products Research Institute, (F.P.R.I.) and the Utilization Branch of the Minis-



1 FLAT SAWN (THROUGH AND THROUGH SAWN) WITH A BOXED HEART WITH STAR SHAKES; GOOD FOR FLOOR JOISTS.
2 QUARTER CUT OR RIFT SAWN, WITH BOXED HEART (STAR SHA-
3 KES) IN 3; GOOD FOR BOARDING.

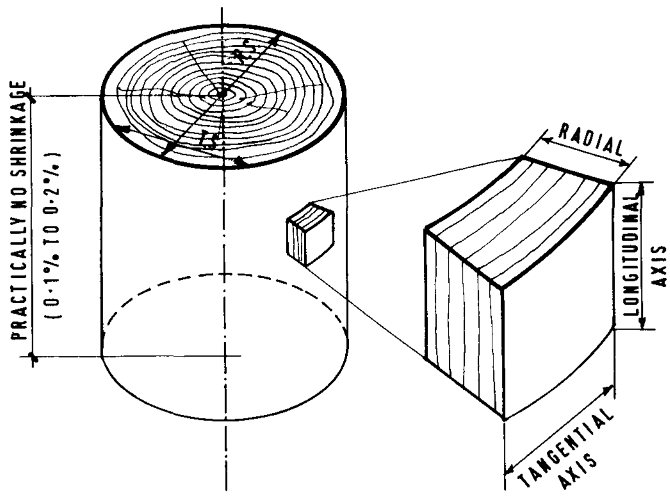
FIG.211 CONVERSION OF TIMBER

try of Forestry is based on strength grouping of timbers. More or less uniformly accepted seem to be the recommended strengths groups of N.S. Bawa ("Working Stress of Ghana Timbers" – Technical Note No. 5 – B.R.R.I.). These are listed in three grades:

- Grade I or 75 % stress grade:
  Faults in this particular grade of timber will require that basic stresses be reduced to 75 % of their values.

- Grade II or 65 % stress grade:
  Working stress values for Grade II timber will be 65 % of the basic stress values.
- Grade III or 50 % stress grade:
  Extends of faults in Grade III timber will require a reduction of basic stresses by 50 % of their values.

Basic properties of some indigenous Westafrican hardwoods are listed on Table 10 (*from*: "Compilation of Data on the Properties of some Hardwoods Indigenous to West Africa" by Isaac K. A. Okoh, Technical Note No. 22, F.P.R.I. For Table 10 see Appendix III).



R.S. = RADIAL SHRINKAGE AS MUCH AS 8% FROM GREEN TO DRY.
T.S. = TANGENTIAL SHRINKAGE AS MUCH AS 14% FROM GREEN TO DRY. VARYING WITH THE SPECIES T.S. IS GENERALLY CONSIDERED TO BE TWICE AS MUCH AS THE RADIAL SHRINKAGE.

FIG. 212 SHRINKAGE OF WOOD AND STRUCTURAL AXES

4.3 PROPERTIES OF TIMBER

4.3.1 PHYSICAL PROPERTIES OF WOOD

Wood ist hygroscopic, it absorbs or gives up moisture to the atmosphere in a constant interchange. Green wood (wood just cut) starts to give up free water first when exposed to the air, then the cell walls start to shrink as the water in them is given up. The wood starts to shrink below the fibre saturation point (fibre saturation point = 25 % to 30 % of the dry weight of wood). During this "drying" period the strength, hardness and stiffness of the wood increase. If this timber is exposed to a humid atmosphere again (after it has been dried below the fibre saturation point) it will absorb water, but only in the cell walls. This "working" of the wood cannot be eliminated but can be kept within reasonable limits by proper seasoning and also correct storage (Fig. 212).

4.3.2 MECHANICAL PROPERTIES OF WOOD

The mechanical or strength properties of wood are a measure of the ability of timber to resist externally applied forces which tend to alter its shape or size or to result in any other deformation. For the structural use of timber its resistance to:

- Bending;
- Compression;
- Tension;
- Shear;

must be known. Unlike steel which is **isotropic** (and has the same properties in all directions) wood is **orthotropic**; it possesses different mechanical and elastic properties in accordance with the direction in which it is stressed (Fig. 213).

FIG. 213 MECHANICAL PROPERTIES OF WOOD:

TENSILE STRENGTH : THIS IS A MEASURE OF THE ABILITY OF TIMBER TO RESIST FORCES THAT TEND TO PULL IT APART, OR TO STRETCH OR ELONGATE IT. WOOD IS STRONGEST IN TENSION PARALLEL TO THE GRAIN.

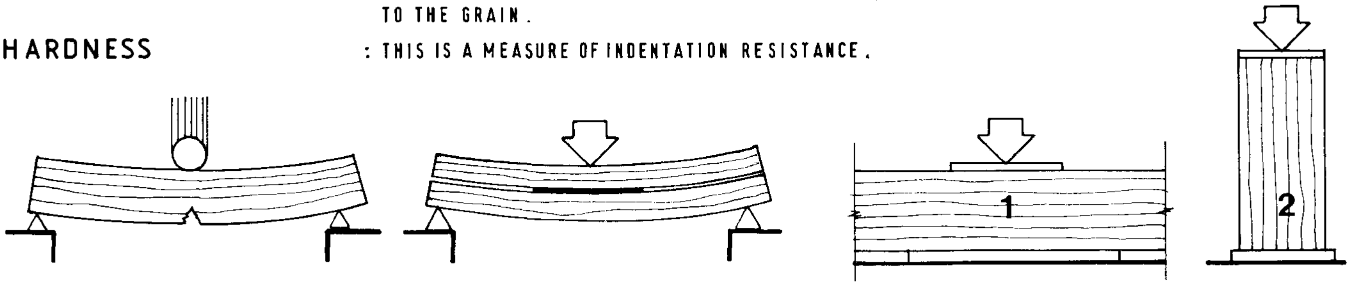
COMPRESSIVE STRENGTH : THIS IS A MEASURE OF THE BEARING STRENGTH OF TIMBER PARALLEL TO AND ACROSS THE GRAIN.

SHEARING STRENGTH : THIS IS A MEASURE OF THE ABILITY OF TIMBER TO RESIST FORCES THAT TEND TO CAUSE ONE PART OF THE PIECE TO SLIDE ACROSS ANOTHER PART ADJACENT TO IT. SHEAR PARALLEL TO GRAIN IS FREQUENTLY THE CAUSE OF FAILURE OF BEAMS UNDER CERTAIN LOADING CONDITIONS.

BENDING STRENGTH : THIS IS A MEASURE OF THE STRENGTH OF TIMBER ACTING AS A BEAM. STRESSES INDUCED ARE COMPOSITES OF SIMPLE COMPRESSION, TENSION AND SHEAR STRESSES.

STIFFNESS : THIS IS A MEASURE OF THE ABILITY OF TIMBER TO RESIST DEFLECTION OR BENDING. IT IS EXPRESSED IN TERMS OF "MODULUS OF ELASTICITY" (E). THE MOST IMPORTANT 'E' IS THAT PARALLEL TO THE GRAIN.

HARDNESS : THIS IS A MEASURE OF INDENTATION RESISTANCE.



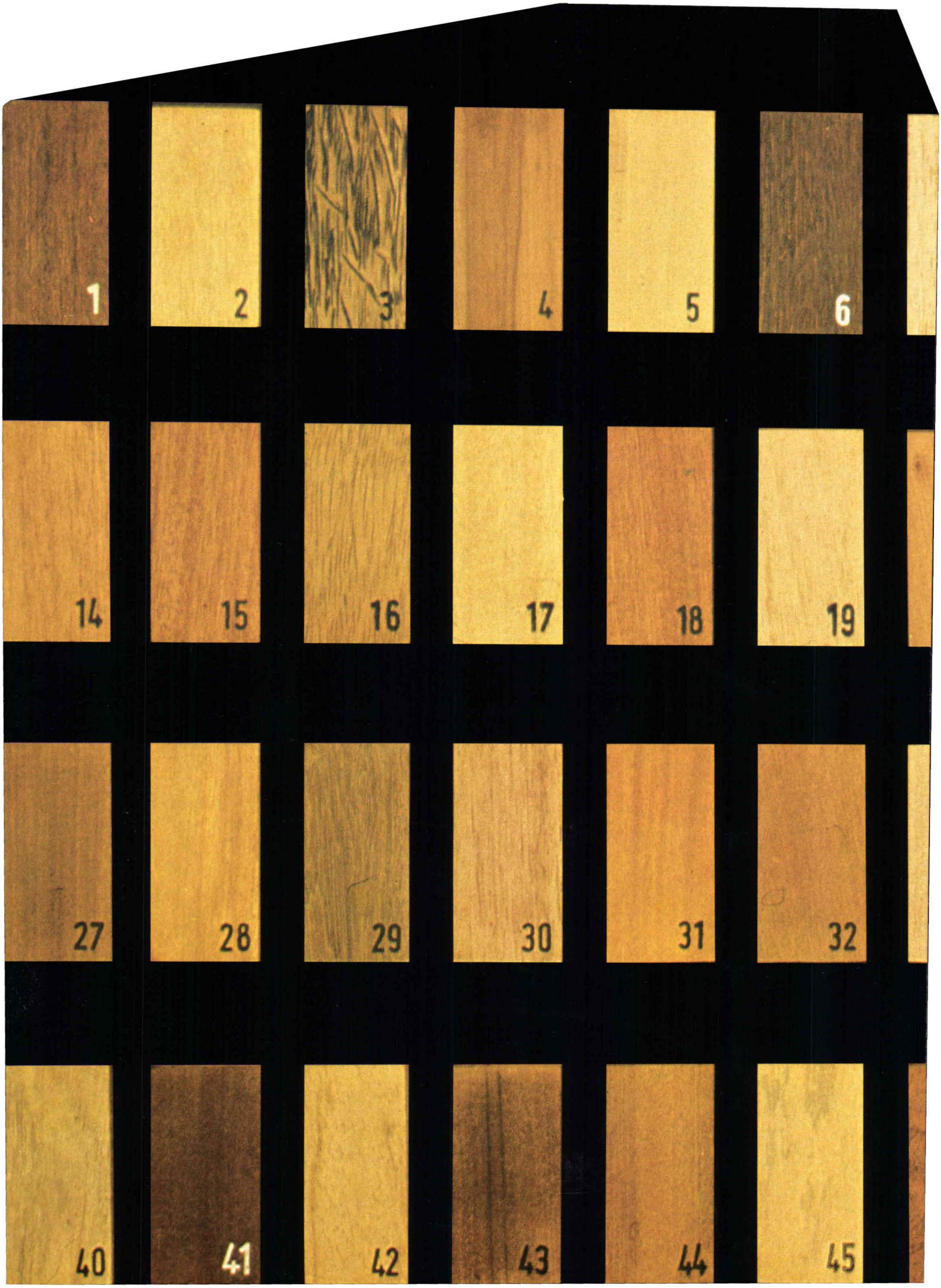
TOUGHNESS: THIS IS A MEASURE OF THE ABILITY OF WOOD TO WITHSTAND SHOCK, TO ABSORB THE ENERGY CAUSED BY THE SHOCK OF IMPACT.

HORIZONTAL SHEAR: THE RESISTANCE TO SHEAR PERPENDICULAR TO GRAIN IS MUCH GREATER THAN PARALLEL TO THE GRAIN.

COMPRESSION: 1 = PERPENDICULAR TO GRAIN AS IN POST OR STUD ON SILL OR PLATE. 2 = PARALLEL TO GRAIN AS IN POSTS, TIMBER COLUMNS, STRUTS AND TRUSS STRUTS.

OVERLEAF FIG. 208 : **52 GHANA - TIMBER SPECIES**

STERCULIA BROWN (WAWABIMA) **13**	PTEROCARPUS ERINACEUS (SENEGAL ROSEWOOD) **26**	ALBIZIA ADIANTHIFOLIA (PAMPENA) **39**	COMBRETODENDROM MACROCARPUM (ESIA) **52**
TIEGHEMELIA HECKELII (BAKU / MAKORE) **12**	TERMINALIA IVORENSIS (EMERI / IDIGBO, SHINGLE WOOD) **25**	CYLICODISCUS (DENYA / OKAN) **38**	SACOGLOTTIS GABONENSIS (TIABUTUO) **51**
MITRAGYNA CILIATA (SUBAHA / ABURA) **11**	GUAREA CEDRATA (SCENTED GUAREA) **24**	STROMBOSIA (AFINA) **37**	CHLOROPHORA EXCELSA (ODUM / IROKO) **50**
ENTANDROPHRAGMA UTILE (UTILE) **10**	ALBIZIA ZYGIA (OKURO) **23**	GLUEMA IVORENSIS (GLUEMA) **36**	CHRYSOPHYLUM ALBIDUM (AKAASA) **49**
ONGOKEA GOR (BODWE) **9**	MAMMEA AFRICANA (BOMPEGYA / AFRICAN APPLE) **22**	HOLARRHENA FLORIBUNDA (OSESE / SESE) **35**	ENTANDROPHRAGMA CYLINDRICUM (SAPELE) **48**
PSEUDOCEDRELA KOTSCHII (KRUBETA) **8**	CEIBA PENTANDRA (ONYINA, SILK COTTON TREE) **21**	NAUCLEA (KUSIA / OPEPE) **34**	DISTEMONANTHUS BENTHIAMUS (AYAN / BONSAMDUA) **47**
PTERYGOTA MACROCARPA (KYERE) **7**	TERMINALIA SUPERBA (OFRAM / AFARA) **20**	ANINGERIA ALTISSIMA (ASAMFONA) **33**	TARRIETA UTILIS (NYANKOM) **46**
LOPHIRA ALATA (KAKU / EKKI) **6**	ALSTONIA BOONEI (NYAMEDUA) **19**	LOVOA (AFRICAN WALNUT) **32**	STERCULIA OBLONGA (OHAA) **45**
SCOTTELLIA CORIACEA (KOROKO) **5**	AFZELIA (PAPAO) **18**	MORUS MESOZYGIA (WONTON) **31**	PIPTADENIASTRUM AFRICANUM (DAHOMA) **44**
MANILKARA LACERA (AFRICAN PEARWOOD) **4**	TRIPLOCHITON (WAWA) **17**	DIOSPYROS SANZAMINIKA (KUSIBIRI) **30**	MANSONIA ALTISSIMA (MANSONIA) **43**
ELAEIS GUINEENSIS (OIL PALM) **3**	ALBIZIA FERRUGINEA (AWIEMFO - SAMINA) **16**	KLAINEDOXA GABONENSIS (KROMA) **29**	DANIELLA OGEA (HYEDUA) **42**
TURRAEANTHUS AFRICANUS (AVODIRE) **2**	KHAYA IVORENSIS (MAHOGANY) **15**	ERYTHROPHLEUM (POTRODOM) **28**	ENTANDROPHRAGMA ANGOLENSE (EDINAM) **41**
CANDOLLEI ENTANDROPHRAGMA (CANDOLLEI) **1**	KHAYA GRANIFOLIOLA (MAHOGANY) **14**	AFRORMOSIA ELATA (AFRORMOSIA) **27**	CELTIS MILDBRAEDII (ESA) **40**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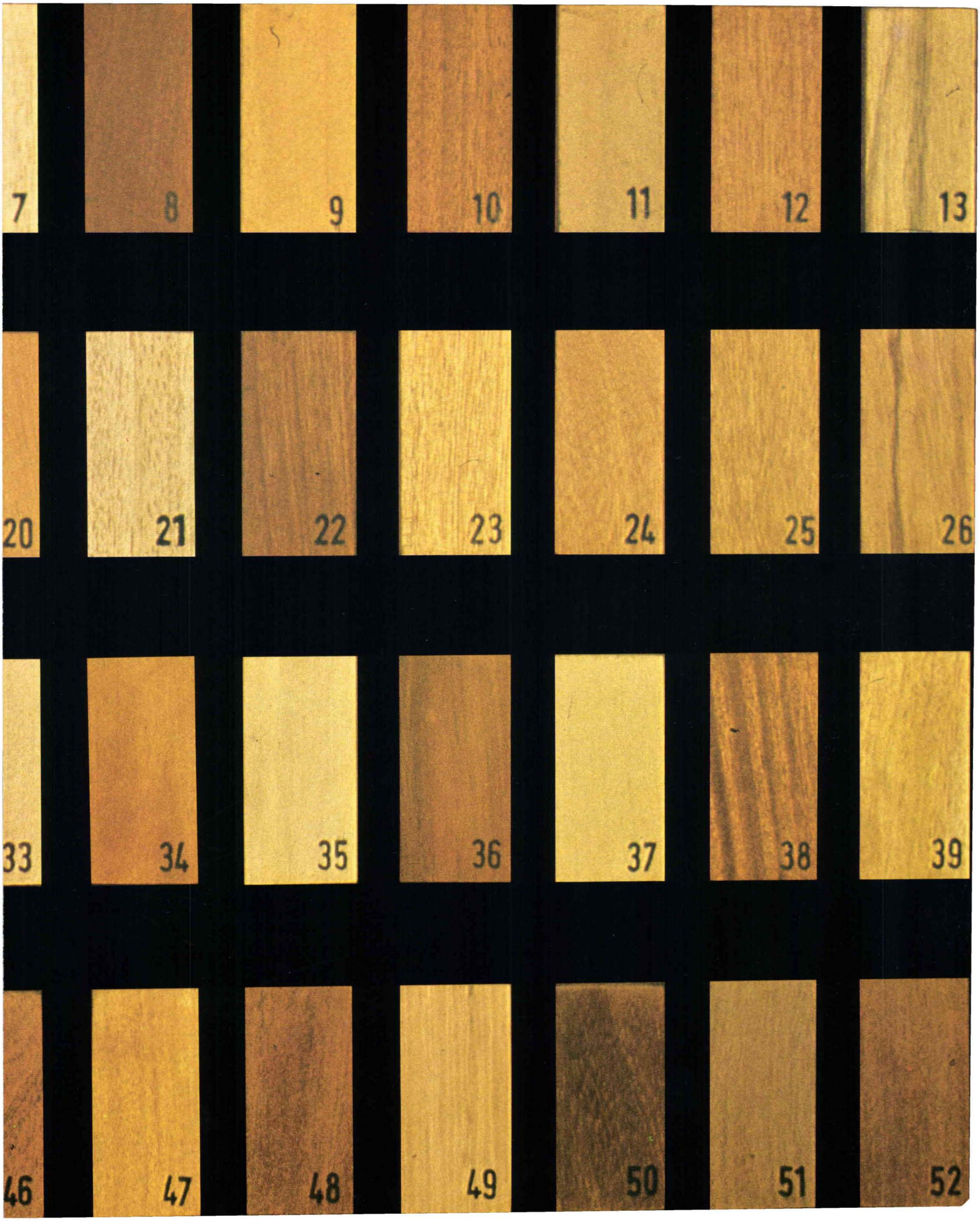
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SOME DEFINITIONS:

Stress = Distributed force; force per unit area;

Fibre Stress = The distributed force tending to compress, elongate or change the relative position of wood fibres;

Tension Stress = An internal stress induced by forces which tend to elongate a member;

Compression Stress = An internal stress induced when opposing forces tend to crush or shorten a member;

Shear Stress = An internal stress induced when opposing forces tend to cause adjoining planes or surfaces of members to slide, one on another;

Working Stress = The maximum stress which may safely be induced in a structural part;

Strenght = A term which embraces those properties of wood which enable it to resist imposed forces;

Bending Strenght = The measure of the load-bearing capacity of a beam;

Bending Stress = A compound stress induced by loads acting perpendicular to the longitudinal axis of a member – a composite of the simple stresses: tensile, compressive and shear;

Stiffness = The property which enables a member to resist deformation when acted on by external forces;

Elasticity = The property which permits changing form with the application of force and immediate recovery upon release. In any elastic material, the deformation is proportional to the force applied, within limits.

4.3.3 THERMAL PROPERTIES OF WOOD

Wood is a natural heat insulator because of its cellular structure. If a timber structure has an outer and inner skin (external boarding and internal lining) the air in between the skin is an insulator. The result in tropical climates is a comfortable in-door condition. In addition the wall cavities between the external boarding and internal panelling or lining can be lined with fibre glass quilts or plastic foam as extra insulation, if so required. In terms of resistance to heat flow a 25 mm thick timber board is the equivalent to a 115 mm thick brick wall (Table 13).

4.4 SEASONING OF TIMBER

As already mentioned seasoning of wood increases its strength properties (Table 14). It is also achieving other objectives:

- to render the timber as stable as possible so that movement ("working") will be negligible when it is used for construction or furniture;
- to make it immune to attack from wood-rotting fungi and to lessen attacks from insects;
- to prepare it for finishes;
- to reduce its weigh (ultimate saving in transport costs).

RESISTANT	LESS RESISTANT, SOME PROTECTIVE MEASURES NEEDED
AFZELIA (AFZELIA AFRICANA)	AFRORMOSIA (PERICOPSIS ELATA)
AVODIRE (TURREANTHUS AFRICANUS)	ALBIZIA (ALBIZIA FERRUGINEA)
ESIA (COMBRETODENDRON MACROCARPUM)	AFRICAN MAHOGANY (KHAYA IVORENSIS)
KOKODUA (PARINARI ROBUSTA)	AYAN (DISTEMONANTHUS BENTHAMIAMUS)
KONKROMA (MORINDA LUCIDA)	DAHOMA (PIPTADENIASTRUM AFRICANUM)
KUSIA (NAUCLEA DIDERRICHII)	DANTA (NESOGORDONIA PAPAVERIFERA)
MAKORE (TIEGHEMELLA HECKELII)	EKKI (LOPHIRA ALATA)
OKAN (CYLICODISCUS GABUNENSIS)	GUAREA (GUAREA CEDRATA)
POTRODOM (ERYTHROPHLEUM IVORENSE)	ODUM (CHLOROPHORA EXCELSA)
SAPELE (ENTANDOPHRAGMA CYLINDRICUM)	MANSONIA (MANSONIA ALTISSIMA)
UTILE (ENTANDOPHRAGMA UTILE)	AFRICAN WALNUT (LOVOA TRICHILIOIDES)
WONTON (MORUS MESOZYGIA)	STERCULIA BROWN (STERCULIA RHINOPETALA)

TABLE 11 **RESISTANCE OF SOME GHANAIAN TIMBER SPECIES TO SUBTERRANEAN TERMITES** (TIMBERS TESTED IN GHANA AND NIGERIA)

HIGHLY RESISTANT	RESISTANT
AFINA (STROMBOSIA GLAUCESCENS)	BONSAMDUA (DISTEMONANTHUS BENTHAMIAMUS)
AFRORMOSIA +	DANTA +
ALBIZIA +	ESIA +
OKAN - DENYA +	TEAK (TECTONA GRANDIS)
EKKI - KAKU +	WONTON +
KUSIA +	
ODUM - IROKO +	
POTRODOM +	

TABLE 12 **RESISTANCE OF SOME GHANAIAN TIMBER SPECIES TO MARINE BORERS**

+ SEE TABLE 11

MATERIAL	THERMAL CONDUCTIVITY K	THERMAL RESISTANCE R	EFFICIENCY AS INSULATOR %
WOOD	0·80	1·25	100·00
AIR SPACE	1·03	0·97	77·6
COMMON BRICK	5·0	0·20	16·0
FACE BRICK	9·0	0·11	8·9
CONCRETE	12·0	0·08	6·4
STONE	12·5	0·08	6·4
STEEL	312·0	0·0032	0·25
ALUMINIUM	1415·0	0·00070	0·06

TABLE 13 **THERMAL PROPERTIES OF SOME BUILDING MATERIALS PER 25mm THICKNESS**

GREEN	BENDING STRENGTH	MAX. COMPRESSIVE STRENGTH ‖ TO GRAIN	MAX. SHEAR STRENGTH PARALLEL TO GRAIN
KUSIA (NAUCLEA DIDERRICHII)	703·28	506·91	118·12
NYANKOM (TARRIETA UTILIS)	710·06	372·64	101·95
ABURA (MITRAGYNA STIPULOSA)	527·30	267·87	-
SAPELE (ENTANDOPHRAGMA CYLINDRICUM)	752·28	367·01	99·84
AFRICAN WALNUT (LOVOA TRICHILIOIDES)	548·40	292·48	-
DRY 12% MOISTURE CONTENT	kg/cm^2	kg/cm^2	kg/cm^2
KUSIA	1160·06	704·48	153·97
NYANKOM	703·28	521·30	129·30
ABURA	808·53	453·49	127·00
SAPELE	1131·94	597·61	182·80
AFRICAN WALNUT	791·47	473·17	89·99

TABLE 14 **COMPARISON BETWEEN THE STRENGTH PROPERTIES OF SOME GREEN AND DRIED GHANAIAN TIMBER SPECIES**

NOTE: ‖ TO GRAIN = PARALLEL TO GRAIN

TABLES 11, 12, 13 AND 14 COMPILED WITH INFORMATION AND DATA RECEIVED FROM THE FOREST PRODUCTS RESEARCH INSTITUTE AND THE B.R.R.I., U.S.T., KUMASI.

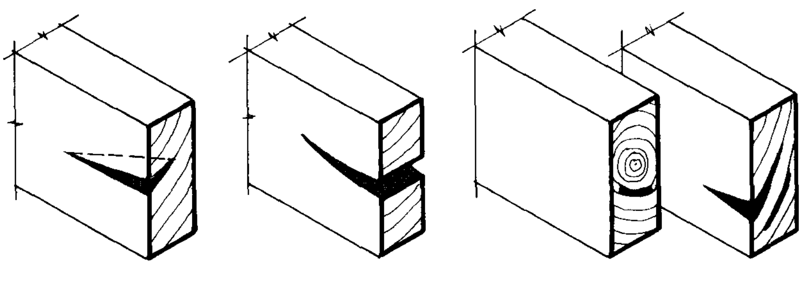
A preliminary seasoning is sometimes accomplished by "girdling" the tree trunk before cutting it down. A strip of bark and wood completely encircling the trunk is cut away. This severs the supply of water from the roots. The leaves, before they die, continue to exhaust some of the water present in the trunk. This could be described as a very slow way of pre-seasoning.

4.4.1 AIR SEASONING

This method makes use of the prevailing winds, the warmth of the air, while protecting the timber from the rain. The timber is stacked off the ground (under cover) so that air can pass over each piece of wood. Each piece is separated from the other by approximately 25 mm. A stack is normally 1.80 m wide. A moisture content of 14–18 % can be achieved in humid areas (depending on the season) after about 4 to 6 weeks air drying per 25 mm of timber thickness.

4.4.2 KILN SEASONING

In kiln seasoning the rate of drying is accelerated by heating and control of humidity. This is accomplished in a closed chamber with controlled temperatures, humidity and air flow. The great advantage is speed and precision in regard to the required moisture content of the timber. Forced draught kilns dry 50 mm thick hardwood from green condition to a moisture content of 10–12 % in 3 to 12 weeks; drying from an air-dry condition (20 % moisture content) down to 10–12 % takes from 1 to 4 weeks (*from* "The Structural Properties of West African Timbers", R. G. Tyler). In natural draught kilns the drying times are considerably longer. The variation in the given times depends on the timber species which are dried; softer species generally take less time.
Comparing the times for air and kiln seasoning one can say that air seasoning will take from two to four times as long as kiln seasoning which is quicker, but at the same time much more expensive.

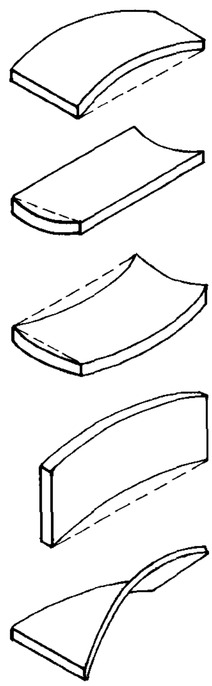


CHECK: A SEPARATION OF THE FIBERS ALONG THE GRAIN FORMING A CRACK OR FISSURE FROM STRESSES SET UP DURING THE SEASONING PROCESS.

SPLIT: A SEPARATION OF THE FIBERS ALONG THE GRAIN FORMING A CRACK OR FISSURE THAT EXTENDS THROUGH THE PIECE FROM ONE SURFACE TO THE OTHER.

TYPICAL SHAKES: A SEPARATION OF FIBERS ALONG THE GRAIN DUE TO STRESSES DEVELOPING IN THE STANDING TREE OR IN FELLING OR DURING SEASONING.

FIG. 214: **SEASONING DEFECTS**



BOW: A CURVATURE OF A PIECE OF TIMBER IN THE DIRECTION OF ITS LENGTH.

CUP: A CURVATURE OF A PIECE OF TIMBER IN THE CROSS-SECTION OF THE PIECE.

DISH: A CURVATURE OF A PIECE SUCH THAT ONE FACE IS CONCAVE (COMBINATION OF BOW AND CUP).

SPRING: A CURVATURE OF A PIECE OF TIMBER IN THE PLANE OF ITS EDGE.

TWIST: A SPIRAL DISTORTION OF A PIECE OF TIMBER.

WARPING: DISTORTION IN CONVERTED TIMBER CAUSING DEPARTURE FROM ITS ORIGINAL PLANE, USUALLY DEVELOPING DURING THE SEASONING PROCESS.

Seasoning of timber must be controlled carefully in order to avoid that the outer layers dry out faster than the inner layers which will result in seasoning defects (Fig. 214). Timber should be dried out to such an extent that it will be in equilibrium with its surroundings in which it is used.
There are two basic methods of seasoning:
(a) Air seasoning;
(b) Kiln seasoning.

A moisture content of timber between 14 and 18 % is acceptable for tropical humid areas. In the dry arid zones of tropical countries timber used in construction should be dried to a moisture content of 8 to 13 %.

4.4.3 UTILIZATION OF SOLAR ENERGY FOR TIMBER SEASONING

Research has been going on in a number of countries into the use of different types of kilns utilizing solar energy as a source of heat for drying wood. For timber seasoning in a tropical developing country solar drying methods will be able to compete with air-drying on an economic basis, with kiln drying on time basis, if used correctly.

Although solar drying kilns have been built and tested in different countries (Australia, India, Philippines, U.S.A. and Britain etc.) no uniform design has yet been developed. The principle of a solar timber drying kiln is as follows:

1. Green timber is stacked as if prepared for air-seasoning.
2. A structure is built around the stack and completely covered with glass (like a green house) or surrounded with a polythene envelope.
3. The roof of the structure is inclined at an optimum angle (which should be equal to the latitude on the earth's surface, with the south wall of the structure being shorter if the location is in the Northern Hemisphere and vice versa).
4. A simple solar heat-absorber (from black painted corrugated metal) is placed 150–200 mm below the roof inside the kiln. These absorbers collect the incident solar energy.
5. An internal baffle regulates air movement within the kiln, with simple vents acting as inlets and exhausts. In addition an electric fan (from an outside power supply) can effect movement of air and the water vapour given off from the wood. Most of the air inside the kiln is recirculated (*from* Appropriate Technology Vol. 6, No. 1: "A Solar Dryer for Timber", A. D. K. Hardie, *see* Fig. 215).

The results so far achieved with solar drying are very satisfactory:

- Drying to a 12 % moisture content takes two to three times as long as in a conventional kiln and is about twice and thrice as fast as air drying;
- The quality of drying in solar kilns is high, because (a) the general rate of drying is slower compared to conventional kilns; (b) the daily variations in temperature are higher but in humidity lower, resulting in a less rapid drying.

The Department of Forestry, Commonwealth Forestry Institute, University of Oxford, supplies a building kit for the construction of the "Oxford Solar Timber Drying Kiln", which has been successfully tested. The costs of one of such kiln works out to be a tenth of the cost of a prefabricated conventional kiln of the same capacity (5.7 to 7.1 m^3 of sawn timber).

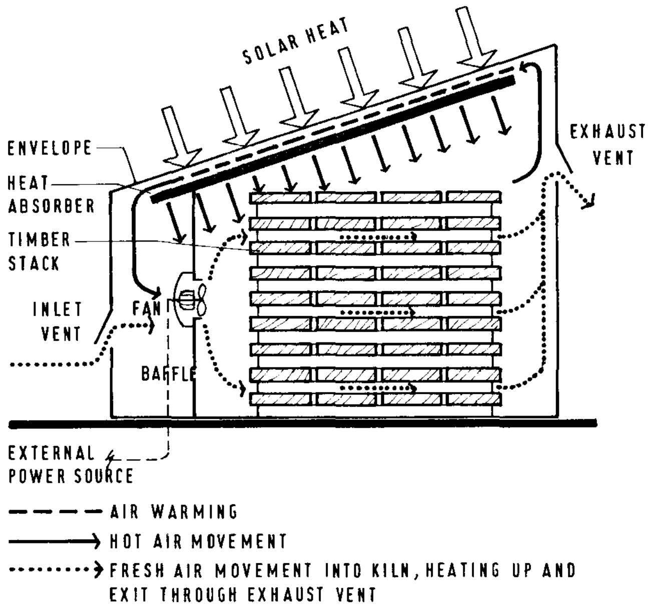


FIG. 215: SCHEMATICAL DETAIL OF THE OXFORD SOLAR HEATED KILN - FROM: "A SOLAR HEATED DRYER" BY A.D.K. HARDIE, "APPROPRIATE TECHNOLOGY", VOL. 6, N° 1, MAY 1979.

4.5 PRESERVATION AND PROTECTION OF TIMBER

There are a number of Westafrican timbers which have a natural durability and are also resistant to fungi, termites and borers. These timbers are normally listed in class I of the commercial timbers, which are used primarily for export. Most of the other timber species which are suitable for construction need one or another form of protection against the following:

- Wood-destroying fungi;
- Wood-destroying insects;
- Weathering;
- Dirt, dust, chemical pollution (in the air);
- Fire.

This protection can be achieved through preservative treatment with chemicals, a protective media (in form of varnishes or paints) and through appropriate construction details (which will help to keep off the causes of harm).

4.5.1 PROTECTION AGAINST INSECTS, TERMITES AND FUNGI

INSECTS: Wood is attacked by pinhole borers (Ambrosia Beetle) in both heartwood and sapwood of the log, later by Powder Post Beetles (in the sapwood only) during and after seasoning (Fig. 216).

TERMITES: There are two types of termites which cause damages to wood, the subterranean or soil termites (***Macrotermes sp., Cubitermes sp.*** and ***Microtermes sp.***), which live in the soil and find their way into buildings in their search for food (Fig. 217 *to* 219) and the drywood termites (***Kalothermitidae***), which live inside wood. Drywood termites tend to concentrate on coastal regions, soil termites are widespread throughout the tropics.

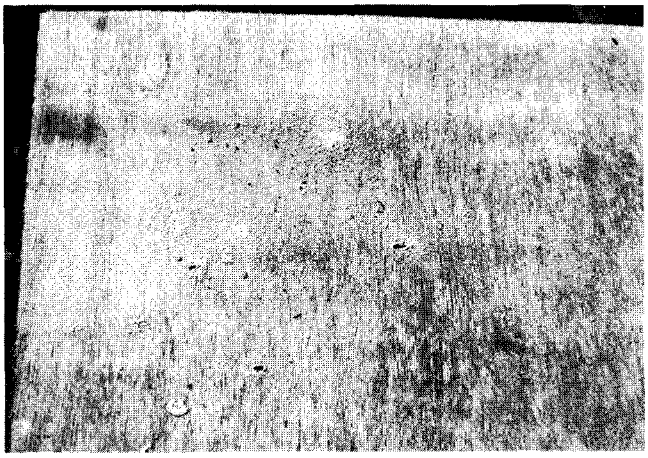


Fig. 216: Wood attacked by pinhole borers.

Fig. 217: Runways of subterranean ants on a house wall in Kumasi.

Fig. 218: An ant mount of MACROTERMES SP. Accra, 1981.

Fig. 219: A CUBITERMES SP. mount, Kumasi, 1981.

FUNGI: These are a low form of plants which digest the wood on which they grow. In order to grow they need temperatures of 5 to 30 °C, an adequate supply of oxygen and a moisture content in their environment of over 20 %.
Protection against insects, termites and fungi is normally achieved through application of preservatives by:

- Brushing or spraying,
- Dipping,
- Hot and cold stepping,
- Pressure impregnation,
- Diffusion impregnation.

PRESERVATIVES:

There are certain requirements which good preservatives must fulfil; they should be:

- Toxic to fungi, insects and termites, but not to humans or animals;
- Permanent after application with no leaching out;
- Not corrosive to metals;
- Capable of accepting subsequent painting;
- Colourless and odourless;
- Safe to handle and easy to apply.

Three types of preservatives are available:

(a) **Tar Oils:**
The well-known preservative of this type is Coaltar Creosote. Tar oils are very resistant to leaching. They help to prevent checking and splitting, and thus assist in preventing the ingress of fungal spores into the timber. They are also not corrosive to metals. Their disadvantage is that they are difficult to paint over. Timber treated with tar oils is normally used for structural timber or for unseen timber components. Coaltar oils are a bulky product to import and therefore expensive.

(b) **Organic solvent type Preservatives:**

These preservatives are soluable in organic solvents. They are:

- *Chlorinated Naphtalenes*
- *Metallic Naphtalenes*
- *Pentachlorophenol*
- Organic deratives of *Pentachlorophenol*

These chemicals are left in the wood when the volatile solvent evaporates. They are suitable for exterior and interior use, because they are resistant to leaching.

They can be painted over, do not stain and are non-corrosive to metals. A better wood penetration is achieved with these chemicals compared to others, so that they can be applied by spraying, brushing or dipping. They are, however, expensive.

(c) **Water-borne type of Preservatives:**

These are salts of such elements as copper, chromium, arsenic, zinc, mercury, sodium and potassium which are dissolved in water to give a toxic solution free from deposit:

- *Copper/Chrome*
- *Copper/Chrome/Arsenate*
- *Sodium Pentachlorophenate*
- *Mercuric Oxide, Magnesium Fluorsilicate, Copper Sulphate, Sodium Fluoride.*

The most important advantage of these preservatives is that they can be imported in solid form and added to water as required. They are usually odourless and can be painted over after drying. For some of the preparations leaching out may occur when the timber becomes wet.

METHODS OF APPLICATION:

1. **Brushing or Spraying**: This is a non-pressure method of application which should be used only on well-seasoned timber. Penetration is poor, usually only about 1 to 2 mm deep. It is generally used to treat timbers in-situ. The preservative should be applied liberally and well brushed into cracks and checks.

2. **Dipping**: This method is more effective than brushing since there is certainty that the preservative reaches all surfaces of members which have been cut to shape prior to the treatment. The longer the dipping period, the deeper the penetration of the preservative. There is, however, little penetration of some of the more resistant heartwoods. But this does not really matter in construction where species are used which normally have a very durable heartwood and dipping gives sufficient protection to the sapwood. If Creosote is used as preservative, better penetration is achieved by heating it.

3. **Hot and cold Stepping**: This open tank treatment gives good protection to permeable timbers but should not be used for timbers resistant to penetration, for which pressure treatment is required. In this treatment the timber is submerged in a tank of preservative and heated for several hours and allowed to cool when the preservative is absorbed to replace the expelled air and moisture.

4. **Pressure Impregnation**: This is probably the best and most effective method of preservative application. It is a combined use of vacuum, pressure and heat to gain complete penetration of permeable and some penetration of resistant timbers. Either Creosote or water-borne preservatives are normally used. Best results are obtained if the moisture content of the timber which is to be treated is about 15 %

5. **Diffusion Impregnation**: This is a comparatively new method of treatment, recommended for use where pressure impregnation has failed to achieve satisfactory results. As preservatives diffusible salts are used, e.g. Boric Acid *(Borax)*. The cut timber is treated in the green condition (with a moisture content of 60 %). It is either dipped or soaked in the preservative, then closely stacked and covered with water-proof sheeting to prevent it from drying out. The timber is left for so long until the salts have diffused through the timber. It is then seasoned in the normal way. Full impregnation of a 25 mm thick piece will take about 3 weeks, of a 50 mm thick piece from 6 to 8 weeks, of a 100 mm thick piece up to 12 weeks.

4.5.2 FIRE PROTECTION

Fire-retarding methods can be achieved through preservative treatment with Boric Acid *(Borax)* at the same time when the timber is treated against insects, termites and fungi. In addition *Monammonium Phosphate* and *Diammonium Phosphate* applied through complete impregnation or for timber sections thicker than 45 mm through pressure treatment give sufficient fire protection.

4.5.3 WEATHERING PROTECTION

Two methods are used to retard weathering:

1. By the provision of a mechanical barrier on the surface of the timber, such as paint or varnish. Paint, however, conceals the natural beauty of timbers, especially West-african timbers. The painted surface has, moreover, to be regularly maintained to ensure that the mechanical barrier is not broken. Already minor breaks and imperfections in the paint film, which are difficult to detect can increase the likelihood of decay by trapping moisture under the surface, thus encouraging the growth of fungi.

2. By the use of chemical preservatives which increase the toxic properties of timber. These "natural" finishes do not form a mechanical barrier on the surface, but permit the timber to "breathe". Application of the colourless preservatives is by spraying, brushing or dipping. Natural finishes are scarcely used in Ghana.

Odum *(Chlorophora Excelsa)* weathers well and does not require paint or varnish for protection. Odum windows and doors in the University of Ghana buildings at Legon near Accra have been brushed with 2 coats of a solution of 15–20 % *Zinc Nephtenate* in white spirit before fixing, when the University was built in 1954. These windows and doors have over the years taken on a pleasant silver-grey patina where they are in exposed positions. They have never been re-painted or maintained and are as sound as when they were fitted (Fig. 220).

4.5.4 PROTECTION BY DESIGN:

Selection of the right timber species with inherent properties which are appropriate to the purpose for which the timbers are to be used is one way of protection; another is treatment, as already discussed in the foregoing section. To protect by design is probably the most effective measure, together with selection and treatment, the latter to reinforce each other so that collectively they provide an effective and economic solution.

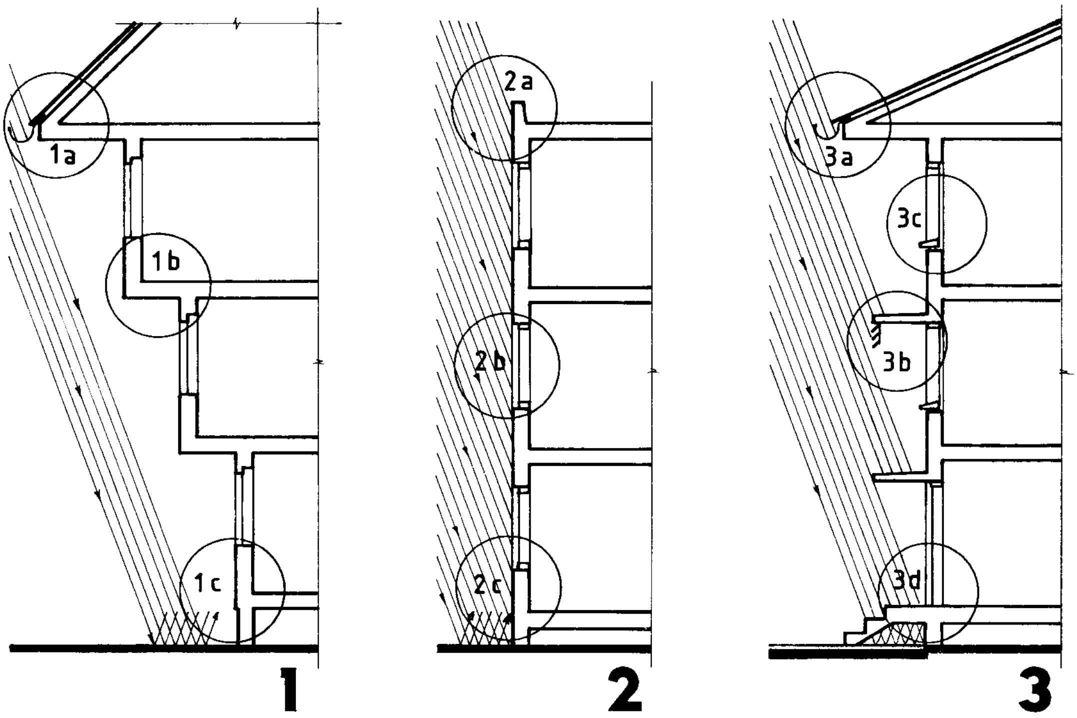
Protection by design should start at the beginning of the design process, to find out what effect the environment, shape and details of a building have in either denying or providing protection to its component parts.

Fig. 220: Odum doors at the University of Ghana, Legon, 1981.

The critical points of a building as regards exposure to the elements are shown in Fig. 221, they are:

- **Eaves**: A large overhang of the roof is an important example of protection by design. Man, the builder, has made use of this from time immemoral to protect the walls of his shelter. The design of centuries old timber buildings throughout the world shows this (Fig. 222). These buildings, of which the framework is filled with wattle and daub or brickwork are witnesses to the knowledge and consideration of how to protect buildings. It is regrettable that in so-called modern designs these protective measures are largely abandoned, resulting in windows, doors and base of the buildings being fully exposed to the elements.
- **Windows, Doors**: In tropical countries shade-giving cantilevers can be provided above window and door openings, which serve at the same time as protection against rain. In addition flashings and throated framing sections safeguard against water getting in by capillary action.
- **Ground Level**: The plynth of a building should be protected against splashing water (normally to a height of 400 mm). A solid apron laid to fall around the building will ensure rapid drain-off of rainwater falling from the roof (if no gutter has been provided) and cantilevered sections. A permanent timber structure should be completely isolated from the ground.

Examples of protective measures by design will be explained in **"Construction Methods"**.



1 TYPICAL CRAFTSMAN'S MEASURES FOR PROTECTION OF WOOD IN TRADITIONAL HALF-TIMBERED STRUCTURES IN EUROPE.

2 "MODERN" DESIGN WHICH DOES NOT PROTECT THE BUILDING AGAINST THE EFFECTS OF MOISTURE PENETRATION.

3 PROPOSED SOLUTION INCORPORATING PROTECTION BY DESIGN OF THE CRITICAL POINTS OF A BUILDING.

1a STEEP ROOF WITH LARGE OVERHANG, NORMALLY WITH RAINWATER GUTTERS, GUARANTEED FRICTIONLESS EVACUATION OF WATER IN THE TRADITIONAL BUILDING.

1b CANTILEVERED FLOORS PROTECTED FACADE BELOW.

1c RAISED GROUND FLOOR PREVENTED PENETRATION OF MOISTURE FROM SPLASHING WATER.

2a FLAT ROOF WITHOUT OVERHANG OF MODERN STRUCTURES EXPOSES COMPLETE FACADE TO WATER.

2b INADEQUATE AND UNPROTECTED WINDOW FRAMES ADMIT RAINWATER.

2c VERTICAL FLOW-OFF OF WATER FROM FACADE AND WATER SPLASHES AT GROUND LEVEL INCREASE DANGER OF MOISTURE ENTERING THE BUILDING.

3a LARGE OVERHANG OF PITCHED ROOF PROTECTS ELEVATION.

3b CANTILEVERED SUNSHADING PROTECT WINDOW AND DOOR OPENINGS AT THE SAME TIME FROM RAINWATER.

3c IN ADDITION WELL SHAPED AND THROATED WINDOW SILLS RETARD ENTRY OF WATER BY CAPILLARY ACTION.

3d RAISED GROUND FLOOR AND DRAIN-OFF APRON AROUND BUILDING PREVENT PENETRATION OF MOISTURE.

FIG. 221 **CRITICAL POINTS OF A BUILDING FACADE AND MEASURES OF PROTECTION**

Fig. 222: 16th century half-timbered houses in Uslar, Lower Saxony, Westgermany, 1978.

4.6 PREFABRICATED TIMBER HOUSES

For the development of an appropriate technology needed in a tropical developing country for the production of prefabricated wooden houses the following conditions have to be taken into account:

- Abundance of unskilled labour;
- Availability of simple machines;
- Scarcity of capital because of the absence of appropriate financial insitutions for long-term financing;
- National Building Regulations which do not emphasize function as well as standardization and do not include prefabricated housing;
- Governmental planning bodies that do not recognize the economic importance of the local building industry;
- General lack of processing industries for improving local building materials;
- Prejudiced attitudes towards prefabricated buildings (the prevalent belief is that the standard of a prefabricated building is lower than that of a traditional building);
- Absence of performance specifications which indicate the physical requirements that would be in harmony with the local cultural and sociological patterns.

After careful consideration of the foregoing (there may be other conditions peculiar to some developing countries which have not been listed here) a choice of methods of prefabrication will have to be made.

4.6.1 PRE-CUT METHOD OF PREFABRICATION

This is the prefabrication of small-size and linear "one-dimensional" components: posts, beams, plates, panels etc., which can be made by artisans at workshops or in small factories with simple machines. This method of pre-cutting off-site and assembling on the site offers greater accuracy of measurement and precision in fit than cutting timber to size and fitting it in-situ. Moreover a considerable saving of raw material is experienced compared to cutting on the job. Pre-cutting allows pre-selection of species and grades of timber for each specific structural use. The prefabricated elements are easier and cheaper to transport. They are light enough to be handled by two but not more than four workers and can be assembled with simple machinery such as pulleys or non-mechanized cranes.

Maximum economy in the cost and time of erection can be achieved if other components such as windows, doors, built-in fittings, etc. together with the specified ironmongery and hardware can also be pre-assembled.

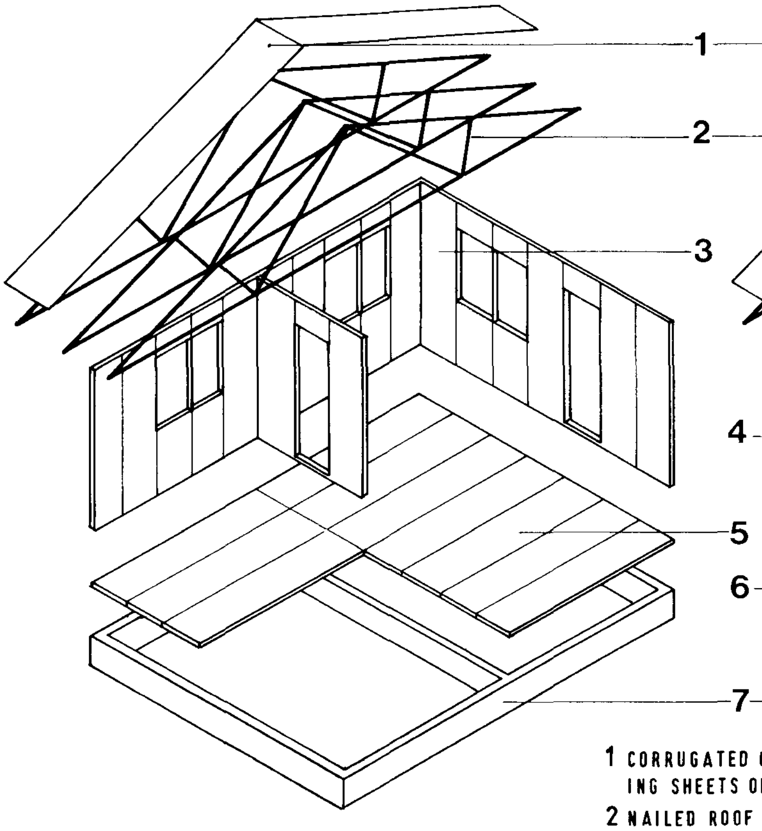
4.6.2 MODULAR PANEL SYSTEM

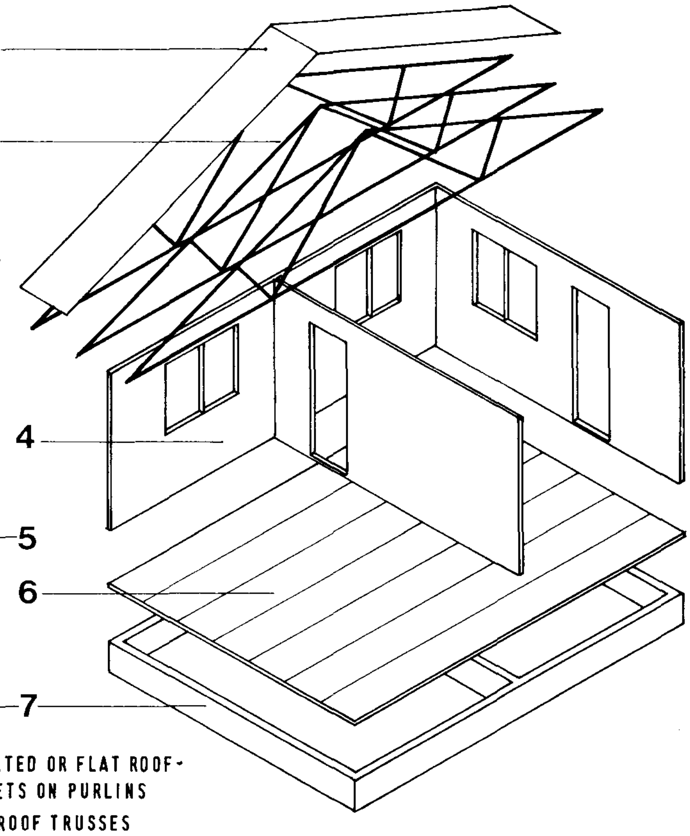
This involves in-plant production of modular panels for floors, ceilings, walls and roof trusses to a developed module "M" as a unit of measure (Fig. 223). Panel sizes are normally 8'-0" x 4'-0" (metric: 2,44 m x 1,22 m) in places where this system has been adopted.

In Ghana "African Timber and Plywood Ltd." (ATP) at Samreboi has produced the ATP-System Building based on a module of 8'-0" x 3'-4" (Metric: 2,44 m x 1,02 m) for many years now. Since a few years, however, following the decline of the economy production has ceased. In Nigeria and other African countries prefabricated panels are produced to a modular system.

A modular panel system ensures maximum possible flexibility in architectural designs. Production can be undertaken by semi-skilled workers under supervision in the plants manufacturing the panels. Handling of the panels, transportation and assembly on the site can be done manually and does not require mechanization. If a large market for different house types has been established, modular panels can be stocked for prompt sale and delivery. Investment needed for the production of modular panels is not much more than that required for the setting up of workshops or small plants producing pre-cut timber building components.

Certain problems arising from the presence of numerous joints when assembling the panels can be solved by special weather-proofing on the site. The additional labour costs (also for fitting the plumbing and electrical installation on the site) are much lower in developing countries compared to the developed countries where





1 CORRUGATED OR FLAT ROOFING SHEETS ON PURLINS
2 NAILED ROOF TRUSSES
3 MODULAR-SIZE WALL PANELS
4 LARGE-SIZE WALL PANELS
5 MODULAR SIZE FLOOR PANELS ON JOISTS OR CONCRETE SLAB
6 LARGE-SIZE FLOOR PANELS
7 FOUNDATION (SOLID OR POST AND BEAM)

FIG. 223 MODULAR PANEL SYSTEM

FIG. 224 LARGE-SIZE PANEL SYSTEM

the ultimate aim of prefabrication of building components is to cut down in labour costs. This has led to the development of the next system.

4.6.3 LARGE-SIZE PANEL SYSTEM

This is a modular panel system based on higher multiples of the same module "M" (Fig. 224) producing complete wall and floor units etc. Because of certain disadvantages this system has limited suitability for developing countries:

- The great weight of the larger panels increases transportation costs;
- Heavy moving and lifting machinery is required in the factory and on the site for assembly;
- Production requires larger plants and more skilled manpower.

In many industrialized countries (especially in the U.S.A.) complete 3-dimensional modular construction units ("ready-built houses" which are delivered more or less complete to any prepared site) and a folding type of 3-dimensional modular construction systems (complete factory fabrication, easier transportation and handling with erection and fitting on the site) have become very popular. This "Volume Element System" allows the prospective buyer to see at the factory what his chosen home will look like before he decides on which type to buy. 3-dimensional modular construction units require full rationalization, mechanization and a rather sophisticated technology. The present economic situation in most developing countries does not encourage the use of such systems of prefabrication.

Since a considerable number of large sawmills are operating in timber-exporting tropical developing countries the prefabrication of components, modular panels and larger-size panels should not be difficult. In these countries moreover a large number of smaller sawmills, carpentry and joinery workshops operate to satisfy the local demand for timber elements and furniture. With the incorporation of standards, sizes of prefabricated components and structural systems based on modular coordination into the local building regulations (subject to regular assessment and review as conditions change) a control of quality of the produced elements is ensured. This could lead to a large output of low-cost building components, if these components can be mass-produced. The houses can be erected cheaply by self-help or co-operative methods without specialized training. The quality of the end product would depend rather less on skilled and first-class workmanship on the site, but more on the production process in the factory or workshop where the components are built. The designer can test his abilities in designing systems which correspond with the different climatic and geographical zones and which fulfil the user's requirements.

4.7 WOOD AND WOOD BASED MATERIALS USED IN BUILDING

Wood products used in construction can be classified in two groups:

1. **Structural Timber**: These are timber elements which form part of the structural system of the building. They are for the load bearing wall frames, floor systems, columns, beams and roof trusses (planks and studs from lumber, laminated and box beams, certain grades of plywood).

2. **Non-Structural Timber**: These are timber elements which are non-load bearing, they are used for internal walls and partitions, windows, doors and finishes (boards, plywood, blockboard, particle-board, woodwool slabs etc.).

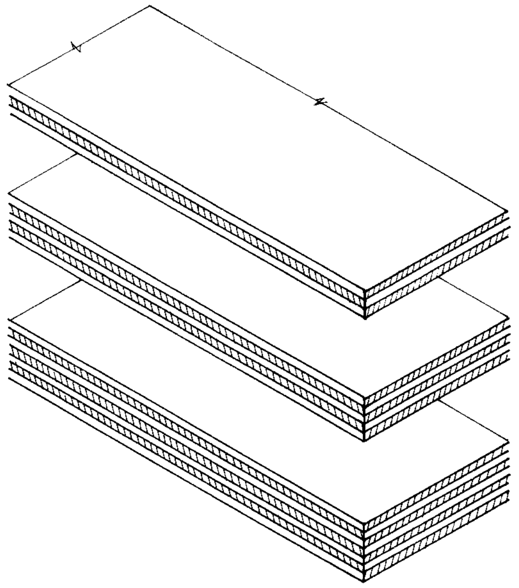


FIG. 225 TYPES OF PLYWOOD

4.7.1 PLYWOOD

Plywood is a glued wood panel made up of relatively thin layers (veneers or plies) with the adjacent layer at 90° (Fig. 225 *to* 227) which improves the strength properties and minimizes the movement in the plane of the board. The number of plies is always uneven (3-ply, 5-ply and above multiply). The veneers (or plies) are normally rotary cut (peeled) for constructional plywood (Fig. 228) or sliced, usually for face veneers in decorative plywoods.

Because of its cross bonding plywood has structural properties which make it suitable for structures where its high panel shear values combined with flexural rigidity and light weight can be fully exploited, e.g. in the construction of plywood beams (I- and box-beams), folded plate roofs of considerable spans and stressed skin structures generally.

Plywood is manufactured in two types: "Exterior" type with nearly 100 per cent waterproof glueline and "Interior" type with a highly water resistant glueline. Veneers used for the exterior type are of higher grade than those used in the interior type.

Plywood beams are built-up members consisting of one or more vertical plywood webs to which timber flanges are attached along the top and bottom edge (Fig. 229). They may be assembled with nails, bolts, screws or glued, or with a combination of these fastenings. Glued construction is the most efficient, but needs careful control during assembly and lends itself to prefabrication off-site rather than in-situ construction.

The use of plywood beams has advantages:

- Economic use of material (high allowable shear stress of plywood permits the use of relatively thin webs);
- High-strength material can be placed at points of greatest stress;
- Flanges may be comparatively thin members, which are readily available and easily seasoned;
- Since only dry wood is used, strength and stiffness are increased and shrinkage minimized;
- Members may be built to a variety of shapes;
- Plywood beams are light; transport and erection are easy (plywood beams are about half the weight of solid timber beams);
- Ceiling and floor materials can be readily attached.

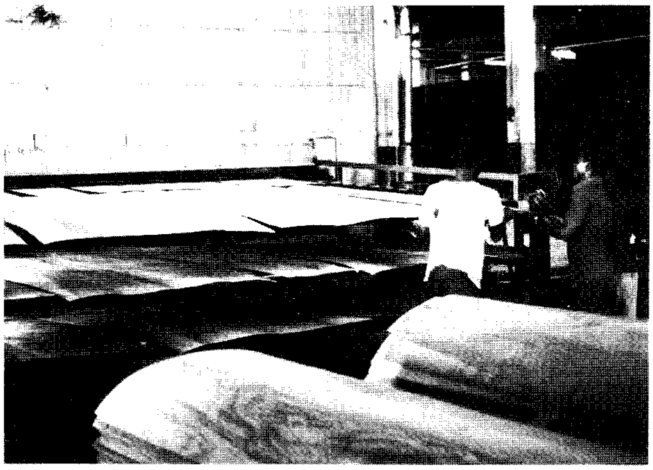


Fig. 226 and 227: Production of plywood in a Kumasi sawmill, 1981.

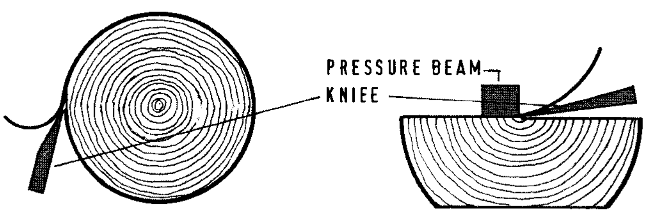
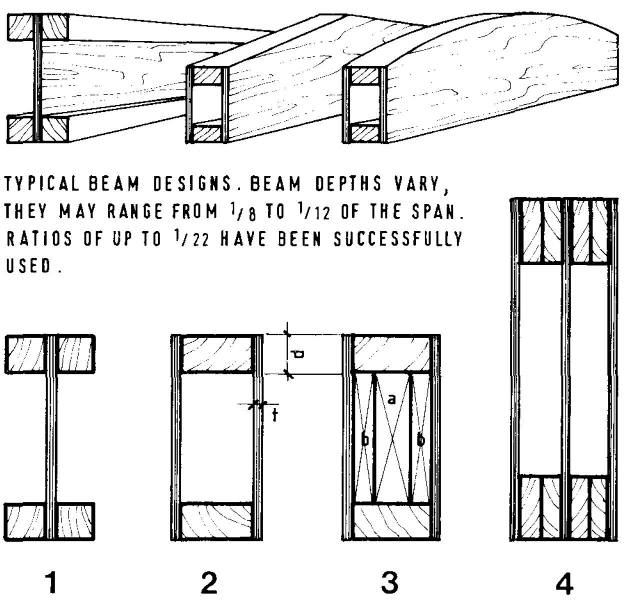


FIG. 228 PEELED OR ROTARY CUT AND SLICED VENEER - SCHEMATICAL DRAWING, PRODUCTION PROCESS INVOLVES SPECIFIC MACHINES.



TYPICAL BEAM DESIGNS. BEAM DEPTHS VARY, THEY MAY RANGE FROM 1/8 TO 1/12 OF THE SPAN. RATIOS OF UP TO 1/22 HAVE BEEN SUCCESSFULLY USED.

1 SINGLE PLYWOOD WEB BEAM
2 PLYWOOD BOX BEAM
3 PLYWOOD BOX BEAM WITH TIMBER STIFFENER (a) AND SPLICES (b). STIFFENERS SHOULD BE PLACED AT SUPPORTS OF BEAM AND AT POINTS OF CONCENTRATED LOADING TO REINFORCE THE WEB AGAINST BUCKLING. (d) OF FLANGE SHOULD BE EQUAL TO 4t IN A GLUED BEAM AND LARGER THAN 4t IN A NAILED BEAM.
4 3-WEB BOX BEAM WITH LAMINATED FLANGES

FIG. 229 PLYWOOD BEAMS

4.7.2 GLUE-LAMINANTED TIMBER

Glue-laminated timber refers to two or more layers of wood glued together with the grain of all layers more or less parallel. Laminated wood is widely used for structural purposes in building construction (roof and floor structures).

4.7.3 FRAMED WALL SYSTEMS

Framework (of external walls) which is load bearing, consists of 50 x 100 mm timber members used as sill, sole and head plates, as studs and partial studs. The spacing of the studs depends on the type of covering material used, it is usually 600 mm from centre to centre of the studs (*see* **"Construction Methods"**).

Floor System:

The floor system is made up of wooden joists which can vary in size from 50 mm x 150 mm to 50 x 225 mm for domestic structures. The timber used for floor joists must be high grade and durable. Spacing of the joists normally follows the framed wall system and depends also on the floor finishing material used (flat boards, plywood or particle board).

Roof Systems:

For timber framework construction the trussed rafter system is normally used. The rafter and purlin system requires load-bearing walls between the sidewalls of the building. The trussed rafter system lends itself to off-site assembly. It is ideal for the pitched roof type. The trusses are fabricated either with metal truss plates, plywood gussets, spiked or ring metal connectors (*see* **"Fixing of Structural Timber"**). Trusses used for timber houses (spanning up to 10 m or more) are 75 mm thick (weighing approximately 80 kg) and can be handled, transported and erected easily without lifting gear.

Interior Finish and Millwork:

These consist of window and door frames, window and door trim, windows and doors, mouldings, skirtings, built-in fittings, manufactured from lumber or wood panel materials from seconary timber species.

4.7.4 TIMBER POLE STRUCTURES

Pole-type structures, if correctly designed, can make use of the fact that a tree or log is naturally "pre-stressed" during growth in a way which is comparable with the prestressing of reinforced concrete, so that it has high resistance to bending. In a timber pole, defects, such as knots and sloping grain have much less effect than in sawn timber. Round timbers have the advantage of low cost, simplicity of construction and rigidity of structural form.
In Papua New Guinea, for example, round timber poles have been used since the earliest settlements thousands of years ago. Timber poles are still a widely used building material today, one of the most important elements in house construction. The Forest Products Research Centre

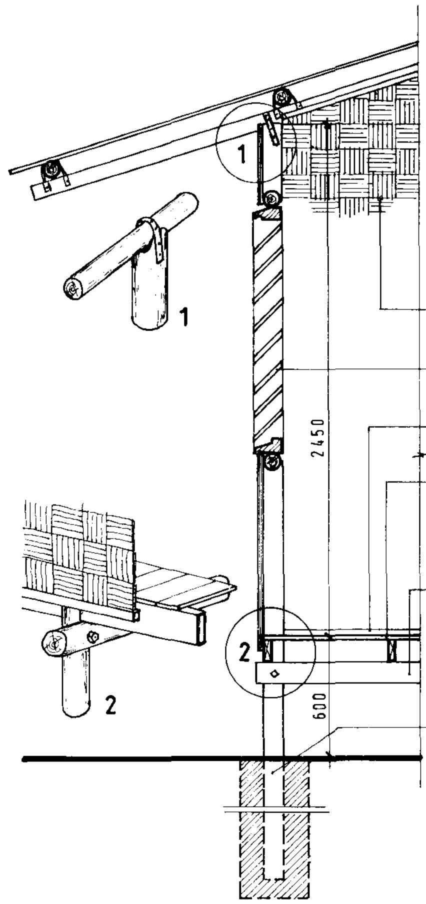


FIG. 230 PART SECTION THROUGH A STANDARD RURAL HEALTH CENTRE FOR PAPUA NEW GUINEA
(FROM :"POLE BUILDINGS IN PAPUA NEW GUINEA" BY P. LATTEY, DEPT. OF FORESTS, PAPUA NEW GUINEA).

in Boroko, Papua New Guinea, has successfully tried to improve and develop construction techniques using timber poles and published results of these efforts in a review of the work ("Pole Buildings in Papua New Guinea", Department of Forests, Forest Products Research Centre, Boroka, Papua New Guinea), of which part of a section through a standard rural health centre is shown in Fig. 230 (with the kind permission of the Forest Products Research Centre of Papua New Guinea).

In Ghana, the Forest Products Research Institute at U.S.T., Kumasi, has for several years successfully grown Caribean Pine trees in its nursery at Mesewam (near Kumasi). Experiments have shown that these pine trees grow well in the transitional forest zone of Ghana and that they grow to appreciable size (Fig. 231 *and* 232). If cultivated on a large scale they could be used for low cost house building in conjunction with other timber and wood based materials. Round poles can be seasoned and preservative treated as any other timber.

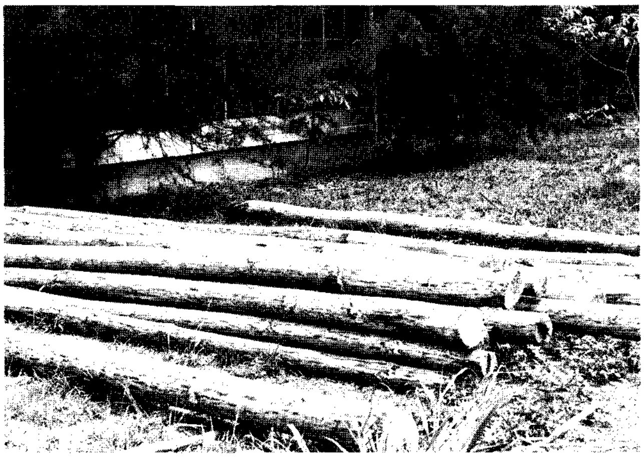
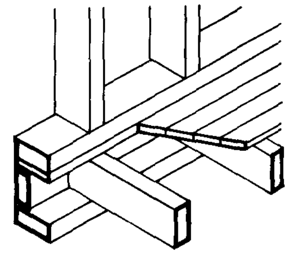


Fig. 231 and 232: Caribean pine trees at the Forest Products Research Institute nursery in Mesewam, near Kumasi, 1981.

Fig. 233: 16th Century square panelled timber framework in Einbeck, Lower Saxony, Westgermany, 1978.

4.8 DEVELOPMENT OF TIMBER FRAME CONSTRUCTION

4.8.1 HISTORICAL DEVELOPMENT :

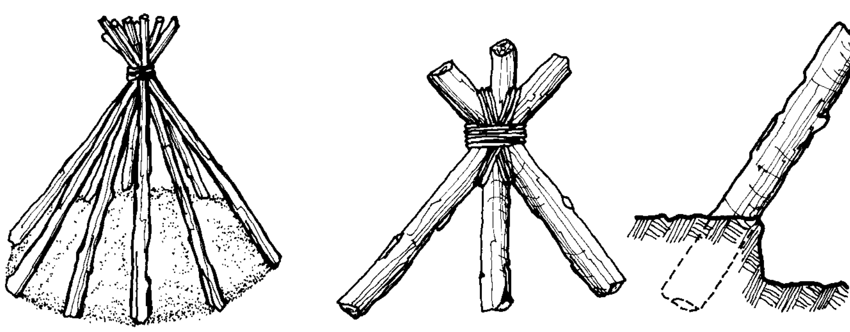


The history of development of wood as building material spans the history of man's own development, going back thousands of years into pre-historic times.

Three elements influenced the development of true timber structure:

- The tools for cutting and shaping;
- The methods of connecting and joining cut pieces;
- The concepts of structural forms for the enclosure of space (or for other purposes such as bridging space).

The flints and stone axes were inventions of the Stone Age which for the first time provided the physical means of separating wood fibres longitudinally and transversely. With the Bronze and Iron Age came an improvement of the cutting tools and craftsmanship. Man learned to harness natural forces. Simple engines were invented to drive the cutting edge. This in turn led to cutting and fixing of larger components of structural timber and timber framework. In all forested areas of the world, including most of Europe, America, the tropical forest areas of Africa and Southamerica, timber was primarily and often the only structural material for small houses used from the Stone Age to the 18th century. In Northamerica, the Scandinavian countries, Britain and Japan it remains today one of the most important domestic structural materials (Fig. 233).



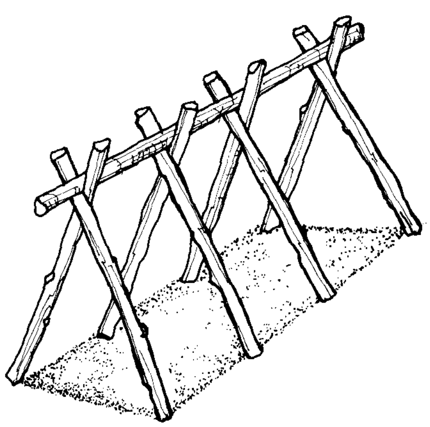
I. CIRCULAR HUT :

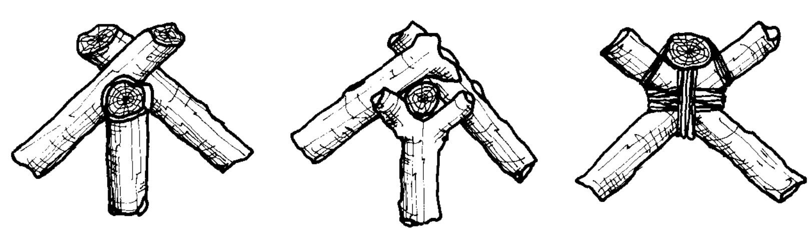
MATERIALS USED : BRANCHES, SPLIT STAKES.

JOINTS : TIED AT APEX WITH BARK STRIPS, CREEPERS OR FLEXIBLE TWIGS. FEET STUCK INTO THE GROUND.

TOOLS : CRUDE STONE IMPLEMENTS FOR TRIMMING TREE BRANCHES TO LENGTH.

NO DISTINCTION BETWEEN ROOF AND WALL FRAMEWORK. IN SOME AREAS A DOME-LIKE VERSION OF THE CIRCULAR HUT WAS DEVELOPED WITH BRANCHES BENT OVER AT THE TOP, INTERLACED AND BOUND TOGETHER.





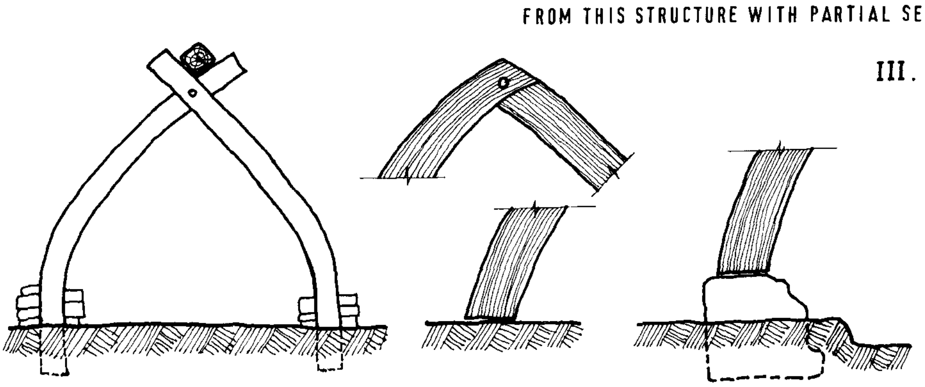
II. ELONGATED RIDGE POLE HUT :

MATERIALS USED : MORE OR LESS THE SAME AS USED FOR THE CIRCULAR HUT AND IN ADDITION SMALL LOGS AND BUSH POLES, WITH FORKED TOP ENDS.

JOINTS : TIED WITH BARK STRIPS, FLEXIBLE TWIGS AND CREEPERS.

TOOLS : STONE IMPLEMENTS, FLINTS AND STONE AXES.

POSTS WERE ADDED LATER AT GABLE ENDS. THE STRUCTURE WAS STABLE IN ITSELF. NO DISTINCTION BETWEEN ROOF AND WALL FRAMEWORK. FEET OF POLES AND POSTS WERE BURIED IN THE GROUND. LATER ON A SIMPLE PURLIN ROOF WAS DEVELOPED FROM THIS STRUCTURE WITH PARTIAL SEPARATION OF ROOF AND WALLS.



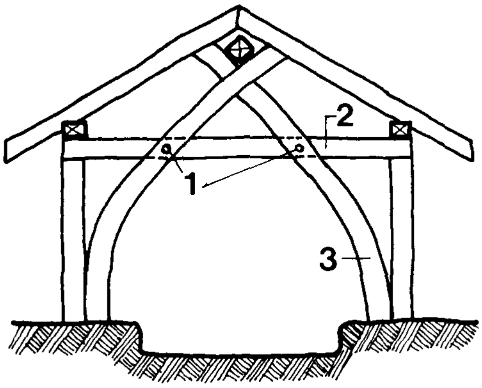
III. CRUCK FRAME STRUCTURE :

MATERIALS USED : HALVED TRUNKS OF NATURALLY BENT TREES.

JOINTS : HALF-LAPPED AND PEGGED OR CROSSED AND PEGGED AT TOP. AT BOTTOM RESTING ON GROUND, LATER ON STONE PADS OR SIMPLE DWARF WALLS.

TOOLS : IRON SAWS, AXES, ADZES AND AUGERS.

4.8.1



IV. CRUCK FRAME WITH RAFTER ROOF SUPPORTED ON TIE BEAM AND POST :

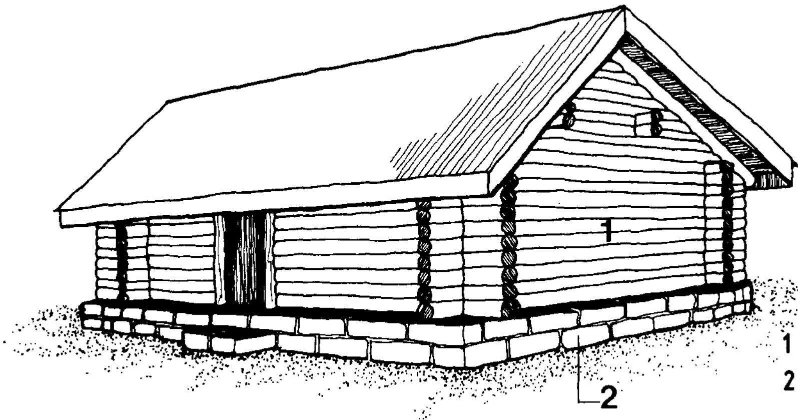
MATERIALS USED : HALVED TRUNKS OF NATURALLY BENT TREES AND ROUGHLY SQUARED MEMBERS.

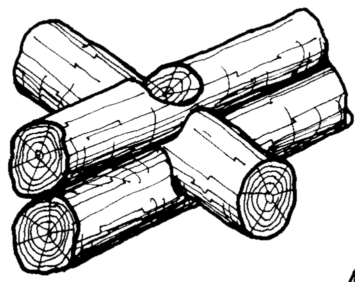
JOINTS : HALVED AND PINNED OR MORTISED AND TENONED, OR BIRD'S MOUTHED RAFTERS.

TOOLS : IRON SAWS, AXES, ADZES, AUGERS.

FOR THE FIRST TIME THERE WAS A COMPLETE SEPARATION OF ROOF AND WALLS IN THIS STRUCTURE.

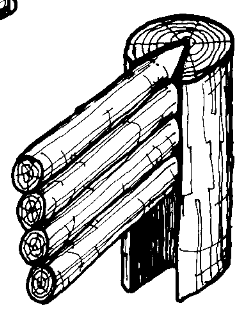
1 PEGGED (PINNED) JOINT
2 TIE BEAM
3 CRUCK





ROUND SCARVING OR SADDLE NOTCH JOINTS

GROOVE AND TENON JOINT



1 SOLID LOG WALL
2 STONE FOUNDATION

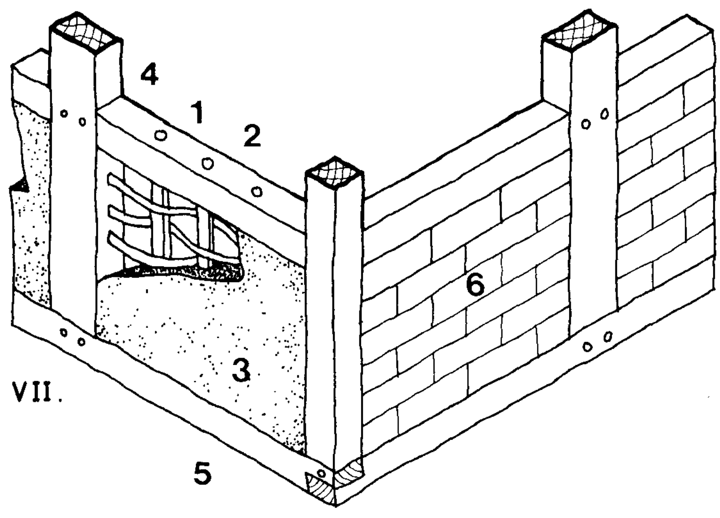
V. LOG CABIN CONSTRUCTION :

MATERIALS USED : STRAIGHT TRIMMED LOGS, LATER SQUARED MEMBERS.

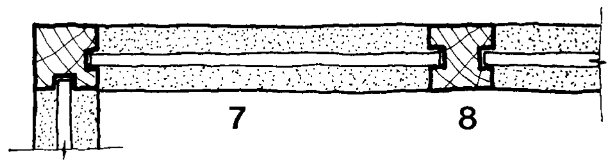
JOINTS : ROUND SCARVING OR SADDLE NOTCH JOINTS BETWEEN WALL JUNCTIONS AT CORNERS. GROOVE AND TENON JOINT BETWEEN WALL AND WINDOW AND DOOR OPENINGS.

TOOLS : IRON ADZE, IRON AXE, IRON SAW.

THIS IS THE EARLIEST WAY OF CONSTRUCTION USING A STONE FOUNDATION.



VII.



VI.

7 OAK STAVES WITH DAUB INFILLING
8 UPRIGHT POSTS WITH VERTICAL GROOVES

AT THIS LEVEL OF DEVELOPMENT OF TIMBER FRAME CONSTRUCTION WOOD WAS PROPERLY SQUARED FOR THE FIRST TIME. LATER, WITH THE INVENTION OF WATER - POWERED SAWS TIMBER WAS ALSO SAWN INTO BOARDS. THE BASIC TYPES OF JOINTS USED WITH SQUARED TIMBER SECTIONS ARE STILL IN USE TODAY: MORTISE AND TENONED JOINT, DOVETAIL JOINT, STEP JOINT, SCARF JOINT AND TONGUED AND GROOVED JOINT.

VI. CLOSE-TIMBERED FRAMEWORK :

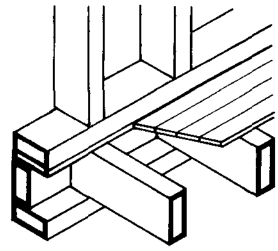
OAK STAVES FIXED INTO VERTICAL GROOVES OF 250 x 150 mm UPRIGHT POSTS. DAUB INFILLING AROUND STAVES.

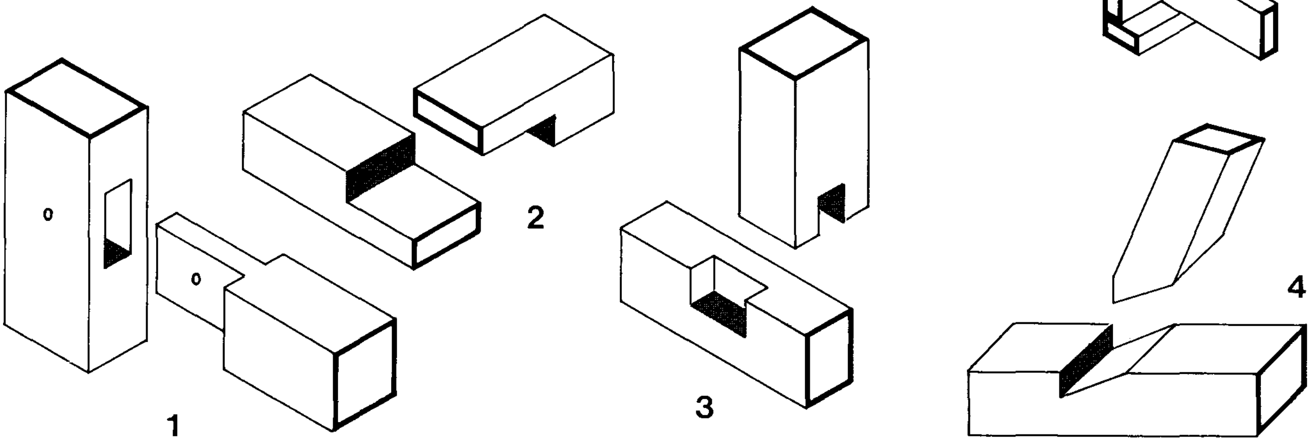
VII. SQUARE - PANELLED FRAMEWORK :

1 BRIDGING PIECE (AVERAGE 150 x 150 mm)
2 WATTLEWORK OF WILLOW WOVEN AROUND OAK STAVES
3 DAUB INFILLING 4 PEGS IN PLACE 5 250 x 150 mm SILL
6 BRICK NOGGED PANEL

THE FRAMING IS MORTISED AND TENONED TOGETHER AND DRAW-PINNED (PEGGED).

4.8.2 DEVELOPMENT OF JOINTS AND FIXING OF STRUCTURAL TIMBER



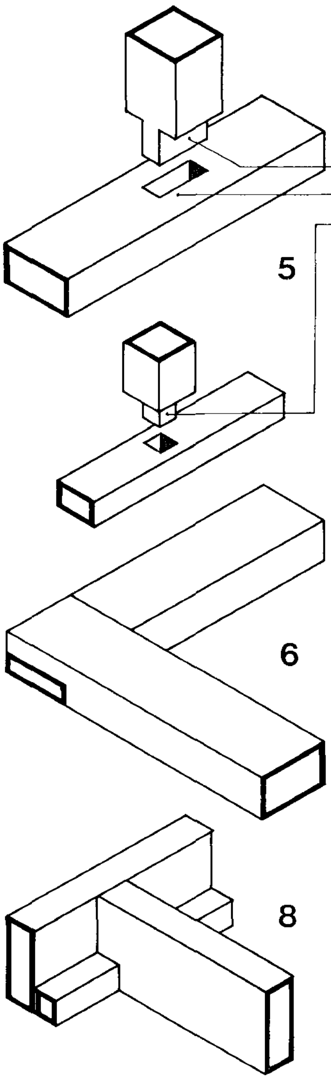


TRADITIONAL JOINTS USED FOR SQUARED (LATER SAWN) TIMBERS :

1 MORTISE AND TENON JOINT WITH WOODEN PEG. STILL USED TODAY WITH OTHER MEANS OF FIXING.
2 SCARF JOINT. STILL USED TODAY AS HALF-LAP ANGLE JOINT.
3 COG JOINT.
4 SKEW NOTCH JOINT.

CONVENTIONAL FRAMING JOINTS:

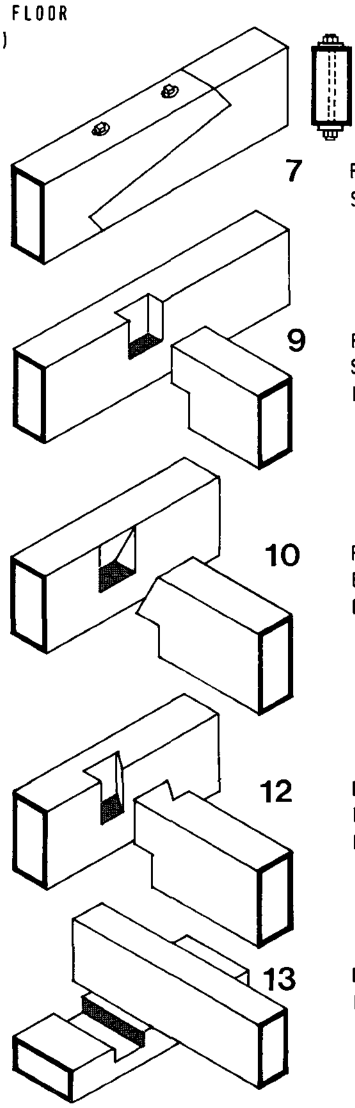
5 STUD TO WALL PLATE
6 PLATE TO PLATE
7 FLOOR JOIST TO FLOOR JOIST (STRAIGHT CONNECTION)
8 TO 12 FLOOR JOIST TO FLOOR JOIST (AT RIGHT ANGLE)
13 FLOOR JOIST TO WALL PLATE



STUD TO WALL PLATE :
STUD TENONED
WALL PLATE MORTISED
STUD STUB-TENONED

PLATE TO PLATE :
HALF-LAP ANGLE JOINT

FLOOR JOIST TO FLOOR JOIST :
LEDGER JOINT



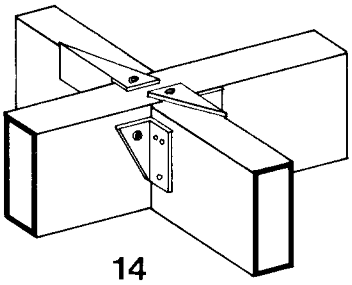
FLOOR JOIST TO FLOOR JOIST:
SCARFED JOINT

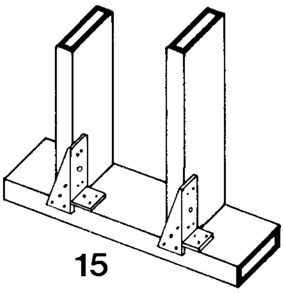
FLOOR JOIST TO FLOOR JOIST:
SQUARE HOUSED JOINT FOR BRIDGING JOISTS

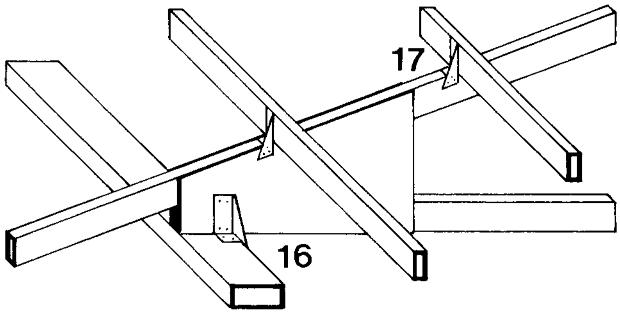
FLOOR JOIST TO FLOOR JOIST:
BEVELLED HOUSED JOINT FOR BRIDGING JOISTS

FLOOR JOIST TO FLOOR JOIST:
DOVETAILED HOUSED JOINT FOR BRIDGING JOISTS

FLOOR JOIST TO WALL PLATE:
HOUSED JOINT



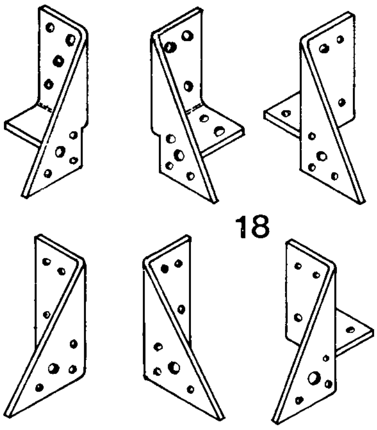




FRAMING ANCHORS :

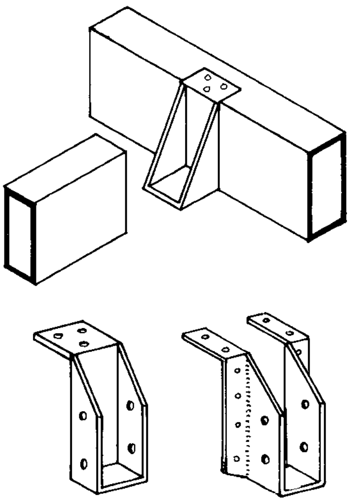
THESE ARE USUALLY MADE FROM 18 GAUGE SHEET STEEL AND SHERADIZED FOR PROTECTION AGAINST CORROSION. THEY ARE PIERCED READY FOR NAILING. TYPICAL USES :

14 : JOIST TRIMMING ; 15 : FOR CONNECTING STUDS TO WALL PLATES ; 16 : FOR CONNECTING ROOF TRUSSES TO WALL PLATES ; 17 : FOR CONNECTING PURLINS TO RAFTERS.



18 DIFFERENT TYPES OF FRAMING ANCHORS

JOIST HANGERS :



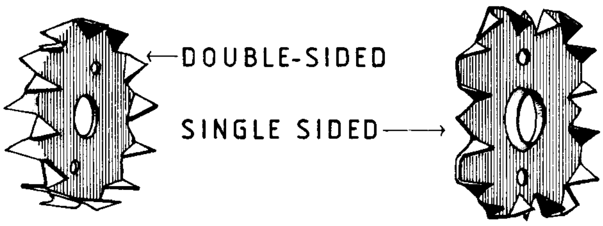
THESE ARE EITHER PRESSED FROM SHEET STEEL OR FORMED FROM 3mm THICK STEEL PLATE AND WELDED. THEY ARE GALVANIZED AND HOLED FOR NAILING. JOIST HANGERS ARE USED AS AN ALTERNATIVE TO FRAMING ANCHORS :

19 : FOR EASY JOIST CONNECTION.

TIMBER CONNECTORS :

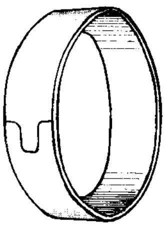
THESE ARE SPECIALLY SHAPED METAL PLATES USED TO JOIN TIMBER MEMBERS IN FLOORS, PARTITIONS AND ROOF TRUSSES. THEY GIVE STRONGER JOINTS, ALLOW THE USE OF SMALLER SECTIONS AND SIMPLIFY PREFABRICATION AND ERECTION.

TOOTHED PLATES :



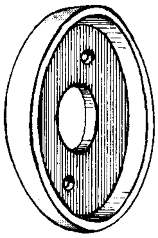
THESE ARE ROUND (OR SQUARE) METAL PLATES WITH TEETH AT THE EDGE. DOUBLE-SIDED PLATES, WITH TEETH ON BOTH SIDES, ARE USED FOR PERMANENT TIMBER TO TIMBER CONNECTIONS (ROOF TRUSSES). SINGLE-SIDED PLATES HAVE TEETH ON ONE SIDE ONLY. THEY ARE USED FOR TIMBER TO METAL JOINTS (PORTAL FRAMES). TOOTHED PLATES ARE FIXED ON A BOLT BETWEEN BORED TIMBER PIECES WITH SQUARE WASHERS AT BOTH ENDS. WHEN NUT AT ONE END IS SCREWED DOWN CONNECTORS ARE EMBEDDED WITH TIMBERS.

SPLIT RINGS :



THESE ARE CONNECTORS WHICH CONSIST OF STEEL RINGS CUT AT ONE POINT TO FORM A TONGUED AND GROOVED JOINT. THEY ARE USED FOR TIMBER TO TIMBER JOINTS AND HAVE A HIGHER LOAD BEARING CAPACITY THAN TOOTHED PLATES. EACH TIMBER MUST BE GROOVED TO HALF THE DEPTH OF THE RING, TO HOUSE THE RING. THE TONGUE ALLOWS THE RING TO EXPAND OR CONTRACT.

SHEAR PLATES :



THESE ARE ROUND STEEL PLATES WITH A FLANGE AT THE OUTER EDGE. THEY ARE USED FOR TIMBER TO METAL CONNECTIONS, AND THEY HAVE ABOUT THE SAME LOAD BEARING CAPACITY AS SPLIT RINGS.

TRUSS PLATES : THESE ARE 16 TO 22 GAUGE GALVANIZED STEEL PLATE CONNECTORS WITH PROTUDING TEETH, USED MAINLY FOR TIMBER TO TIMBER JOINTS (ROOF TRUSSES) AND ARE FIXED AT THE FRONT AND BACK OF THE JOINT.

FIXING OF STRUCTURAL TIMBER :

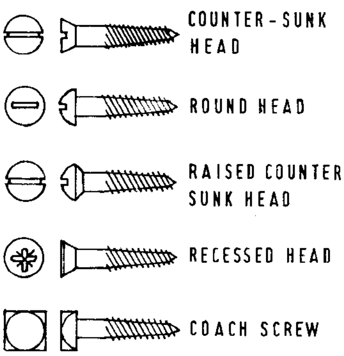
THERE ARE TWO WAYS OF FIXING STRUCTURAL TIMBER : BY MECHANICAL MEANS AND WITH ADHESIVES.

MECHANICAL FASTENING AND FIXING DEVICES :

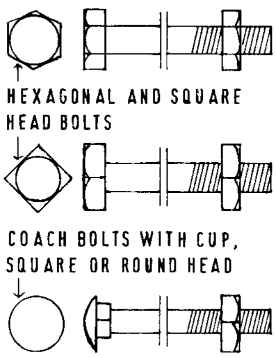
NAILS : ROUND PLAIN-HEAD WIRE NAILS, ROUND LOST-HEAD WIRE NAILS, CLOUT OR SLATE NAILS, PNEUMATIC DRIVEN NAILS, TWISTED SHANK NAILS, ANNULAR RING-SHANKED NAILS.

STAPLES

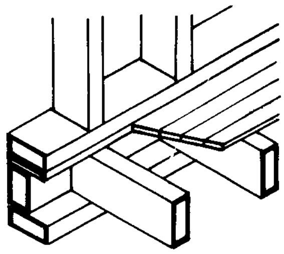
SCREWS :

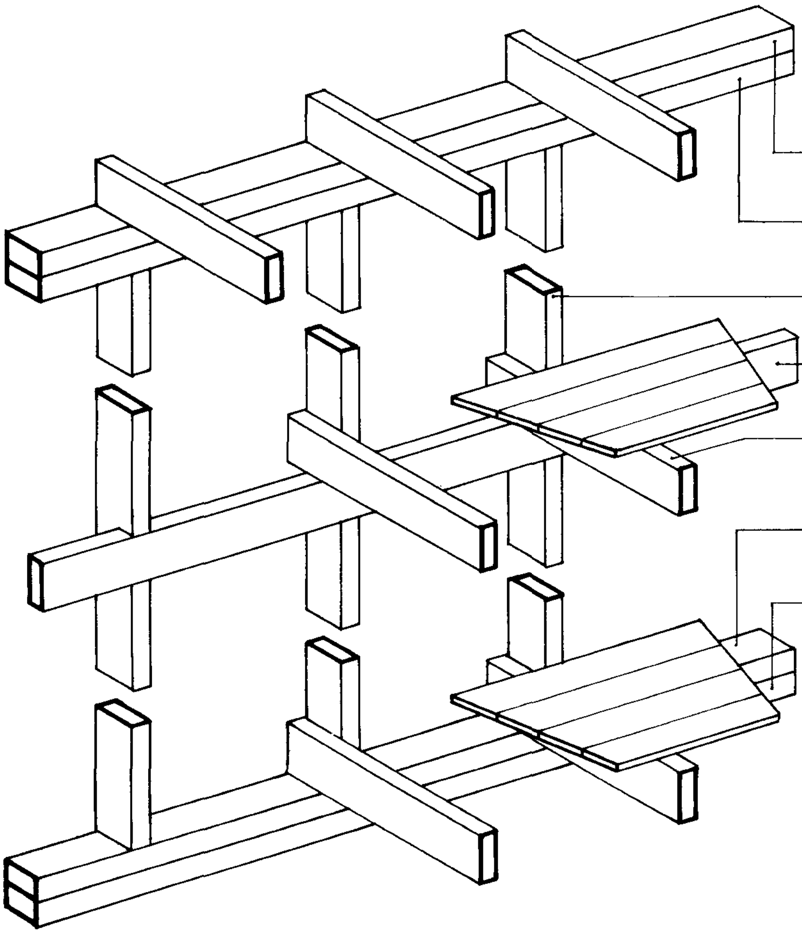


BOLTS :



4.8.3 CONVENTIONAL FRAMING METHODS





HEAD BINDER : CONTINUOUS MEMBER LINKING WALL FRAMES AND CARRYING ROOF.

HEAD PLATE : TOP MEMBER OF WALL FRAMES CARRYING HEAD BINDER AND ROOF.

STUDS : VERTICAL STRUCTURAL MEMBERS OF WALL FRAME EXTENDING THROUGH TWO STOREYS.

RIBBON : CONTINUOUS MEMBER LET INTO STUDS AND CARRYING FIRST FLOOR JOISTS.

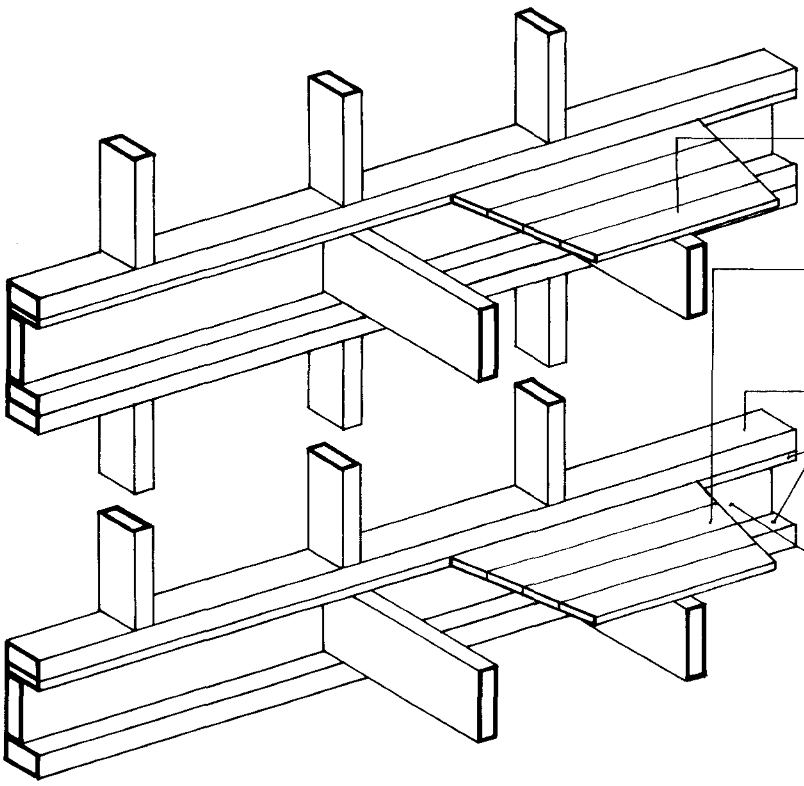
FIRST FLOOR JOISTS : STRUCTURAL FLOOR MEMBERS CARRIED ON RIBBON. GROUND FLOOR JOISTS CARRIED ON SOLE PLATE.

SOLE PLATE : BOTTOM MEMBER OF WALL FRAME.

SILL PLATE : LEVEL BASE PLATE FOR ERECTION OF WALL FRAME, ANCHORED TO FOUNDATION WALL.

BALLOON FRAME : THIS IS AN EARLY SYSTEM OF TIMBER FRAME CONSTRUCTION. THE STUDS IN TWO-STOREY CONSTRUCTION ARE CONTINUOUS FROM THE GROUND FLOOR SOLE PLATE TO THE EAVES WITH INTERMEDIATE FLOOR JOISTS CARRIED ON A RIBBON LET INTO THE STUDS. THE USE OF THIS METHOD HAS LAPSED IN FAVOUR OF THE PLATFORM FRAME CONSTRUCTION DESCRIBED BELOW.

BALLOON FRAME METHOD



NOTE : HEAD BINDER AND HEAD PLATE ARE THE SAME AS IN THE BALLOON FRAME.

FIRST FLOOR PLATFORM : WITH SOLE PLATE, FILLER PLATE (TO THE THICKNESS OF THE FLOORING), HEADER, HEAD BINDER AND HEAD PLATE, AND FLOOR JOIST.

FLOORING : CONTINUOUS FLOORING OF FLOOR SHEATHING (PLYWOOD OR TONGUED AND GROOVED BOARDING) FORMS BASE FOR ERECTION OF WALL FRAMES.

SOLE PLATE (TOP), **SILL PLATE** (BOTTOM)

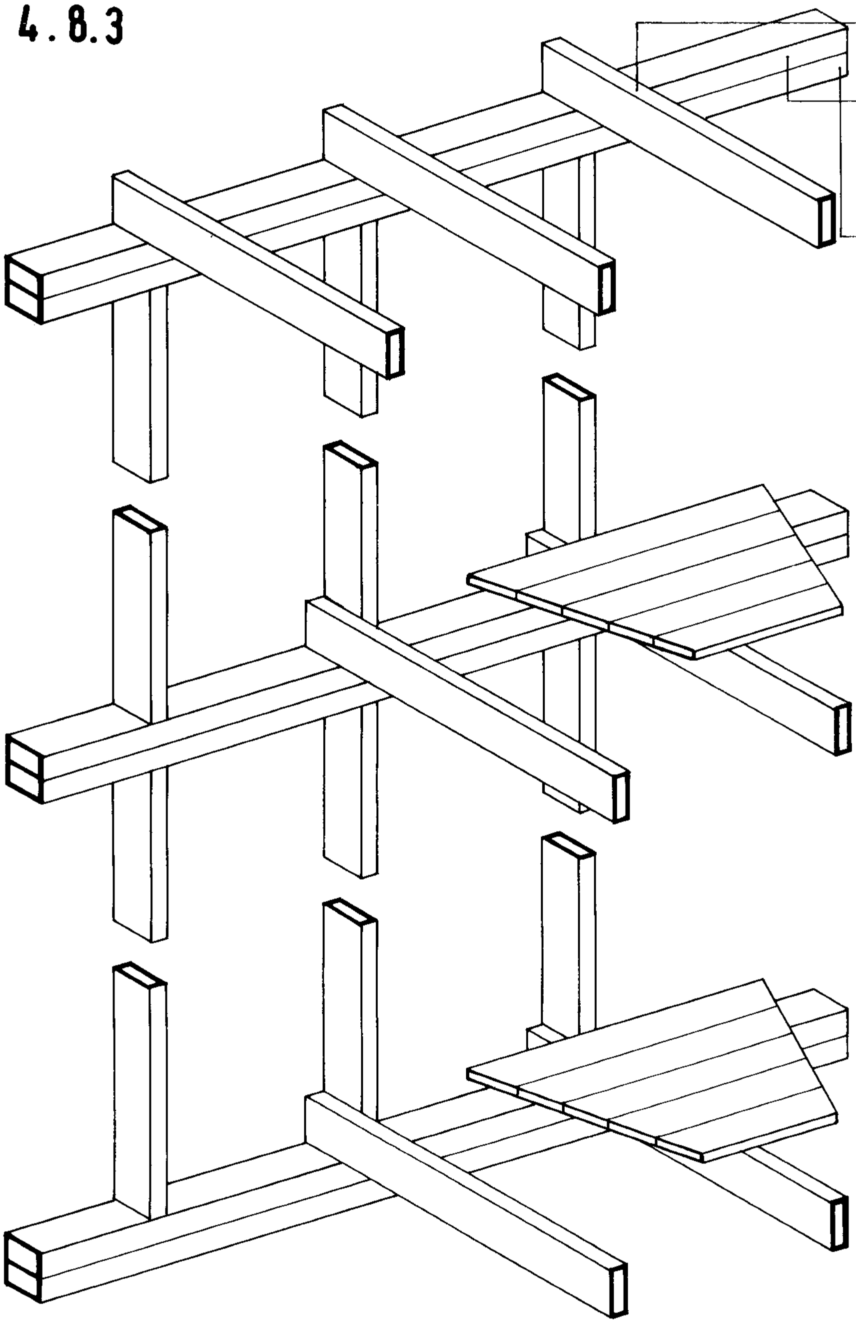
FILLER PLATE : SAME THICKNESS AS THE FLOOR FINISH SO THAT FLOOR PLATFORM CAN BE BUILT BEFORE ERECTION OF SUCCESSIVE WALL PANELS.

HEADER : FLOOR FRAMING MEMBER FORMING EDGE OF PLATFORM.

PLATFORM FRAME : A METHOD OF CONSTRUCTION WHERE EACH FLOOR EXTENDS TO THE OUTSIDE EDGES OF THE BUILDING AND PROVIDES A PLATFORM UPON WHICH THE EXTERIOR WALLS AND INTERIOR PARTITIONS ARE RAISED IN SINGLE STOREY HEIGHT UNITS. THIS METHOD OF CONSTRUCTION IS MOST WIDELY PRACTICED IN THE U.S.A., CANADA AND BRITAIN.

PLATFORM FRAME METHOD

4.8.3



MODIFIED FRAME METHOD

PART OF ROOF STRUCTURE:
ROOF JOISTS OR NAILED TRUSSES.

HEAD BINDER:
CONTINUOUS MEMBER LINKING WALL FRAME AND CARRYING ROOF MEMBERS; NAILED TO HEAD PLATE.

HEAD PLATE:
TOP MEMBER OF WALL FRAME, NAILED OR MORTISED AND TENONED TO STUDS.

FIRST FLOOR STUDS:
VERTICAL STRUCTURAL MEMBERS OF WALL FRAME OF SINGLE STOREY HEIGHT; NAILED OR MORTISED AND TENONED TO SOLE PLATE.

FIRST FLOOR FLOORING

FIRST FLOOR SOLE PLATE

HEAD PLATE

FIRST FLOOR JOISTS:
STRUCTURAL FLOOR MEMBERS CARRIED ON SOLE PLATE OF UPPER WALL FRAME; NAILED TO SIDES OF STUDS.

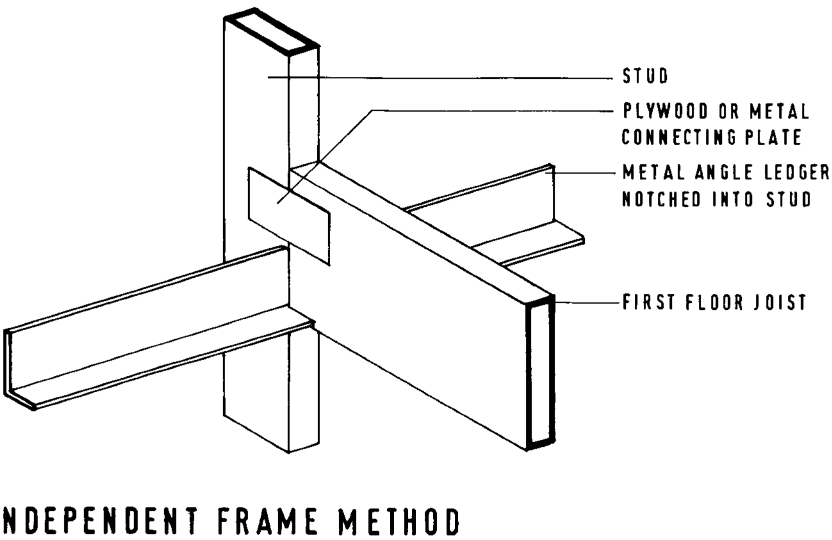
GROUND FLOOR FLOORING

GROUND FLOOR JOISTS

SOLE PLATE:
BOTTOM MEMBER OF WALL FRAMES, NAILED TO SILL PLATE AT GROUND FLOOR AND TO HEAD PLATE AT FIRST FLOOR LEVEL.

SILL PLATE:
LEVEL BASE PLATE FOR ERECTION OF WALL-FRAME; ANCHORED TO FOUNDATION.

MODIFIED FRAME:
THIS IS A FRAMING METHOD WITH WALL FRAMES OF SINGLE STOREY HEIGHT. THE FLOOR JOISTS ARE FIXED TO SIDES OF STUDS. RIGIDITY IS ACHIEVED THROUGH THE JOIST-TO-STUD FIXING AT FLOOR / WALL JUNCTION. ROOF STRUCTURE AND COVERING CAN BE COMPLETED IN THE EARLY STAGES OF THE WORK SINCE THE WALL FRAMING CAN BE ERECTED INDEPENDENT OF FLOOR CONSTRUCTION.



INDEPENDENT FRAME METHOD

INDEPENDENT FRAME:
FIRST FLOOR CONSTRUCTION IS "INDEPENDENT" OF THE CONSTRUCTION OF THE EXTERNAL WALL FRAME. THE STRUCTURAL MEMBERS OF THE FLOOR ABUT THE FACE OF THE WALL AND DO NOT ENTER THE WALL STRUCTURE AS IS THE CASE IN THE BALLOON, MODIFIED AND PLATFORM FRAMING METHODS.

THE BALLOON, PLATFORM, MODIFIED AND INDEPENDENT FRAMING METHODS HAVE BEEN ADAPTED FROM "TIMBER FRAME HOUSING - DESIGN GUIDE" (TIMBER RESEARCH AND DEVELOPMENT ASSOCIATION, TRADA, HIGH WYCOMBE, ENGLAND).

4.9 CONSTRUCTION METHODS

Timber frame construction is a structural system in which all live, dead and wind loads are carried by elements fabricated from timber. Sheathing, boarding, cladding or lining provide rigidity and structural stability. The structural systems employed in timber frame methods of building construction can be classified in four basic groups:

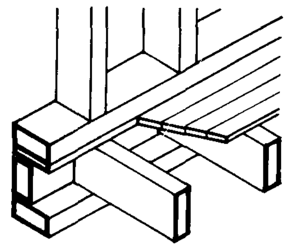
- Stud frame construction;
- Post and beam construction;
- Portal frame construction;
- Membrane construction.

1. STUD FRAME CONSTRUCTION

This construction system has been detailed and described on the preceding pages under **4.8.3 Conventional Framing Methods**. It consists of wall elements built up of a series of vertical members (or studs) of relatively small size (normally 100 to 125 x 50 mm) spaced from 400 to 600 mm apart and framed with horizontal head and sole plates to form structural wall panels of convenient size. The stud framed walls carry the floors and roof. Windows and doors are framed within wall units. Stud framed wall panels can easily be prefabricated.

2. POST AND BEAM CONSTRUCTION

The basic structural grid consists of solid timber beams (laminated timber or plywood box construction) supported on posts spaced widely apart (normally between 1.25 m and 3.50 m in domestic buildings). The posts are individual timber columns or built-up columns. Floor and roof elements of joisted, plank or panelled construction span between the beams. Roof construction can be nailed



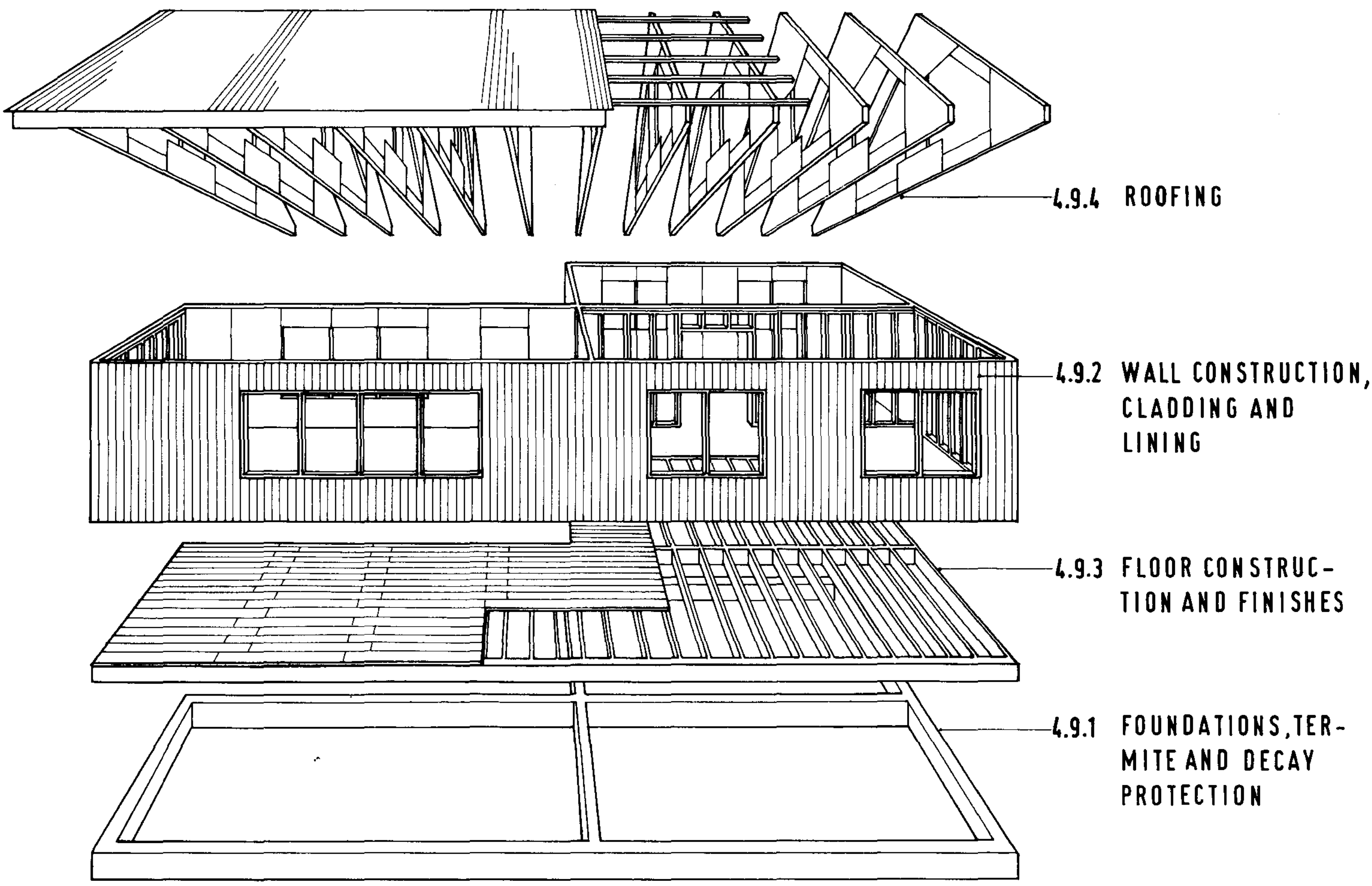
trusses with purlins and corrugated sheeting. Non-load bearing infill panels form wall and window units between the columns.

3. PORTAL FRAME CONSTRUCTION

This was developed primarily for clear-span industrial and storage buildings. The portal frame system has, however, been used for domestic structures of two, three and four storeys in height. It consists of rigid portal frames of solid, laminated or plywood construction spaced from 2.50 m to 4.50 m or more apart. These support joisted floor or roof elements, with non-load-bearing wall infill panels of stud frame construction.

4. MEMBRANE CONSTRUCTION

In this system the structural elements of walls, floors and roofs take the form of stressed skin panels of composite construction using outer skins of plywood with lightweight timber framing and bonded core of insulating material. The stressed skin components give structural rigidity to the building. This system is being used for large pre-finished building compartment units.
The different parts of a timber house below, constructed in the platform framing method show the details of construction which will be explained on the following pages. Window and door details will form part of section **5 "Construction"**, as well as roof finishes.



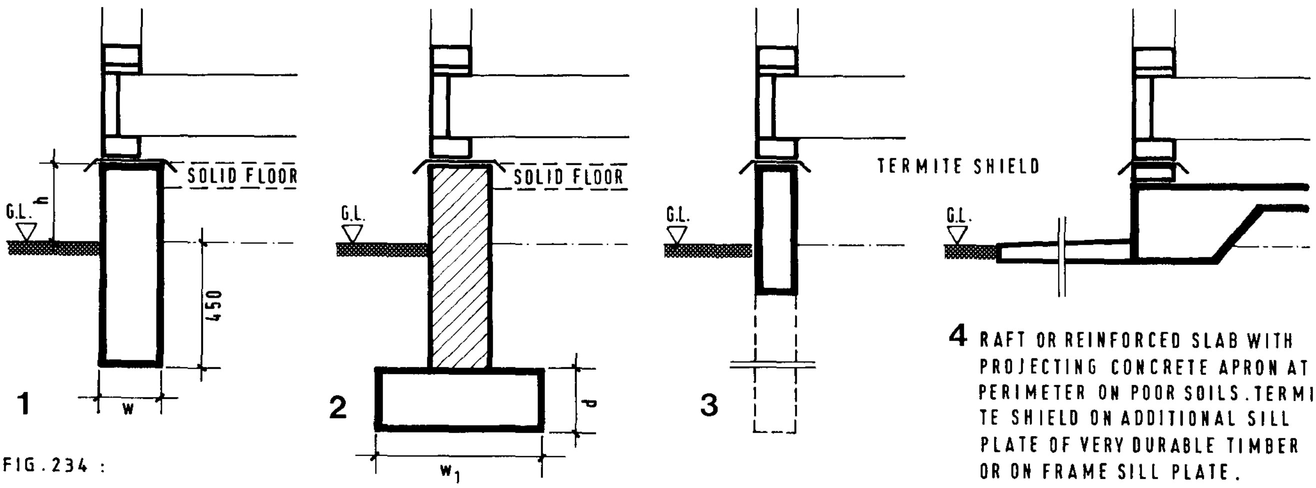
4.9.1 FOUNDATIONS, TERMITE AND DECAY PROTECTION

A timber frame house is noted for its lightness, resilience, strength and rigidity. It is, however, essential to provide adequate and properly installed foundations. At the same time termite and decay protection is necessary at the level of possible contact with and closeness to the ground.
It is absolutely essential that the bottom plate of the timber framing should be set dead level. The foundations and foundation walls must be true and square. The footing of the foundation must be taken down to load bearing soil. As a rough rule the following can be adopted: The footing should be twice as wide as the width of the foundation wall, its depth equal to the thickness of the foundation wall. The basic types of foundations suitable for timber houses are shown in Fig. 234. Details shown are based on the platform framing method.

Foundation walls may be of brick, stone, block or poured concrete. The exterior of foundation walls should, in damp conditions, be plastered with minimum 12 mm thick cement-sand plaster and then coated with two coats of emulsified asphalt or an equivalent waterproofing compound, carried down to the bottom of the footing.

Termite and decay protection is achieved through the following fundamental construction practices:

- Positive site and building drainage;
- Adequate separation of timber elements from known moisture sources and a necessary physical barrier for termite protection;
- Soil poisoning beneath the building and around the foundation walls;
- Use of durable and treated wood;



4 RAFT OR REINFORCED SLAB WITH PROJECTING CONCRETE APRON AT PERIMETER ON POOR SOILS. TERMITE SHIELD ON ADDITIONAL SILL PLATE OF VERY DURABLE TIMBER OR ON FRAME SILL PLATE.

FIG. 234 :
SUITABLE FOUNDATIONS FOR TIMBER FRAME HOUSING

1 IN-SITU NARROW CONCRETE STRIP FOUNDATION - INTEGRAL WITH FLOOR SLAB IF SOLID FLOOR OR ISOLATED TO SUPPORT FLOOR JOISTS OF SUSPENDED FLOOR. w = DETERMINED BY WEIGHT IMPOSED BY BUILDING AND LOAD-BEARING CAPACITY OF SOIL. h = HEIGHT OF BASE OF BUILDING ABOVE GROUND LEVEL 400 mm, MINIMUM 150 mm, IF SOLID APRON IS BUILT AROUND BUILDING.

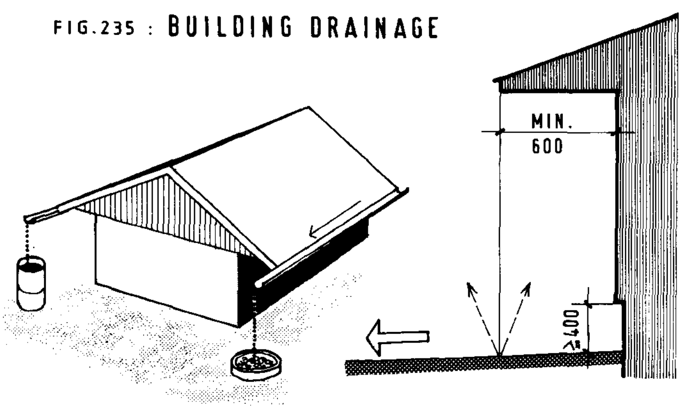
2 IN-SITU CONCRETE STRIP FOUNDATION SUPPORTING FOUNDATION WALL. w_1 = WIDTH OF FOOTING STRIP ABOUT TWICE THE WIDTH OF FOUNDATION WALL. d = DEPTH IS DETERMINED BY w_1, BUT SHOULD NOT BE LESS THAN 150 mm.

3 REINFORCED CONCRETE BEAMS SPANNING BETWEEN SHORTBORED PILES WHERE SOIL CONDITIONS NECESSITATE PILING.

NOTE : THE ABOVE SHOWN FOUNDATIONS ARE CONVENTIONAL FOUNDATION TYPES. DETAILS ON 4.9 (a) 1. TO 3. INCLUDE TIMBER POST FOUNDATIONS AND SUPPORT OF POSTS IN ISOLATED CONCRETE PADS.

- Ventilation and condensation control in enclosed spaces.

FIG. 235 : **BUILDING DRAINAGE**



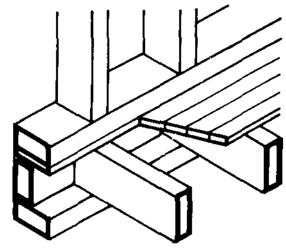
RAINWATER CAN BE COLLECTED IN DRUMS FOR USE OR IN RECEPTACLES FILLED WITH LARGE PEBBLES OR STONES. AN UNDERGROUND PIPE DISCHARGES IT INTO A STORMWATER DRAIN. A CHAIN IS FIXED TO THE RAINGUTTER OR GARGOYLE TO GUIDE THE WATER IN WIND. GOOD DRAINAGE AWAY FROM HOUSE IS PROVIDED WITH SOLID APRONS FROM STONES, RAMMED GRAVEL OR CONCRETE.

The site should be graded such that provision is made for easy draining away of surface water around the building (Fig. 235).

Soil poisoning can be achieved with the following soil poisons: **Dieldrin, Aldrin, Chlordane, Benzene Hexachloride** and **DDT**. These chemicals have been found suitable in humid tropical regions where the risk of termite attack is very high, as well as in the dry and hot tropical zones. They are normally applied as a 0,5 % emulsion in water (Dieldrin and Aldrin) or as 1.0 % emulsion (the others).

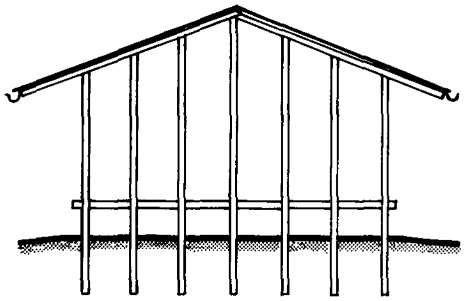
Termite shields – physical barriers for separating wood from the foundation of a building – should be of 26 gauge galvanized iron, zinc or copper sheeting. They are to be installed as shown in the details on the following pages on top of all foundation walls, piers, etc. Longitudinal joints should be locked and soldered. It is advisable to undertake periodic inspections to check on any termite activity close and around the building.

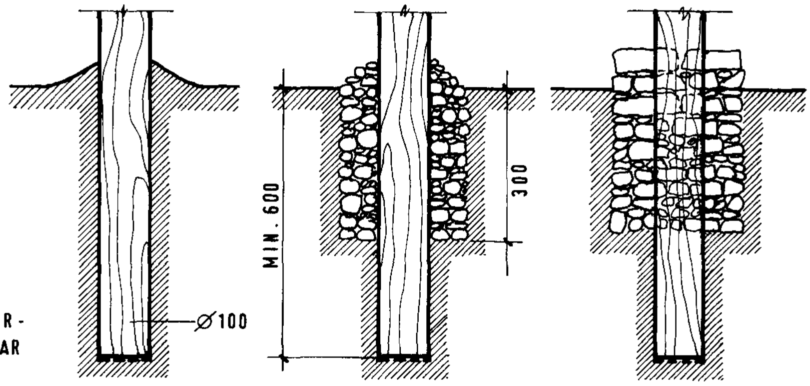
4.9.1 FOUNDATIONS, TERMITE AND DECAY PROTECTION



FROM : "GRÜNDUNG FÜR LOW COST / SELF HELP HOUSING" BY K.VORHAUER, G.A.T.E., 10 / 78.

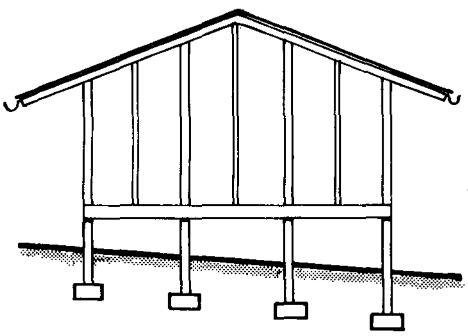
1 FOUNDATIONS OF TIMBER POLE BUILDINGS :

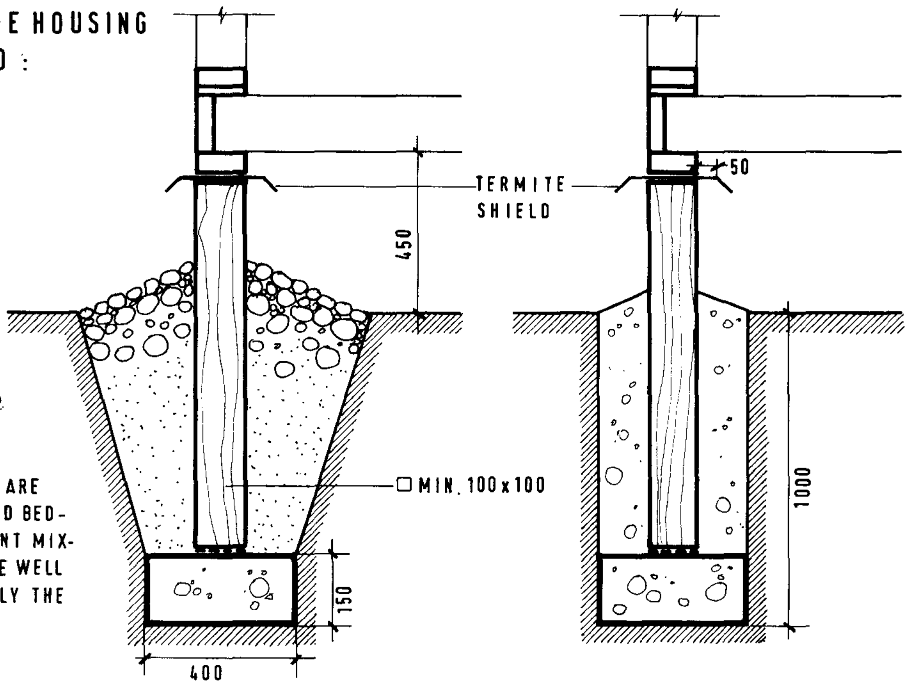




TREATED POLES (SOAKED IN WASTE OIL, TAR OR PRESERVATIVE) WITH SAWN ENDSWELL COVERED WITH COAL TAR OR ASPHALTIC PAINT RAMMED INTO BORED HOLES AND PACKED WITH GRAVEL OR STONES OR BEDDED INTO CONCRETE.

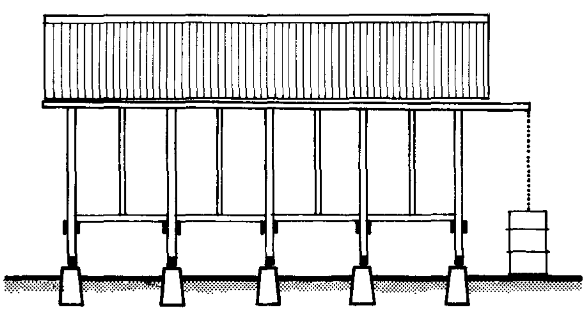
2 FOUNDATIONS OF TIMBER FRAME HOUSING SUITABLE FOR SLOPING GROUND :

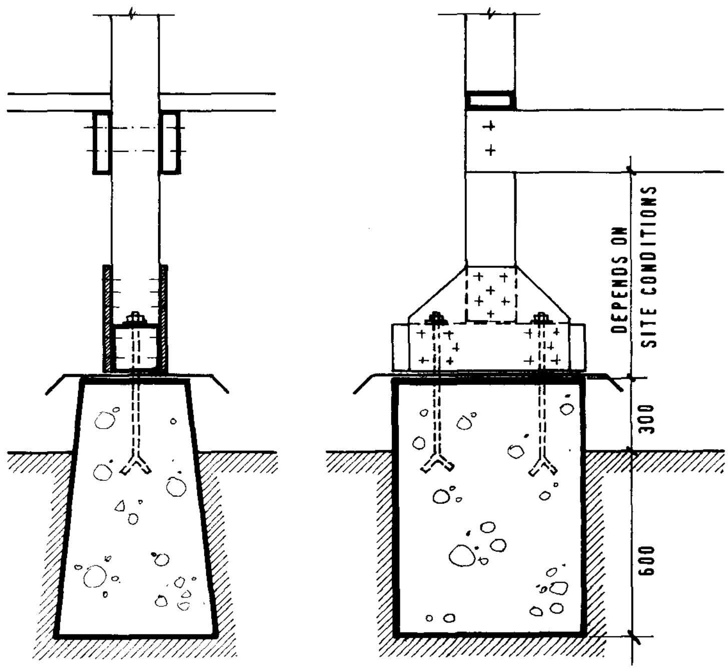




PRESERVATIVE TREATED SOLID TIMBER POSTS ARE SUPPORTED ON CONCRETE PAD FOUNDATIONS AND BEDDED IN RAMMED GRAVEL OR GRAVEL AND CEMENT MIXTURE OR CAST INTO LEAN CONCRETE. POSTS ARE WELL COVERED WITH BITUMENOUS PAINT, ESPECIALLY THE SAWN ENDS.

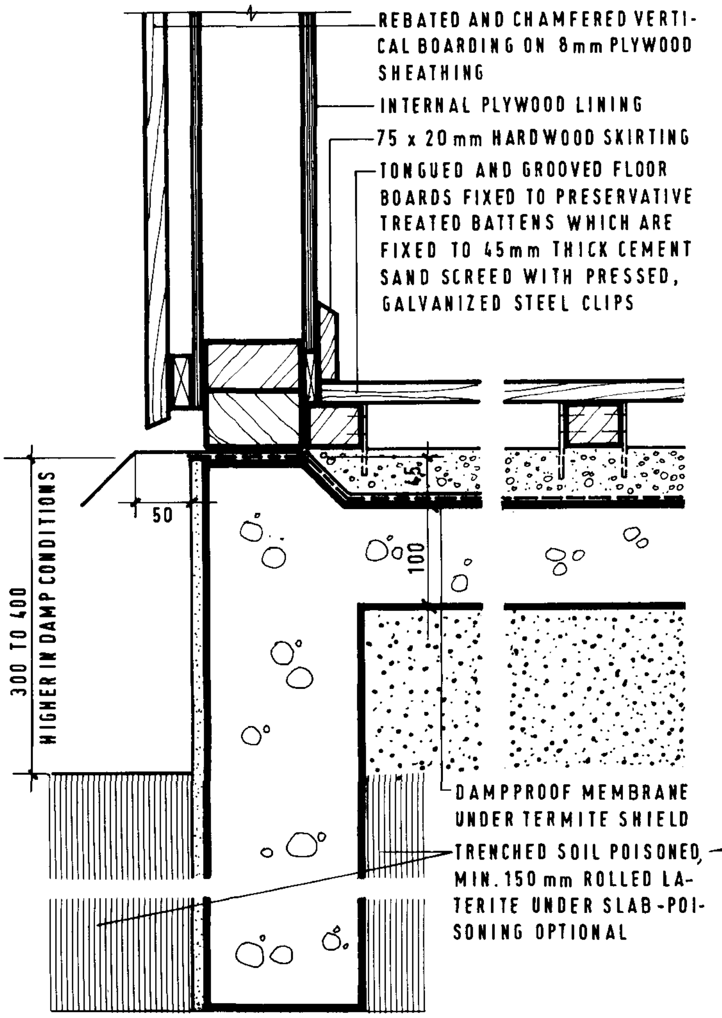
3 FOUNDATIONS FOR TIMBER FRAME HOUSING WITH INDEPENDENT FRAMING SYSTEM :



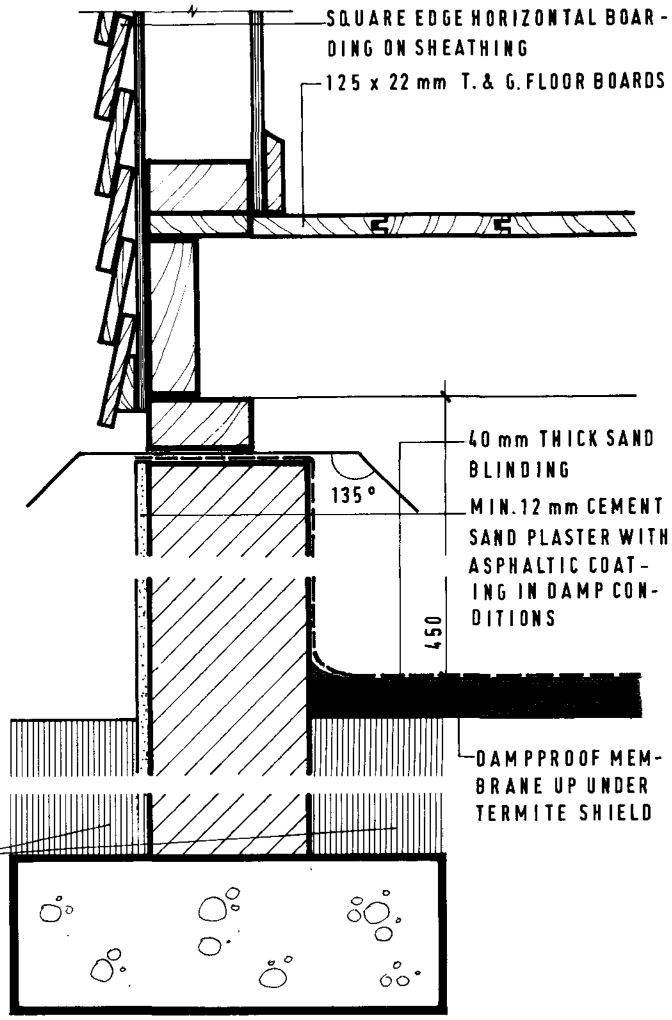


LOADBEARING POSTS OF TIMBER FRAMEWORK ARE SUPPORTED ON CONCRETE, STONE OR BRICK PILLARS. THEY ARE NAILED WITH GUSSET PLATES (FROM PLYWOOD OR GALVANIZED STEEL) TO SHORT BLOCKING PIECES WHICH ARE FIXED TO PILLARS WITH 12 mm DIAMETER ANCHOR BOLTS. END OF POST AND BLOCKING PIECE MUST BE PROTECTED WITH TWO COATS OF BITUMINOUS PAINT.

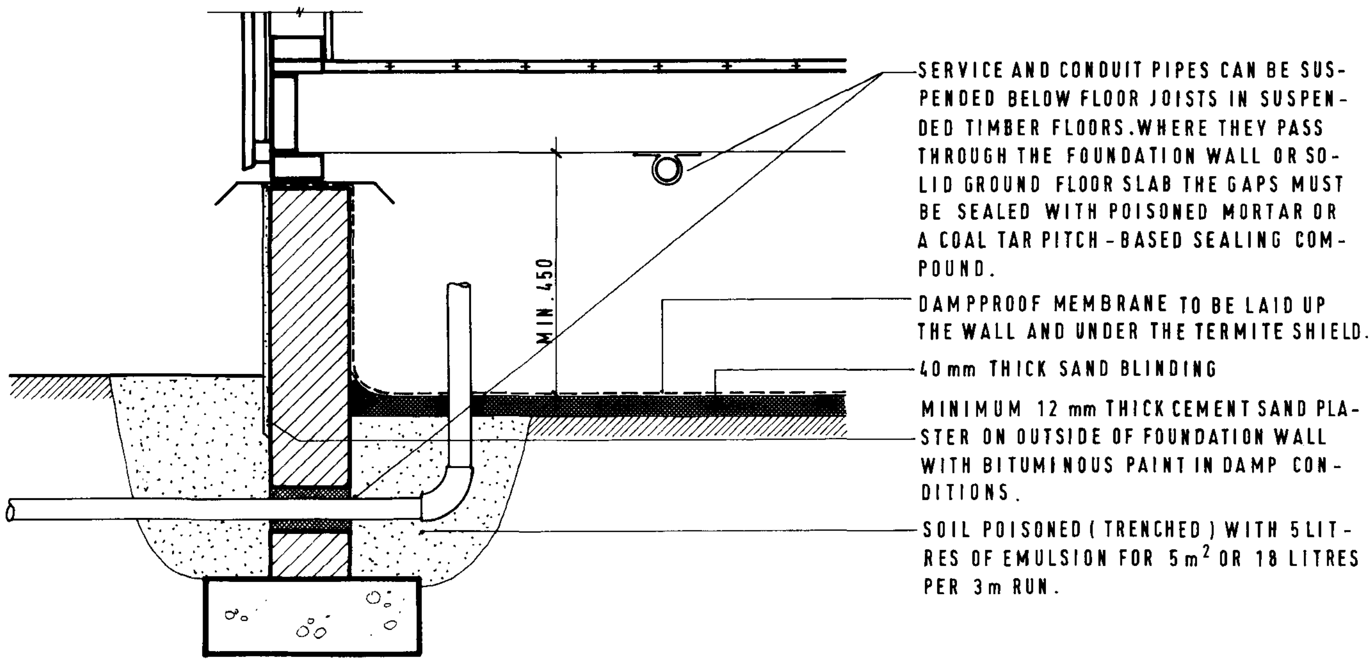
4.9.1



4 TIMBER FLOOR ON SUSPENDED CONCRETE GROUND FLOOR WITH NARROW CONCRETE STRIP FOUNDATION IN AREA WITH SUBTERRANEAN TERMITES



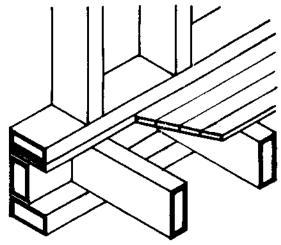
5 SUSPENDED TIMBER FLOOR ON CONCRETE STRIP FOUNDATION WITH BLOCK WORK FOUNDATION WALL

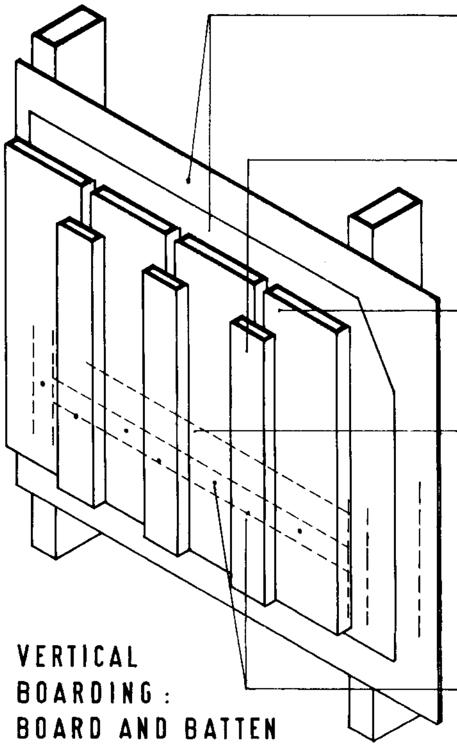


6 SOME SOLUTIONS TO GROUND LEVEL PROBLEMS IN AREAS WITH SUBTERRANEAN TERMITES

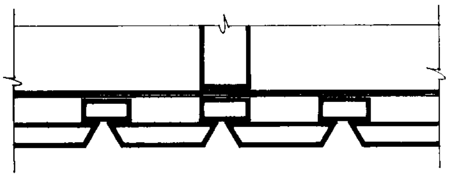
ADAPTED FROM "TIMBER IN TROPICAL BUILDING", OVERSEAS BUILDING NOTES N°146, BUILDING RESEARCH STATION, GARSTON, ENGLAND

4.9.2 WALL CONSTRUCTION, CLADDING AND LINING



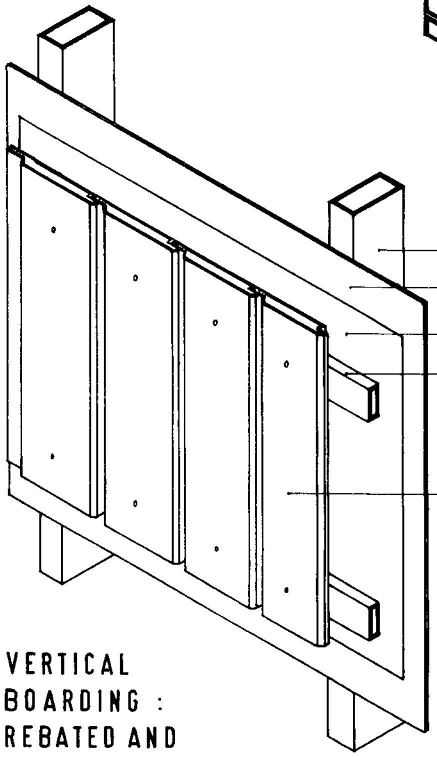


VERTICAL BOARDING: BOARD AND BATTEN

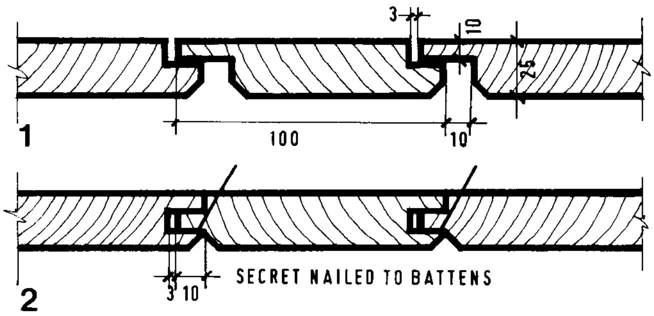


ALTERNATIVE ARRANGEMENT WITH BOARDS ON BATTENS

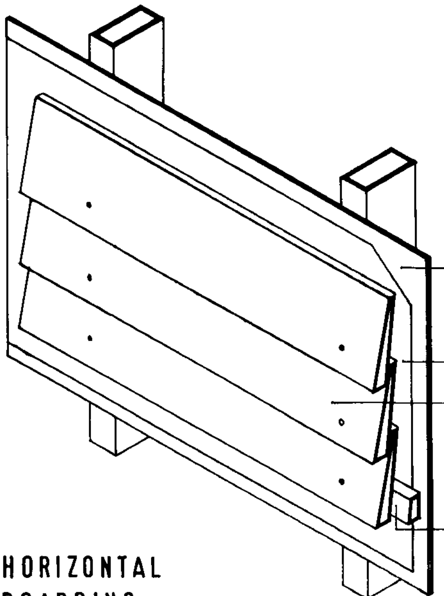
SHEATHING: INCREASES THE RACKING RESISTANCE OF FRAMED COMPONENTS WHICH ARE SUBJECTED TO HORIZONTAL FORCES. IT PROVIDES OVERALL FIXING TO CERTAIN FORMS OF CLADDING AND A RIGID BACKING FOR THE MOISTURE BARRIER.



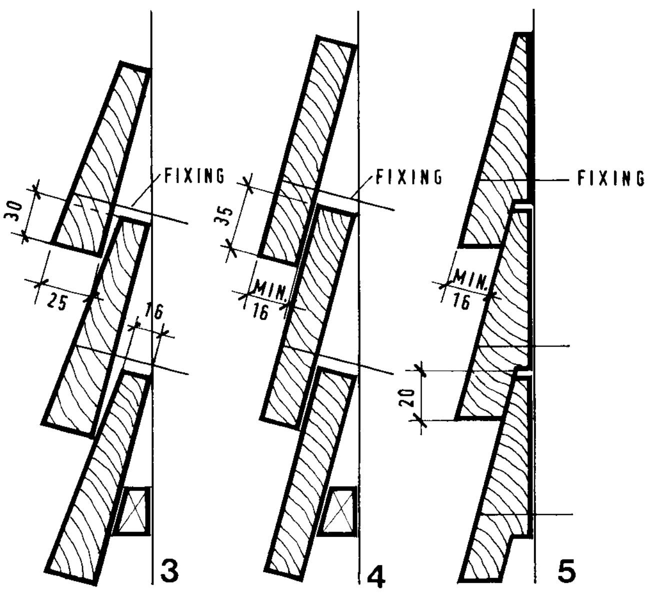
VERTICAL BOARDING: REBATED AND CHAMFERED OR TONGUED AND GROOVED



1 REBATED AND CHAMFERED BOARDING
2 TONGUED AND GROOVED BOARDING



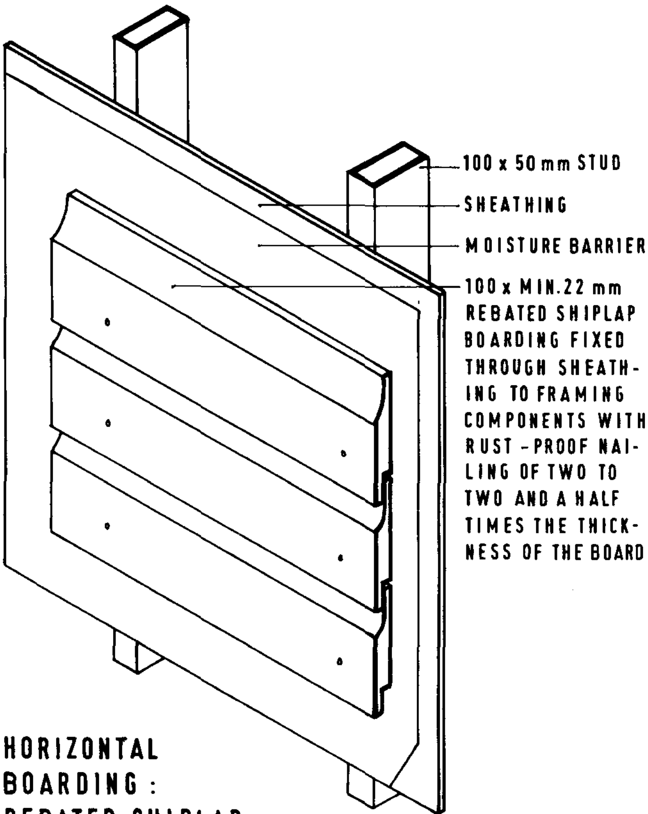
HORIZONTAL BOARDING: FEATHER EDGE



3 FEATHER EDGE 4 SQUARE EDGE 5 REBATED FEATHER EDGE

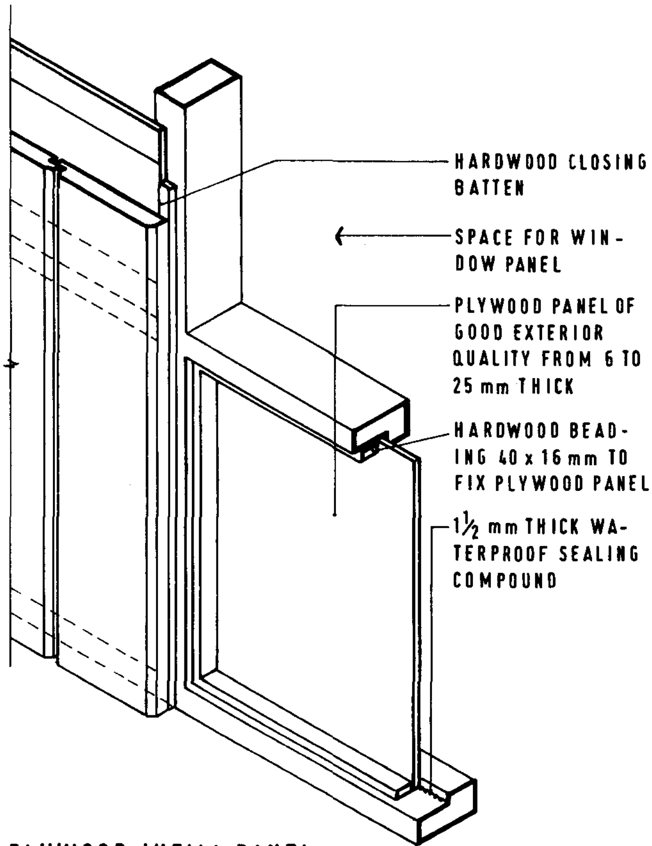
NOTE: FIXING BATTENS MUST BE PRESERVATIVE TREATED.

4.9.2



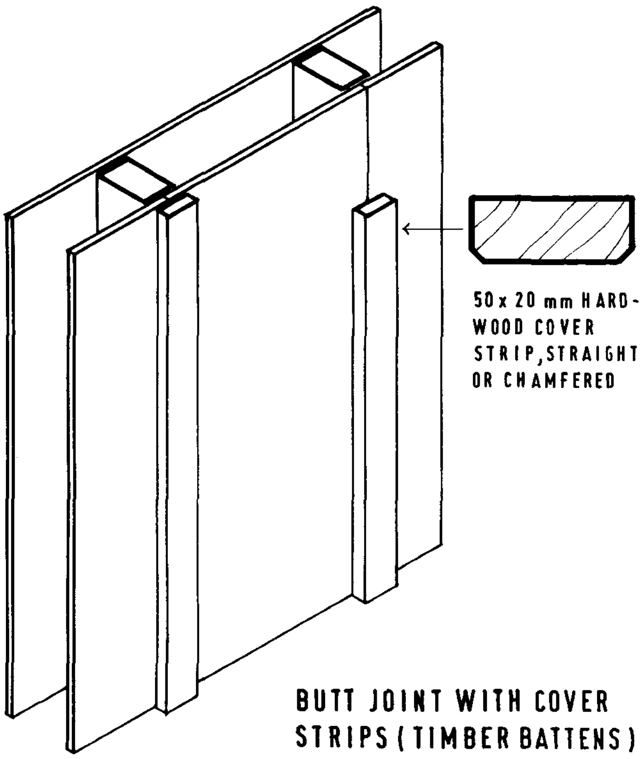
HORIZONTAL BOARDING : REBATED SHIPLAP :

REBATED AND CHAMFERED BOARDS CAN ALSO BE USED FOR HORIZONTAL BOARDING, BUT ARE MORE COMMONLY USED FOR VERTICAL BOARDING.



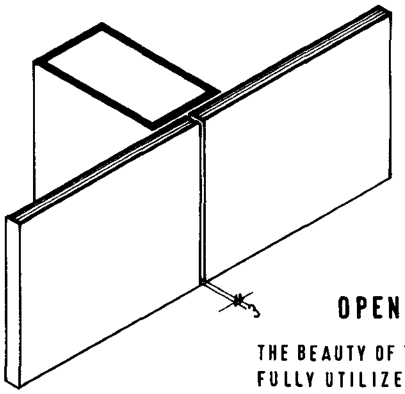
PLYWOOD INFILL PANEL :

RECOMMENDED FOR USE BELOW AND ABOVE WINDOW PANELS IN SHELTERED POSITIONS.



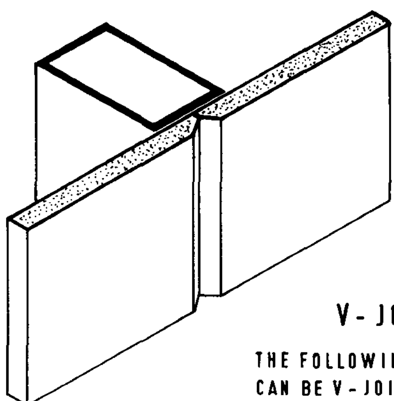
BUTT JOINT WITH COVER STRIPS (TIMBER BATTENS):

PLYWOOD LINING : LONG EDGE PARALLEL TO MAIN FRAMING MEMBERS, WITH ADDITIONAL NOGGINGS.



OPEN JOINT LINING:

THE BEAUTY OF THE VENEER CAN BE FULLY UTILIZED IF WHOLE PLYWOOD SHEETS ARE USED IN THE PANEL ARRANGEMENT



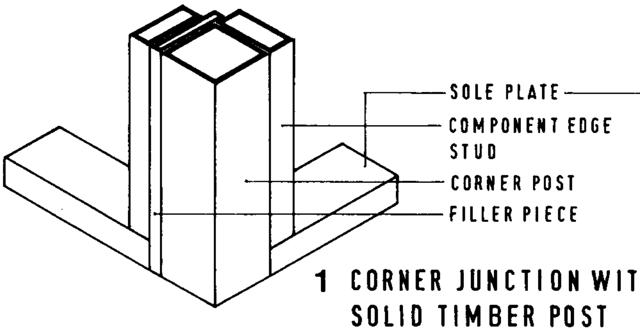
V-JOINTED LINING :

THE FOLLOWING PANEL MATERIALS CAN BE V-JOINTED : HARDPRESSED FIBRE BOARD, PARTICLE BOARD, MEDIUM DENSITY ASBESTOS

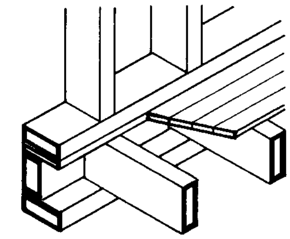
PLYWOOD LINING :

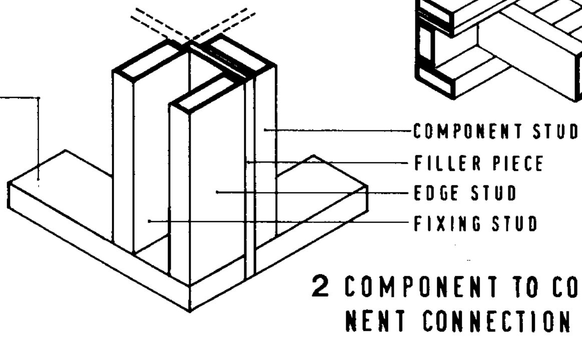
THIS IS USED FOR INTERNAL WALL AND PARTITION COVERING. AN EXCELLENT FINISH IS ACHIEVED BY USING DECORATIVE VENEERS ON THE PLYWOOD.

4.9.2 CORNERS AND JUNCTIONS

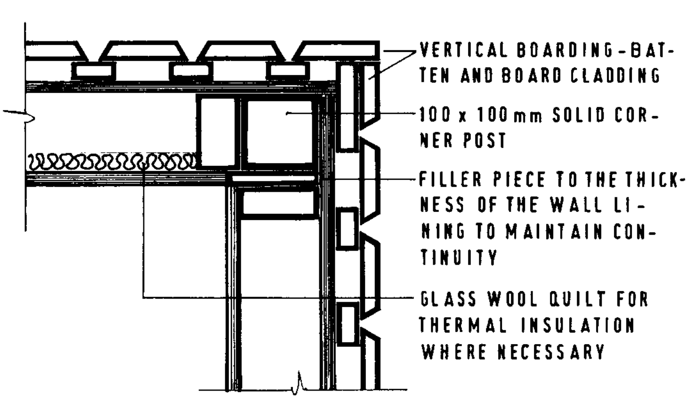


1 CORNER JUNCTION WITH SOLID TIMBER POST

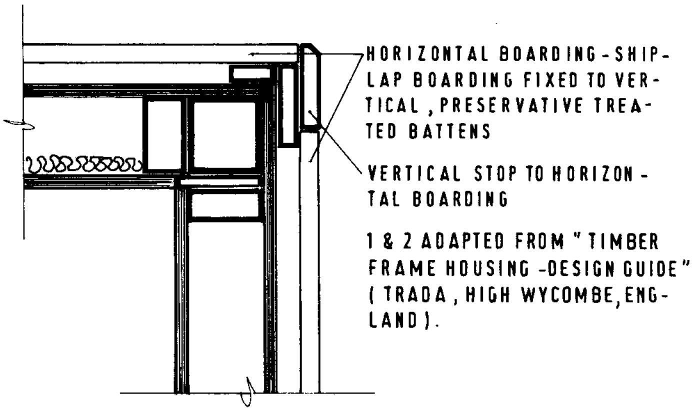




2 COMPONENT TO COMPONENT CONNECTION

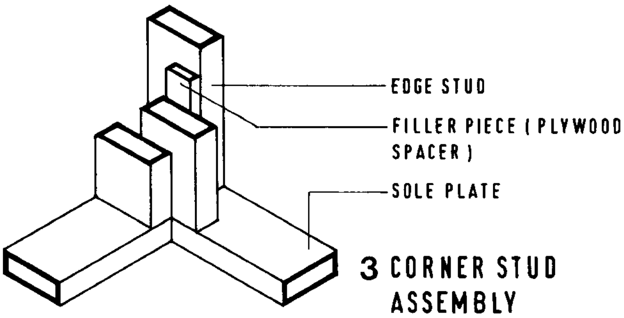


PLAN OF CORNER JUNCTION WITH SOLID TIMBER POST AND BATTEN AND BOARD VERTICAL CLADDING

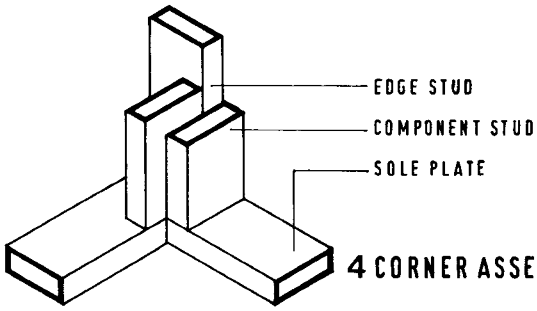


1 & 2 ADAPTED FROM "TIMBER FRAME HOUSING-DESIGN GUIDE" (TRADA, HIGH WYCOMBE, ENGLAND).

PLAN OF CORNER JUNCTION WITH SOLID TIMBER POST AND HORIZONTAL SHIPLAP BOARDING

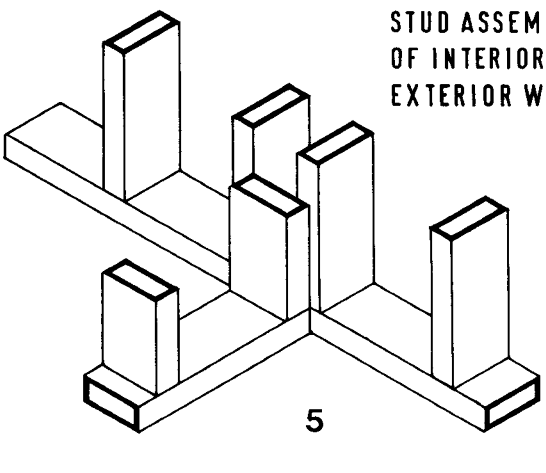


3 CORNER STUD ASSEMBLY

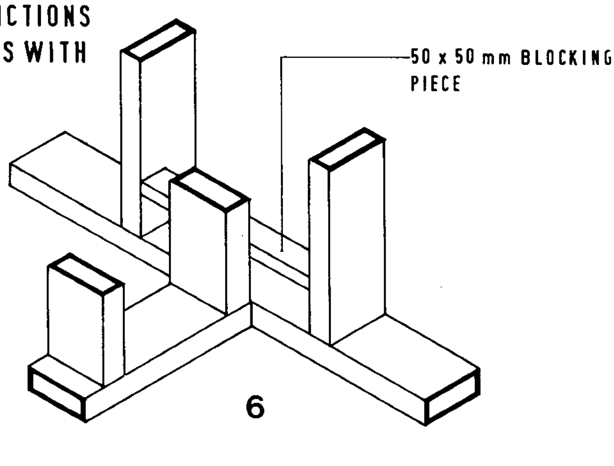


4 CORNER ASSEMBLY

STUD ASSEMBLY AT JUNCTIONS OF INTERIOR PARTITIONS WITH EXTERIOR WALL



5



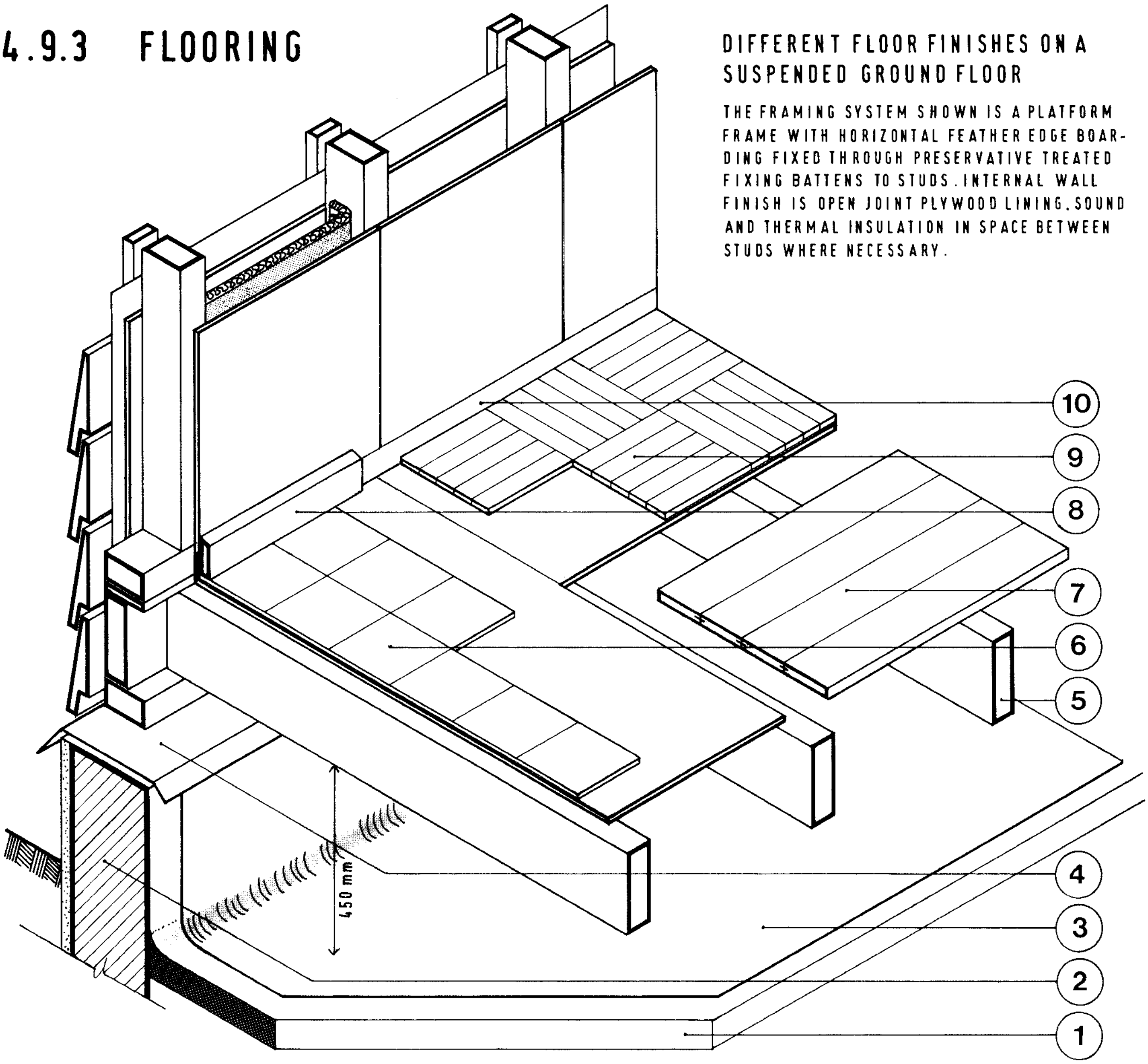
6

NOTE: IN SINGLE-STOREY STRUCTURES STUDS ARE PLACED AT 600 mm CENTRES. FOR TWO-STOREY BUILDINGS STUDS ON THE GROUNDFLOOR SHOULD BE SPACED AT 400 mm CENTRES. AN ARRANGEMENT OF MULTIPLE STUDS AT EXTERNAL CORNERS PROVIDES FOR READY FIXING OF CLADDING AND LINING MATERIALS. FOR SOLID CORNER POSTS A SILL PLATE BELOW THE SOLE PLATE IS NECESSARY. MULTIPLE STUDS ARRANGEMENTS ARE MORE ECONOMICAL.

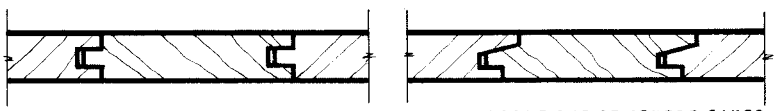
4.9.3 FLOORING

DIFFERENT FLOOR FINISHES ON A SUSPENDED GROUND FLOOR

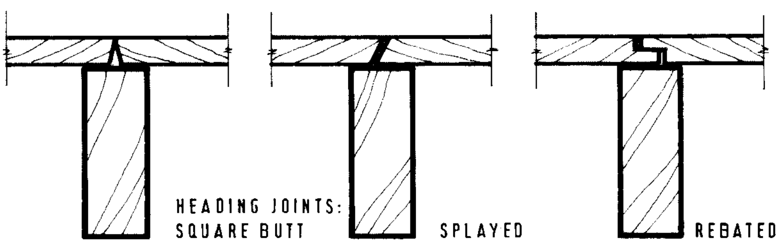
THE FRAMING SYSTEM SHOWN IS A PLATFORM FRAME WITH HORIZONTAL FEATHER EDGE BOARDING FIXED THROUGH PRESERVATIVE TREATED FIXING BATTENS TO STUDS. INTERNAL WALL FINISH IS OPEN JOINT PLYWOOD LINING. SOUND AND THERMAL INSULATION IN SPACE BETWEEN STUDS WHERE NECESSARY.

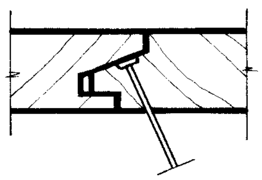


1 40 mm THICK SAND BLINDING
2 FOUNDATION WALL
3 DAMP PROOF MEMBRANE TO GO UP FOUNDATION WALL UNDER TERMITE SHIELD
4 TERMITE SHIELD
5 GROUND FLOOR JOIST 150 x 50 mm AT 600 mm CENTRES IN A 600 mm GRID SYSTEM
6 RESILIENT FLOOR TILES ON 20 mm THICK PLYWOOD SHEETING
7 TONGUED AND GROOVED FLOOR BOARDING 100 x 22 mm FIXED STRAIGHT TO FLOOR JOISTS
8 90 x 20 mm HARDWOOD SKIRTING
9 MOSAIC WOOD FLOORING PANELS FIXED TO PLYWOOD SHEETING
10 FILLER PIECE AT BOTTOM OF LINING

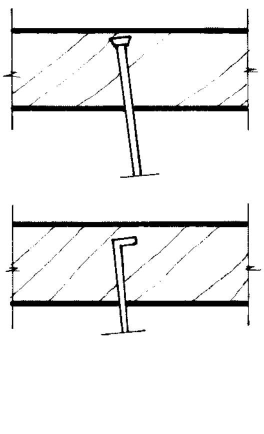


TONGUED AND GROOVED FLOOR BOARDING WITH GROOVE OUT OF CENTRE FIXED ON FLOOR JOISTS (SEE ABOVE) OR ON BATTENS (IN CASE OF A SOLID FLOOR SLAB)





SPECIAL SHAPED TONGUED AND GROOVED BOARDING FOR SECRET NAILING

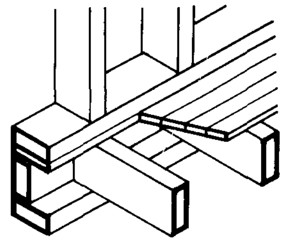


LOST HEAD BRAD, NAILED THROUGH THE FACE AND PUNCHED IN. LENGTH OF NAILS $2\frac{1}{2}$ TIMES THICKNESS OF BOARDS.

ORDINARY FLOOR BRAD

DETAILS OF FLOOR BOARDING AND NAILING

4.9.4 ROOFING



The functions of a roof will be fully described and detailed in part 5 (**"Construction" – Roofs and Roof Finishes**). It is, however, important to know before deciding on a suit-

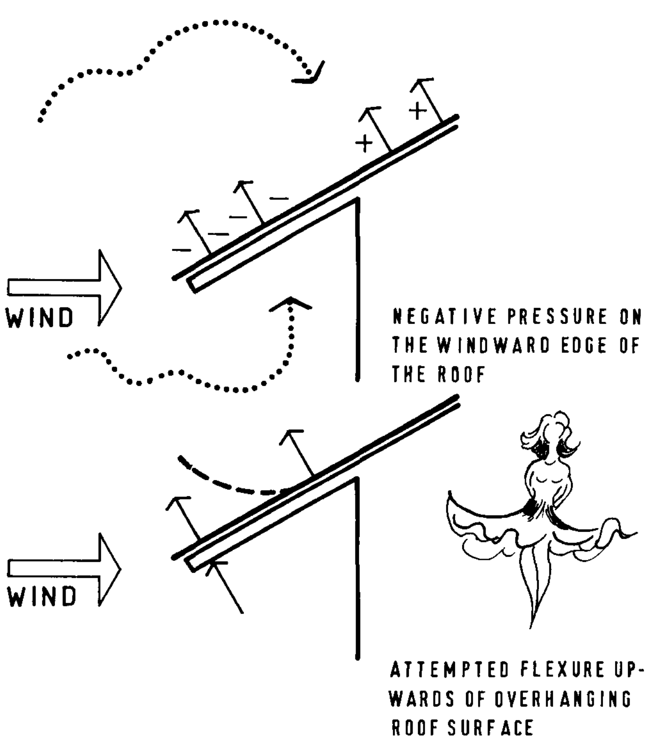


FIG.236: THE MONROE EFFECT

(FIG.236 AND 237 ADAPTED WITH KIND PERMISSION FROM "CYCLONE-RESISTANT RURAL PRIMARY SCHOOL CONSTRUCTION - A DESIGN GUIDE" BY I.T.SINNAMON AND G.A.VAN'T LOO, EDUCATIONAL BUILDING REPORT Nº 7, UNESCO REGIONAL OFFICE FOR EDUCATION IN ASIA, BANGKOK, THAILAND, 1977)

able roof construction for timber frame housing that the roof structure should be sufficiently strong to withstand anticipated wind loads and to span between structural supports without noticeable deflection. Roof members should be adequately anchored to the exterior walls. Purlins must be securely fastened to the rafters or trussed rafters. This is especially important in tropical areas where typhoons and cyclones may occur.

In Ghana a common occurrence happens with the onset of the rainy season. Inadequately or inefficiently secured roof covers and often complete roof components are ripped off roof members or walls during rainstorms which are normally accompanied by winds reaching gale strength. Modern lightweight roof structures and coverings which are commonly used (corrugated iron, aluminium or asbestos cement roofing sheets on timber substructure) are especially susceptible to damage from suction caused by strong winds ("Monroe-effect", Ambrosius R. Flores: "Design methods for wind effects on buildings and structures", Philippine Architecture, Engineering and Construction Record, April, 1972).

Negative pressure is always on the windward edge of roof structures (Fig. 236) with an attempted upwards flexure of the overhanging surface. Long eaves projections which are a design feature for building in tropical countries are increasing the buffeting effect.

It is possible to take precautions against this in different ways as shown in Fig. 237 as an alternative to using framing anchors which may not always be readily available, especially in rural areas.

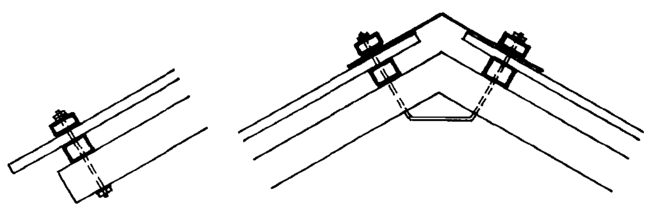
For timber frame construction two types of roof structures are recommended for the ordinary double pitched roof with gable or hipped ends:

- Rafters and purlins,
- Trussed rafters and purlins.

Trussed rafters have the advantage of not needing load bearing side and interior partition walls and can be prefabricated off-site. They result in a more rapid installation of roof and ceiling framing. Trussed rafters are normally spaced at 600 mm centres. Where trussed rafters are used gable ends are usually framed in a conventional manner using common rafters fixed to gable end studs.

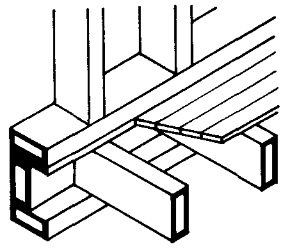
For nailed truss construction no special pneumatic or hydraulic equipment is needed during assembly. These trusses not only reduce timber requirements but also save construction time and site labour. Numbers of nails required and nailing arrangements are shown in Fig. 238 of a truss spanning up to 8.50 m.

Other details are shown on the following pages.



CORRUGATED SHEETING FIXING AT EAVES AND RIDGE WITH THE HELP OF BATTENS ON OUTSIDE OF ROOFING SHEETS THROUGH WHICH 8 mm DIAMETER BOLTS ARE FIXED (AT OVERLAPPING OF SHEETS) TO PURLIN AND RAFTER. AT RIDGE THE BOLT IS SHAPED IN ONE PIECE TO FIX BATTENS OVER RIDGE PIECE, SHEETING, RIDGE PURLIN AND RAFTER.

FIG.237: SECURING ROOFS FOR STRONG WINDS



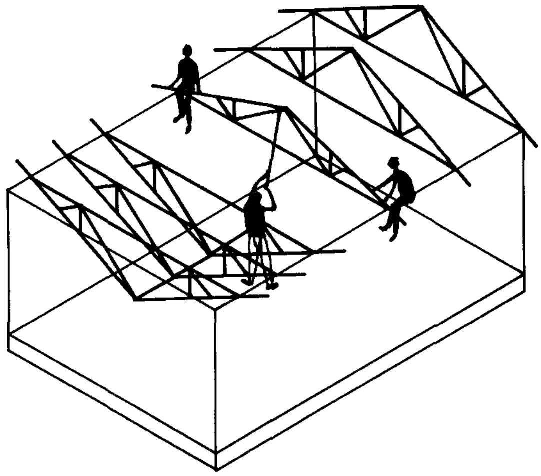
4.9.4 TRUSSED RAFTERS

NOTE:

THE CORNER ASSEMBLY, STUD ASSEMBLY AT JUNCTION OF INTERIOR PARTITION WITH EXTERNAL WALL (PAGE 151, FIG. 3, 4, 5 AND 6) AND DIMENSIONS OF NAILED "W" TRUSSES (PAGE 154) HAVE BEEN ADAPTED FROM "TIMBER FRAME CONSTRUCTION - A GUIDE TO PLATFORM FRAME" (COUNCIL OF FOREST INDUSTRIES OF BRITISH COLUMBIA). THE "ERECTION OF TRUSSES" HAS BEEN ADAPTED FROM "NOTES ON THE SCIENCE OF BUILDING LIGHT TIMBER TRUSSES" (COMMONWEALTH EXPERIMENTAL BUILDING STATION, DEPT. OF WORKS AND HOUSING, CHATSWOOD, N.S.W., AUSTRALIA).

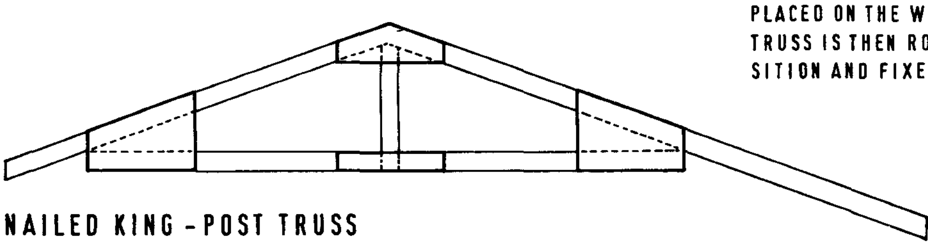
MAX.SPAN m	BOTTOM CHORD mm	TOP CHORD mm	WEB MEMBERS mm
4.90 m	75 x 40	75 x 40	75 x 25
6.75 m	75 x 45	100 x 45	75 x 25 & 75 x 40
8.50 m	100 x 45	100 x 45	100x25 & 100x45

TABLE 15: **EXAMPLE OF MEMBER SIZES OF SIMPLE NAILED TRUSSES**



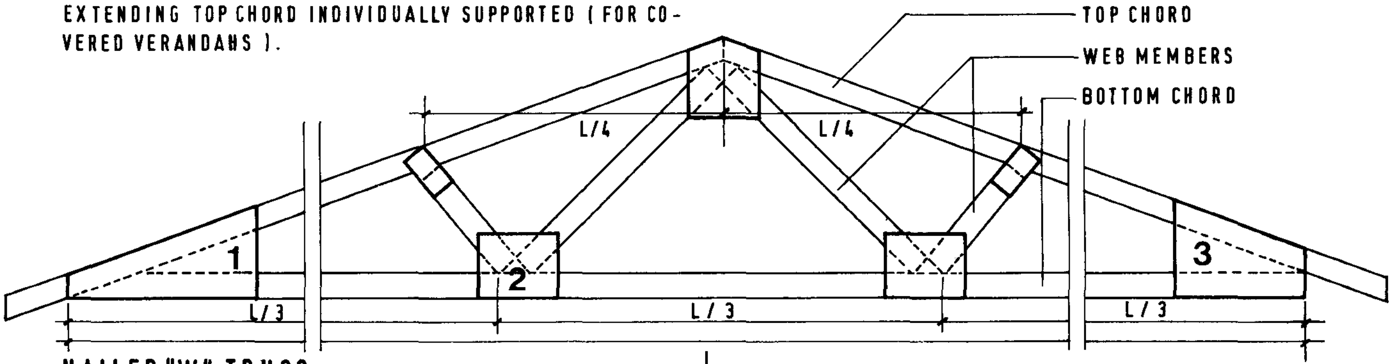
ERECTION OF TRUSSES

THREE WORKERS ARE NEEDED. THE TRUSSES ARE FIRST PLACED ON THE WALL PLATE HANGING UPSIDE DOWN. EACH TRUSS IS THEN ROTATED UPWARDS INTO THE CORRECT POSITION AND FIXED INTO PLACE.



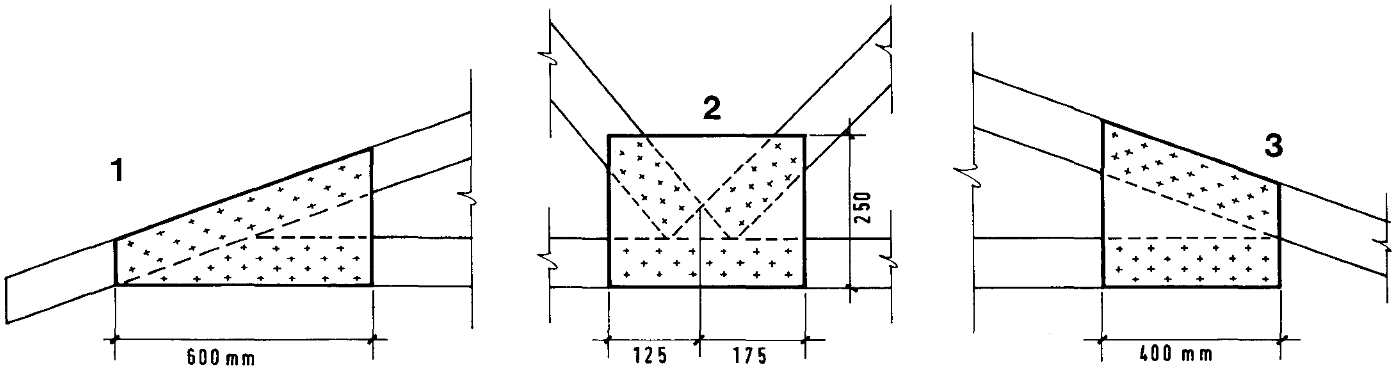
NAILED KING-POST TRUSS

WITH PLYWOOD GUSSETS, SUITABLE FOR SPANS UP TO 7.50 m. EXTENDING TOP CHORD INDIVIDUALLY SUPPORTED (FOR COVERED VERANDAHS).



NAILED "W" TRUSS

WITH PLYWOOD GUSSETS, USING UNCLINCHED 45 mm NAILS, SPACED AT EVERY 600 mm CENTRES. SUITABLE FOR SPANS UP TO 8.70 m.

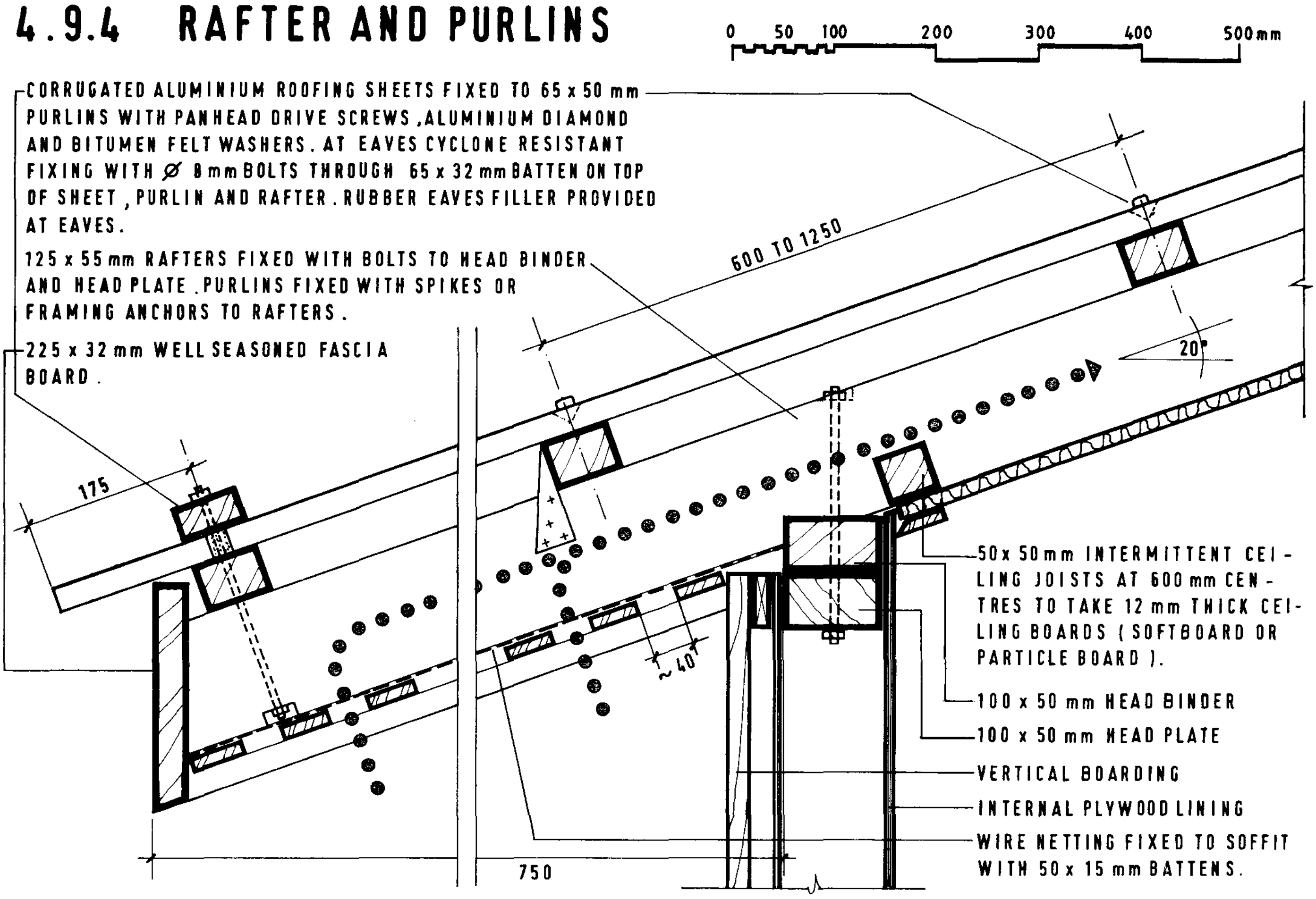


GUSSET PLATES AND SPACING OF NAILS

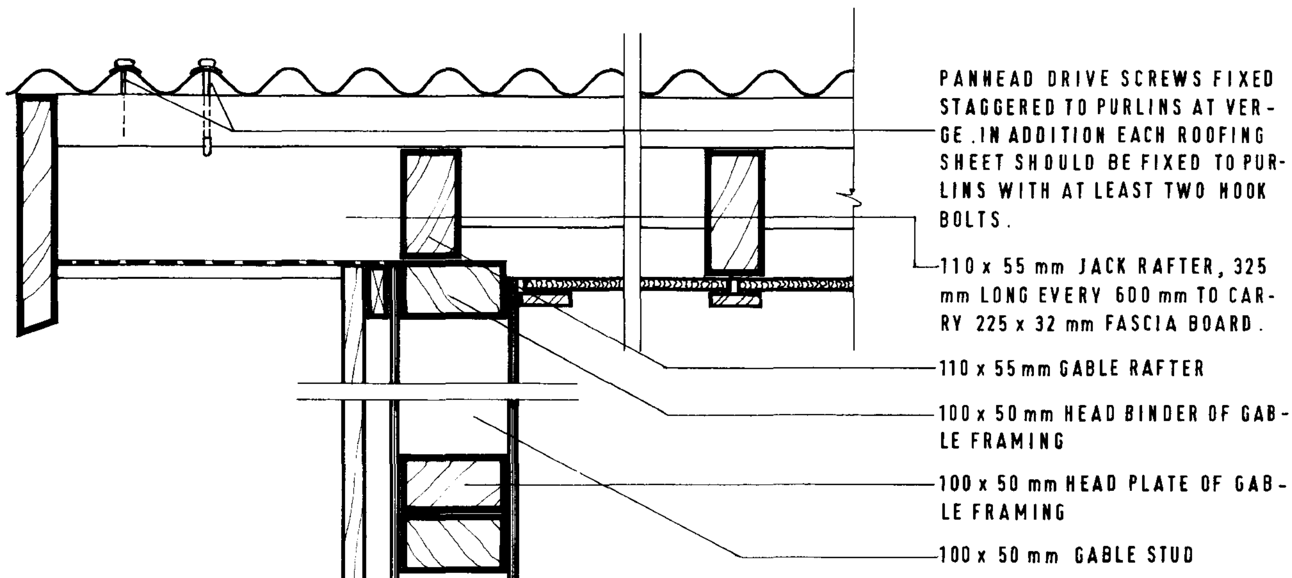
GUSSET PLATES ARE MADE FROM 9.5 mm THICK, GOOD EXTERIOR QUALITY PLYWOOD. NAILS ARE SPACED STAGGERED, 38 mm AND 17.5 mm APART.

FIG.238: **TRUSSED RAFTERS**

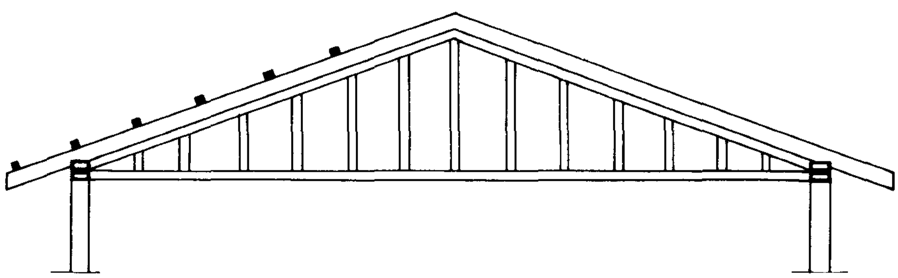
4.9.4 RAFTER AND PURLINS



RAFTER AND PURLIN ROOF - EAVES DETAIL

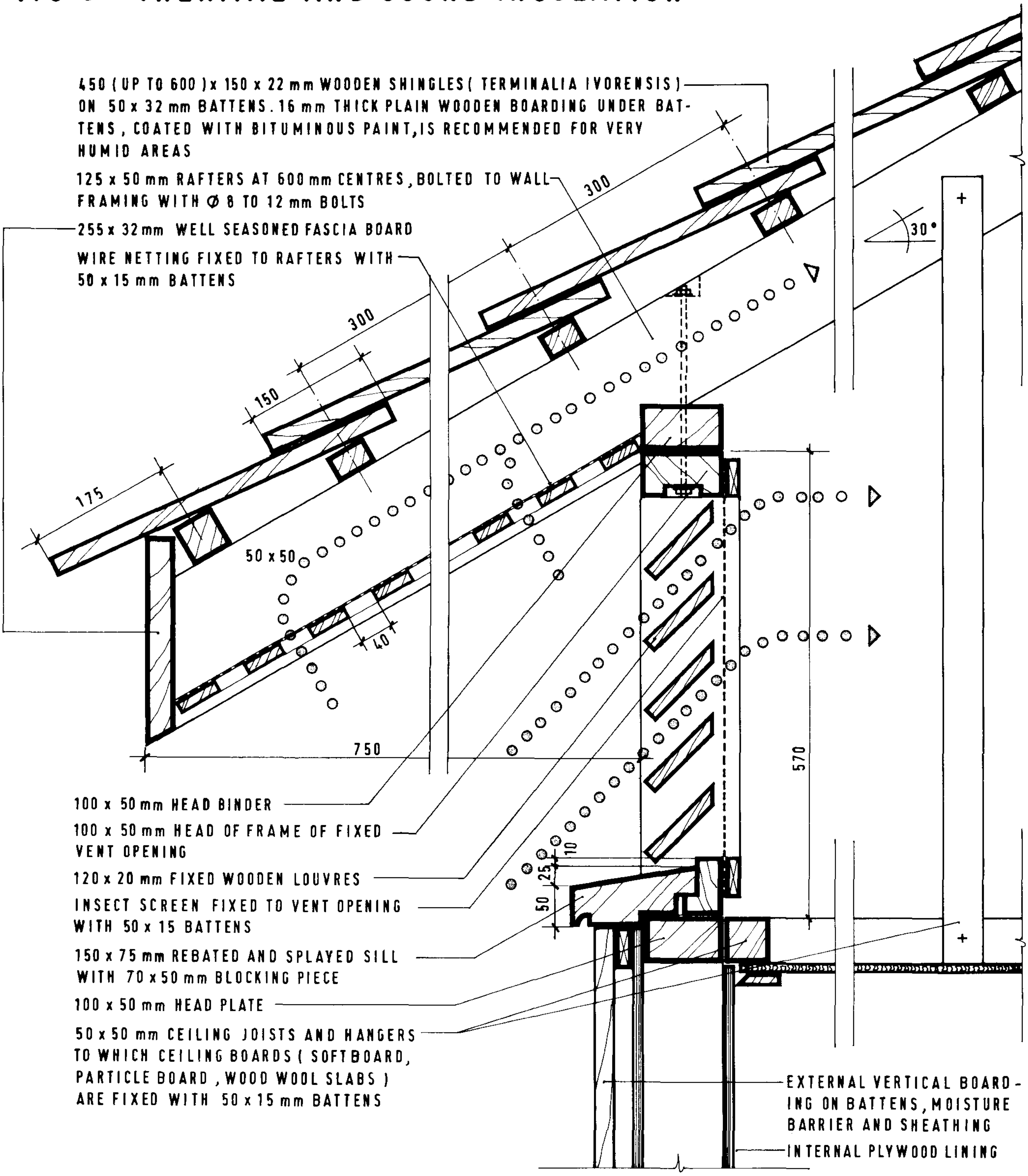


VERGE DETAIL



ARRANGEMENT OF GABLE FRAMING FOR RAFTER AND PURLIN ROOF WITH HEAD BINDER, HEAD PLATE AND GABLE STUDS

4.9.5 THERMAL AND SOUND INSULATION



SHINGLE ROOF WITH SUSPENDED CEILING

COMFORT INDOORS CAN BE ACHIEVED IN A TIMBER HOUSE WITH WOODEN SHINGLE ROOF BY REDUCING SOLAR HEAT TRANSMISSION THROUGH THE ROOF WITH A SUSPENDED CEILING AND PROTECTED VENT OPENINGS TO ALLOW FOR CROSS-VENTILATION UNDER THE ROOF. INSULATIVE CEILING MATERIAL WILL FURTHER IMPROVE THE INDOOR CONDITIONS. ROOFS WITH NO CEILINGS CREATE UNCOMFORTABLE MICRO-CLIMATIC CONDITIONS THROUGH THE HIGH DEGREE OF THERMAL TRANSMITTANCE IN TROPICAL AREAS. ANY OPTED SOLUTION SHOULD TAKE INTO ACCOUNT THE COST OF THE ROOF COMPARED TO OTHER ELEMENTS OF THE HOUSE.

On some sites, insulation from outside sources of noise (traffic, aircraft) may be an important functional consideration, as well as excessive noise transmission within a dwelling.

In timber frame construction it is often sufficient to use the "air cushion" between the two leaves of the framing elements as cavity which must not contain any rigid bridges, on the condition that the containing surfaces are rigid and of sufficient thickness (minimum 20 mm). This air cushion can be supplemented with glass fibre or mineral wool quilts in or to one side of the cavity (as shown on sheet **4.9.3 Flooring**).

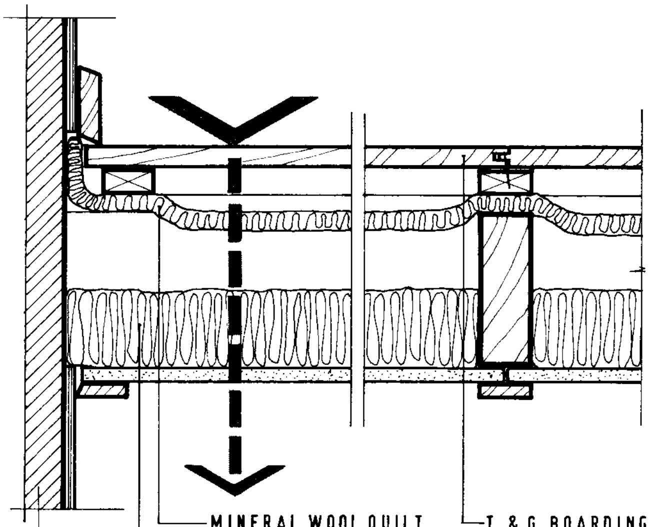


FIG. 239 : SOUND INSULATION OF A TIMBER FLOOR
(FROM "TIMBER FRAME HOUSING - DESIGN GUIDE" (TRADA, HIGH WYCOMBE, ENGLAND).

In timber floors sound insulation is achieved through constructional separation of the upper and lower surfaces of the floor element. This will considerably reduce impact sound from walking and transmission of other sound (Fig. 239)

4.10 SUMMARY

There are many approaches to design and construction of wooden houses:

- Use of timber for all structural, non-structural and finishing parts from foundation to roof construction;
- Use of pre-cut and prefabricated timber components and panel systems;
- Use of timber parts, light framework or stressed-skin panel systems above solid foundation and suspended floors or solid floors (depending on the prevailing site conditions) for walls;
- Use of timber posts or light framework in conjunction with other materials (e.g. brick cladding, metal cladding, asbestos-cement cladding, bamboo mat walling etc.).

There is no doubt that with good designs and appropriate construction details wooden houses can be constructed at reasonable costs. They can moreover compete with any houses which are constructed with conventional materials in thermal properties, durability in tropical conditions, in comfort and good family living provided for its occupants and in their aesthetic appearance.

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17. UNESCO Regional Office for Education in Asia (Bangkok, Thailand) – Cyclone – Resistant Rural Primary School Construction – a Design Guide (Educational Building Report, No. 7, 1972).
18. A. K. VORHAUER – Protection of Structure for Low-cost/self help Housing (German Appropriate Technology Exchange, No. 1/79).
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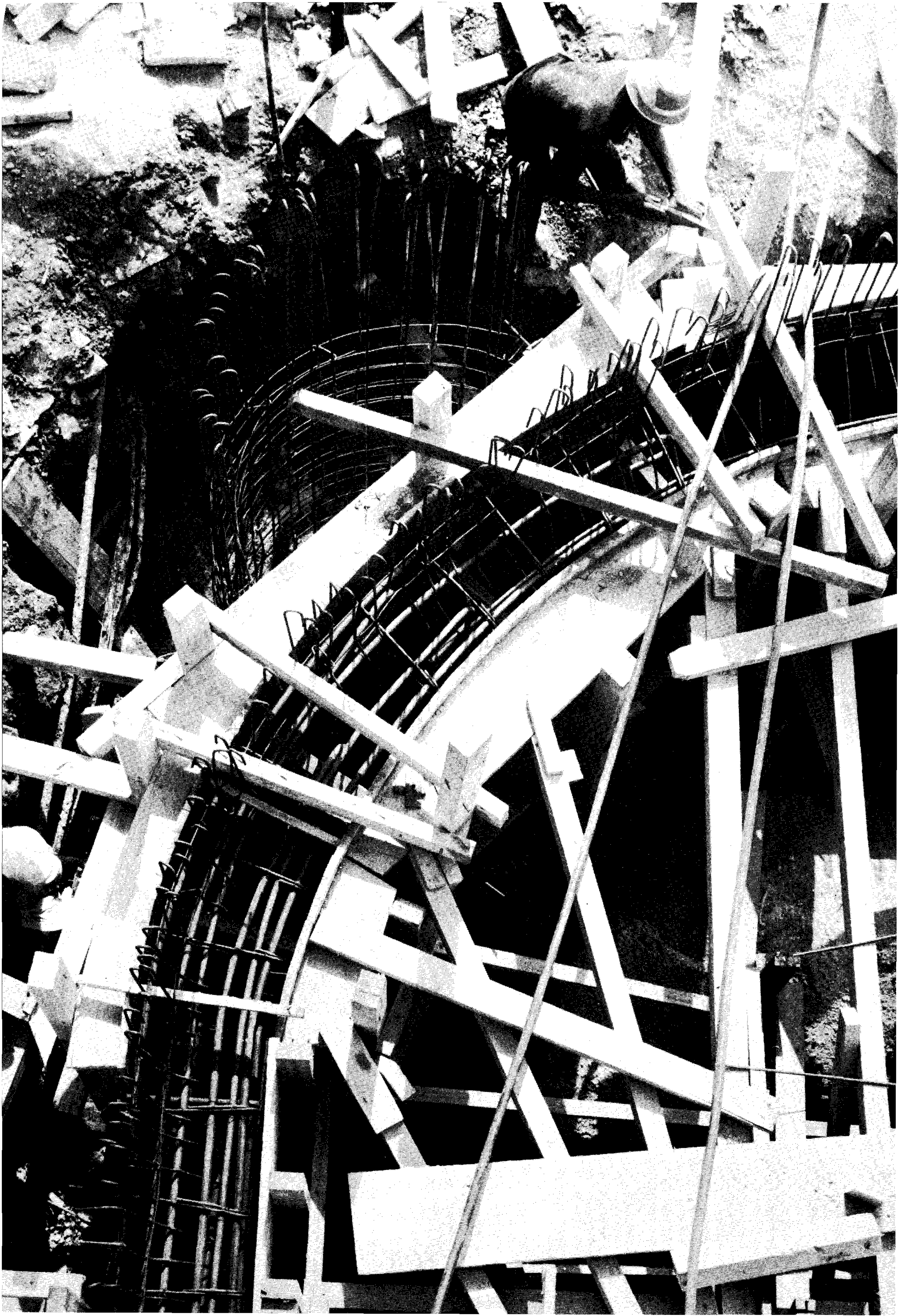


5 CONSTRUCTION

5.1 INTRODUCTION

In order to understand what is involved when talking about **Construction,** it is necessary to explain some other definitions in the same context:

- **Building**: This could be described as our "built" environment with its own function and form of appearance. A building may be simultaneously regarded as an enclosure of spaces for specific uses and as a system to distribute services and to discharge wastes.
- **Structure**: This is the skeleton, or better, the "bones and tendons", of a building; it could be described as that part of a buildung which makes it stand up. Understanding of structural behaviour (which is our appreciation of the laws of nature) serves two aspects in architecture:

  (I) It should be the starting point in the design process and at the same time an inspiration to form;
  (II) It should lead to economical solutions of building problems.

  Not always do these two aspects coincide. Sometimes they diverge. The larger the span of a building, the more its shape and appearance is dictated by structural considerations (Fig. 240). It is necessary that the architect is fully aware of all structural problems, especially in areas where earthquakes, hurricanes, typhoons etc., are likely to occur. But with new materials, more efficient use of traditional materials and the knowledge of their behavior, the modern architect has also a much larger freedom of design compared to the traditional builder. This freedom of design, based on knowledge and appreciation of materials and structural behaviour, has resulted in many new forms undreamed of in the past. Our understanding of the laws of nature which govern structural behaviour have enabled us to use our resources with greater economy and a minimum of waste.
- **Structural System**: This could be described as the fundamental principle by which the "standing-up" of a building is achieved. The function of the structural system is to absorb the various forces to which a building is exposed and to direct them in such a way

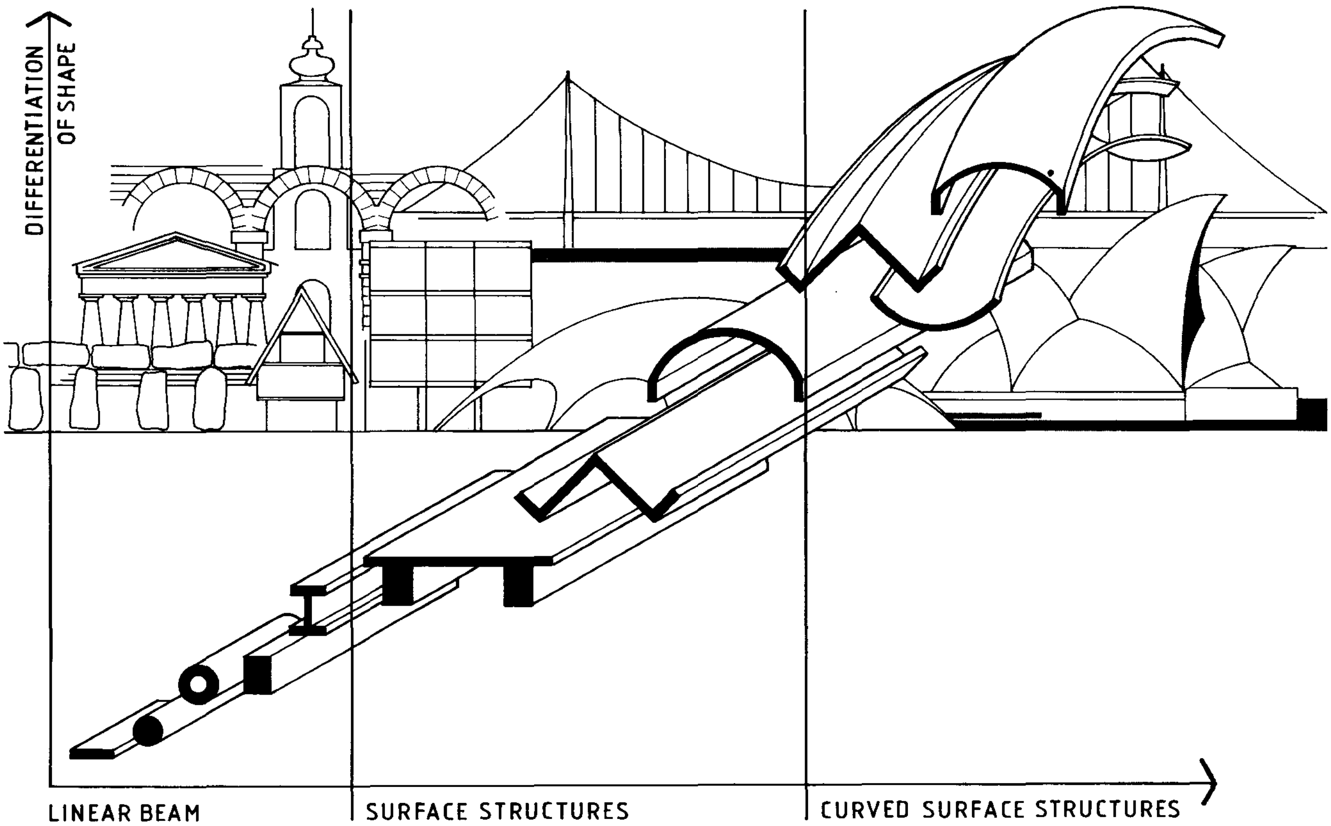


FIG.240 : STRUCTURAL SYSTEMS AND SPAN
ADAPTED FROM "BAUWERK, TRAGWERK, TRAGSTRUKTUR" BY BÜTTNER AND HAMPE, VEB - VERLAG FÜR BAUWESEN BERLIN, 1976.

that ideally the state of equilibrium is achieved, which is the most important requirement for the stability of a building. A structural system must be able to carry its own weight and applied loads and direct them into the ground. To be built, a building must, however, be conceived as a constructional system.

- **Construction:** This could be described as the art of putting the elements together which, in addition to making the building "stand up", makes it fulfil all the other functions of a building, such as keeping the weather out, admitting or excluding light, providing ventilation and generally providing shelter and space for the many different activities for which it has initially been designed and, last but not least, providing comfort for its occupants.
- **Forces and the State of Equilibrium:** A building and its components are subject to different forces which tend to disrupt the state of equilibrium. The structure of a building must therefore be designed in such a way that the building is able to withstand these forces.

Forces can be perceived by the movements they cause. The downward movement of gravity is perceived as weight. Gravity is one of the most important forces. In a state of equilibrium an object remains static, that is, the movement which gravity attempts to create is arrested. It is the action of a force in one direction which is equilibriated by an equal and opposite force on the same line of action (Fig. 241). A static equilibrium in a structure or in the elements of which it is composed is achieved, if the forces can be arranged to be equal and opposite so that they cancel each other out. The more directly this can be achieved the more economical and simpler the structure will be.

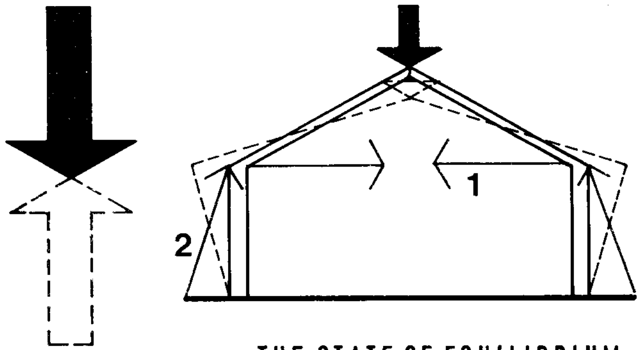


FIG. 241: THE STATE OF EQUILIBRIUM
THE ACTION OF A FORCE IN ONE DIRECTION IS EQUILIBRATED BY AN EQUAL AND OPPOSITE FORCE ON THE SAME LINE OF ACTION. THE OUTWARD THRUST OF A PAIR OF RAFTERS IS EQUILIBRATED BY A TIE (1) OR A PAIR OF BUTTRESSES (2) TO RESIST THE TURNING EFFECT.
FROM: "STRUCTURES" BY H.W. ROSENTHAL, ESSENCE BOOKS ON BUILDING, THE MACMILLAN PRESS LTD. LONDON.

The early history of building shows that man has utilized the materials available to him, stones, soil, sand, plants and wood, in structures in direct compression (Egypt, Assur, Babylon, Greece, Rome, Gothic, Renaissance), limiting the span. With the development of tools and better knowledge and processing of materials (wrought iron, steel) a reduction of the mass of the building and an increase of span was achieved which resulted in new technologies and structural elements in direct tension (Fig. 242).

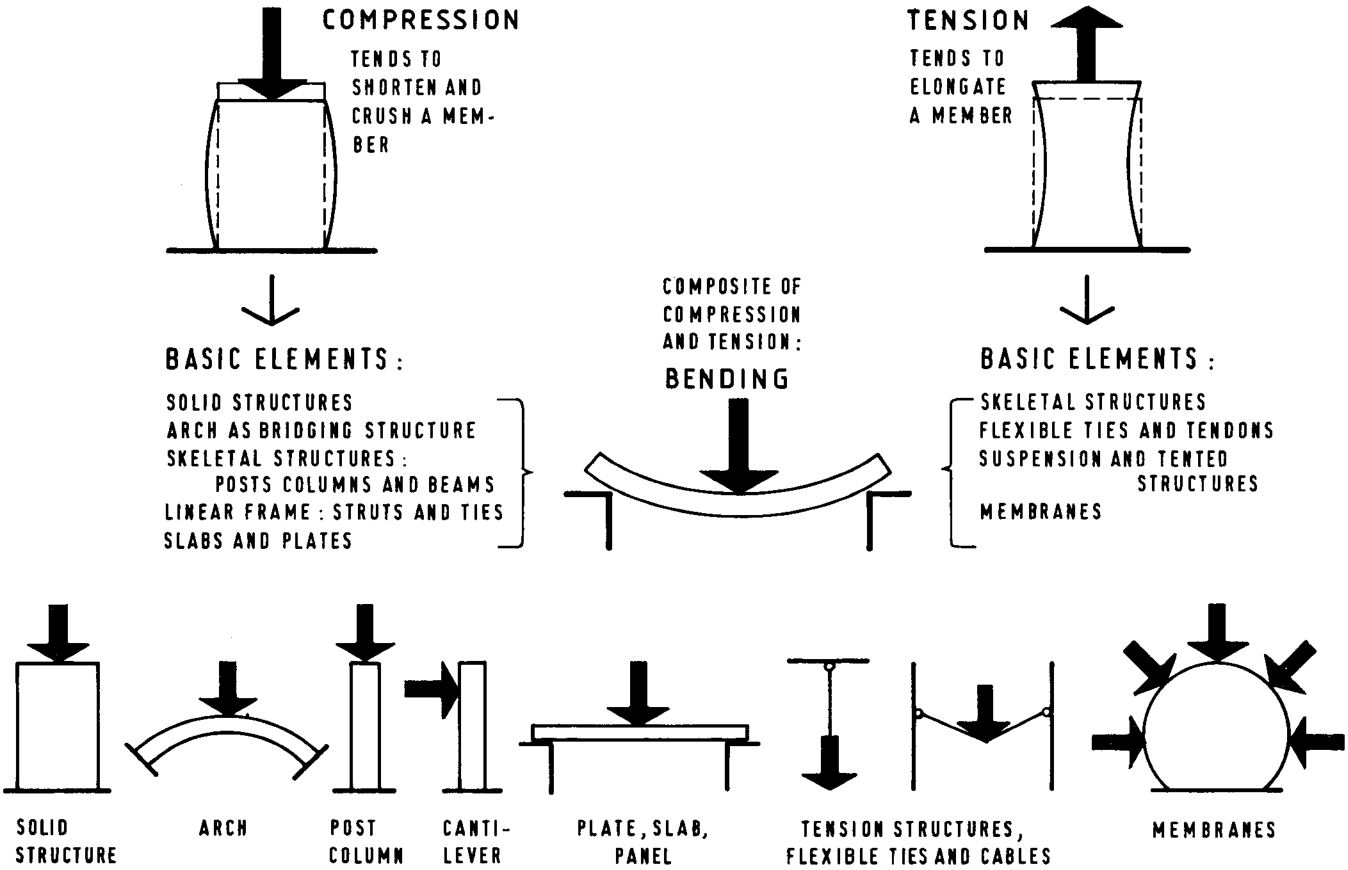
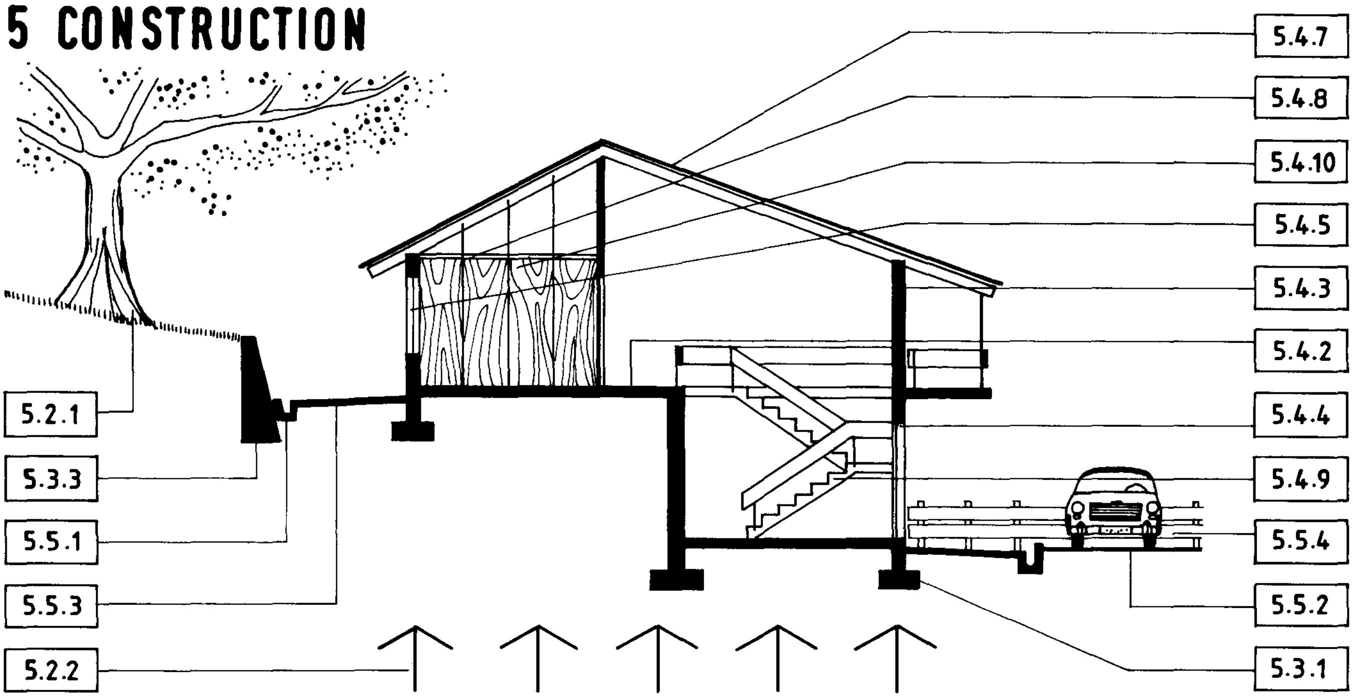


FIG. 242: COMPRESSION AND TENSION STRUCTURES
FROM: "BAUWERK, TRAGWERK, TRAGSTRUKTUR", BAND 1, BY O. BÜTTNER AND E. HAMPE, VEB-VERLAG FÜR BAUWESEN, BERLIN.

5 CONSTRUCTION



5.2 GROUND INVESTIGATIONS

The massive structures of the past rested on rock as foundation. Up to the Middle Ages foundation design was inspired guesswork on a background of past experience resulting in rather crude methods. Winchester Cathedral has survived for 750 years on foundations of short oak piles and bundles of wattles in a thick bed of peat, no doubt due to the preservative character of peat. The Tower of Pisa (Campanile at Pisa, 12th to 14th century) however, began to lean over as soon as it was completed and is out of plumb today by 4.30 m at the top. The top storeys had originally been reinforced on the north side to counteract the "leaning". At the moment it seems to be a question of leaving it the way it is as one of Italy's most famous tourist attractions or giving in to the frustrated engineers who, with present day knowledge and technologies, no doubt could arrest the continuing movement of the building and make it completely safe.
(V. C. Launders in "Foundations")

Not until the late 19th century did the scientific study of foundations really begin. It was necessitated by problems which arose from the construction of large commercial buildings on difficult sites in Chicago, where the Borden Block (1880) became the first building in the world with independent footings taken through a considerable layer of clay down to load-bearing soil.

Scientific principles and methods for the analysis and testing of soils to establish their load bearing capacity, possible settlement and probable failures of a structure became known only from the publication of "Erdbaumechanik" by Terzaghi (described by V. C. Launder as "father of soil mechanics" in "Foundations", Essence Books on Building) in 1925.

Good foundation design must ensure that structural loads (including the weight of the foundations) are transferred to the ground:

- **Economically:** This will require the choice of the most suitable foundations;
- **With due safety**: This will require an adequate safety design factor providing against failure of the foundations and the ground below;
- **Without any unacceptable movement** either during or after construction: This refers to estimated settlements or movements associated with particular ground conditions (including earthquake-prone zones) and a comparison with those settlements and movements which are considered as acceptable in the circumstances, including possible movement in the superstructure.

5.2.1 SITE SURVEY

A thorough site survey is a prerogative to good foundation design. It should be the basis for the decision:

- Wheter the site is suitable to build on;
- Where the best practical place to built the foundation is to be;
- What the load-bearing capacity of the soil is likely to be.

A site survey involves a thorough analysis of the site to find out:

- Levels and contours;
- Surface characteristics, e.g. rock outcrops, hollows, filled-in ground;
- Location and species of existing trees;
- Surface water flow on or around the site and water table;
- Existing underground services (water supply and drainage pipes, electrical and telephone cables);
- Subsoil characteristics (can it be used for construction, backfill, base course etc.);
- Existing structures adjacent to site and closeness of their foundations to boundary line;
- Geological formations underlying the site, e.g. soil faults due to earthquakes, change of strata etc.

5.2.2 SOIL INVESTIGATIONS

These are normally undertaken by properly equipped laboratories. Their purpose is:

- To estimate the load bearing capacity of the soil at various depths;
- To estimate the order of settlement which is likely to occur with the established safe bearing pressure on the soil at various depths or with the applied pressure where this is lower;
- To decide on suitable construction methods;
- To determine the level of groundwater in permeable soils;
- To check on any harmful chemicals present in the soil or in the groundwater.

5.2.3 METHODS OF INVESTIGATIONS

I. BY TRIAL PITS:

For a simple two-storey structure this is the quickest method of investigations. Normally holes of 1.0m × 1.0m are hand-excavated to a depth of about 2.50m. Quite accurate information regarding soil conditions can be collected in this way, but it will become an expensive undertaking if investigations are to be carried out very deep or below the water table. Trial pits are usually dug at the corner locations of the proposed building.

II. BY BORING:

Soil investigations by boring are done with hand-auger boring equipment of boring rigs with casings which can bore up to 250mm in diameter (Fig. 243 *and* 244). Boring is generally the best and most economic method of determining soil conditions on sites for larger structures higher than 2-storeys. With boring, depths of 30 to 50m can be reached. Soil taken out is tested either in disturbed or undisturbed condition. Undisturbed samples are taken in special samplers as the holes are bored. Table 16 shows a typical borehole record from the sub-soil investigations on the site for the extensions to the Faculty of Pharmacy Building at U.S.T., Kumasi (B.R.R.I., No. SM/Consult/17, August, 1969).

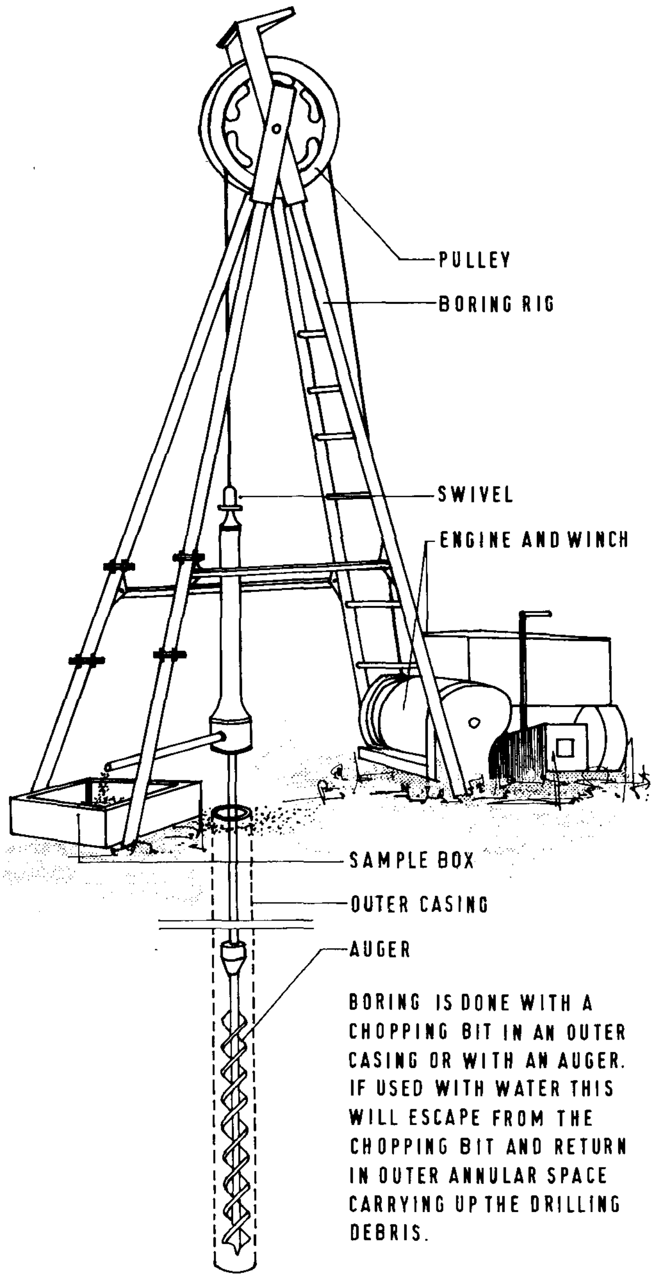
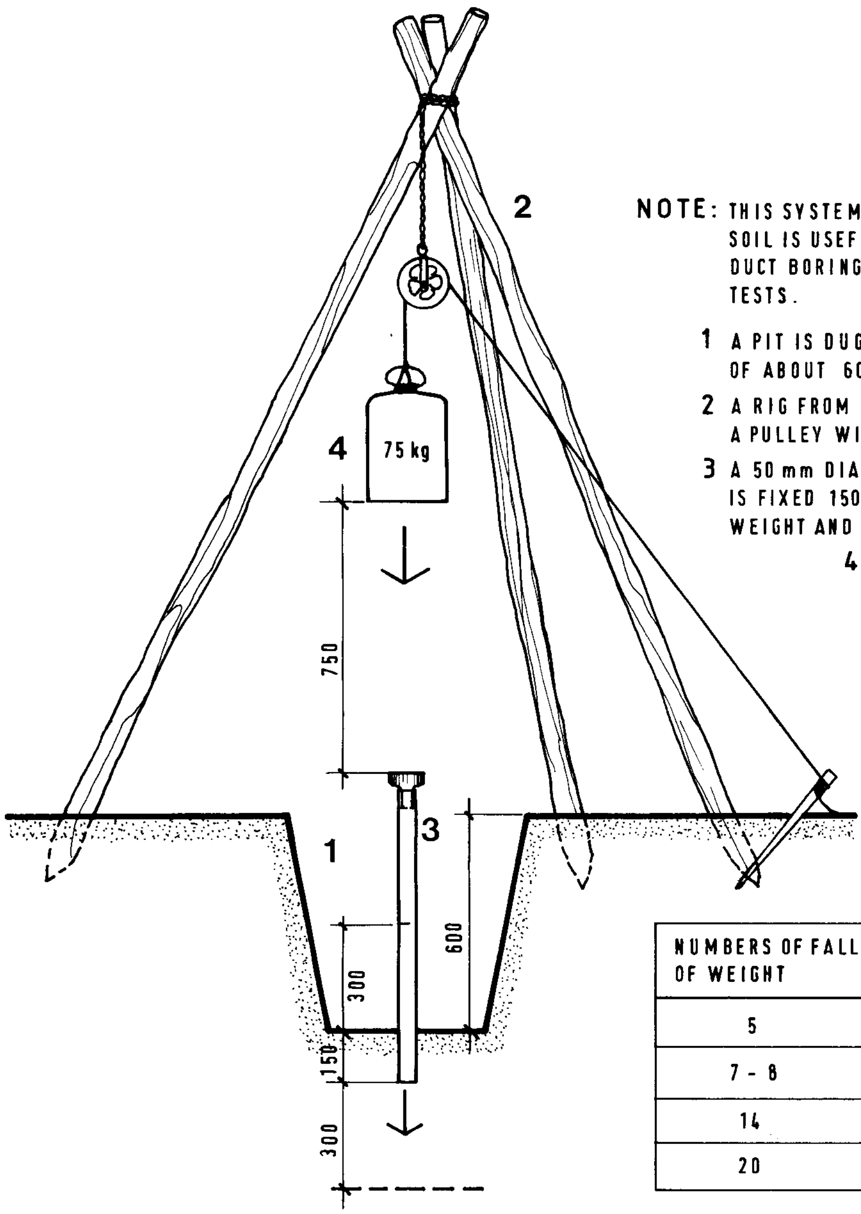


FIG. 243: A DRILLING RIG

Fig. 244: Soil tests with the B.R.R.I. drilling rig at the Faculty of Engineering, School of Mining Engineering site, U.S.T., 1982.

The laboratory tests which are conducted with the soil examples taken out of various depths include the following:

- Identification and description;
- Shear and compression tests;
- Determination of moisture content, density, etc.;
- Particle size analysis;
- Consolidation tests.



NOTE: THIS SYSTEM OF ESTABLISHING THE BEARING CAPACITY OF SOIL IS USEFUL IN AREAS WHERE IT IS DIFFICULT TO CONDUCT BORING INVESTIGATIONS AND PROPER LABORATORY TESTS.

1 A PIT IS DUG THROUGH TOP SOIL AND SUB SOIL TO A DEPTH OF ABOUT 600 mm.

2 A RIG FROM BUSH POLES IS HOISTED OVER THE PIT HOLDING A PULLEY WITH A 75 kg WEIGHT.

3 A 50 mm DIAMETER STEEL TUBE (INNER DIAMETER 35 mm) IS FIXED 150 mm DEEP IN THE PIT DEAD CENTRE UNDER THE WEIGHT AND CLOSED ON THE TOP WITH A WOODEN PLUG.

4 THE WEIGHT WHICH IS HELD EXACTLY 750 mm ABOVE THE TOP OF THE TUBE IS REPEATEDLY RELEASED TO FALL DOWN ON TO THE TOP OF THE PLUG UNTIL THE TUBE IS PUSHED 300 mm DEEP INTO THE SOIL. THE NUMBER OF FALLS COUNTED ARE ANALYSED BELOW:

NUMBERS OF FALLS OF WEIGHT	BEARING CAPACITY OF SOIL IN kg / cm²	CLASSIFICATION
5	0.5	POOR
7 - 8	1.0	MODERATE
14	2.0	GOOD
20	3.0	VERY GOOD

FIG. 245 : **SIMPLE SOIL TEST** (FROM AMERICAN SOCIETY OF TESTING AND MATERIALS, ASTM - D/1586, 1967)

From these an estimate can normally by produced of the safe bearing capacity of the soil and possible settlement under load. The American Society of Testing and Materials uses a very simple test to establish safe bearing pressure of soils under load, which is shown in Fig. 245.

5.2.4 SOIL TYPES, THEIR STRUCTURE AND STRENGTH

- **Rocks:** These are normally excellent founding materials with high load bearing capacities and negligible settlement under load.
  Igneous Rock: Basalts and granites; have 2 to 3 times the safe bearing capacity of hard sedimentary rocks and 25 to 50 times that of clays and sands.
  Metamorphic Rock: Gneisses, slates and schists; have good bearing capacity.
  Sedimentary Rock: Solid stratified and consolidated deposits, usually of weathered material from other rocks, shales, mudstones, ironstones, coal, chalk, limestones and sandstones. When massively bedded these rocks have high bearing capacity. Care must be taken over limestone deposits, where so-called "swallow holes" might occur (Fig. 246). Caves and deep fissures are also found in sedimentary rock.
- **Gravels** (non-cohesive): These are deposited loosely and can easily be removed by shovel; 50 mm diameter stakes can be driven in without trouble.
- **Laterite** (non-cohesive): Good bearing capacity.

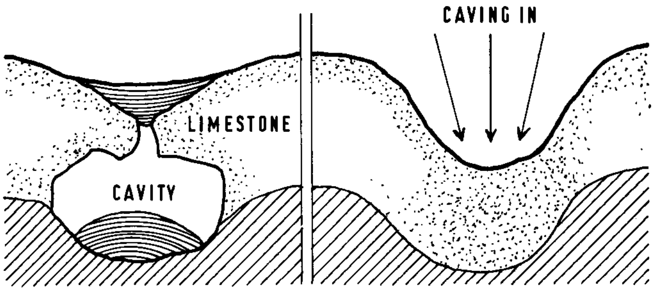
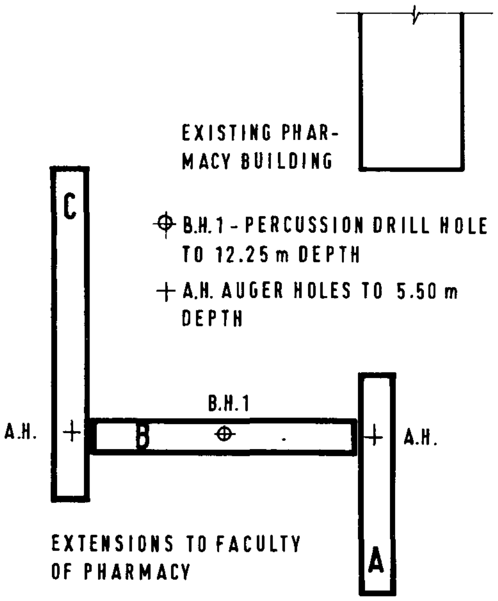


FIG. 246 : **SWALLOW HOLE IN LIMESTONE**



DESCRIPTION OF STRATA	LEGEND	DEPTH
DARK BROWN PEBBLY LATERITIC RESIDIUM		G.L. 1.25m THICK 1.25m
SLIGHTLY PLASTIC, FERRUGINOUS LATERITIC RESIDIUM		2.50m THICK 3.75m
PLASTIC TO SILTY LATERITIC RESIDIUM		2.95m THICK 6.70m
SILTY, HIGHLY MICACEOUS VARIEGATED LATERITIC RESIDIUM		1.55m THICK 8.25m
HIGHLY WEATHERED GRANITE WITH THE GRANITE STRUCTURE STILL VISIBLE		PENETRATED TO 12.25m END OF BOREHOLE 1

TABLE 16: **BOREHOLE RECORD**

BOREHOLE RECORD OF B.H.1 FROM THE REPORT ON THE SUBSOIL INVESTIGATIONS ON THE SITE OF THE EXTENSIONS TO THE FAULTY OF PHARMACY, U.S.T., KUMASI. THE ALLOWABLE BEARING CAPACITY OF THE SOIL AT A DEPTH OF 1.50m USING LOWER SHEAR PARAMETERS WAS 4.806 kg/cm^2. WIDTH OF STRIP FOOTING 1.20 m.

- **Sands** (non-cohesive): These are compact and require a pick for excavation. There are silty, micaceous, lateritic and clayey sands.

  Gravel, laterites and sands are the principal non-cohesive soils. Their shear strength is frictional and their structural properties depend on their density (closeness of packing). The allowable safe bearing pressure is governed by considerations of possible settlement under load rather than by strength. These non-cohesive soils are very permeable and subject to seepage. When sand is wet (seasand along the beach on the fringes of the water) it is tightly packed and has a very high load bearing capacity. This was used on one occasion in Ghana, when a heavy crane which was used for moving heavy rocks into position during the construction of the harbour breakwater at the Sekondi-Takoradi naval base, could not be returned to Takoradi by road because a bridge was declared unsafe for crossing along the road. The engineers in charge of the harbour construction investigated the possibility of driving the crane over the beach at low tide. This was done along a stretch where the sand was still wet and very tightly packed. The heavy crane moved without mishap along the beach and onto the road behind the bridge making hardly any impression in the wet sand.

- **Silt** (fine-grained, cohesive): These are soft soils, easily moulded with fingers, or firm. There are clayey silts, organic silts, micaceous silts. They have low shear strength.

- **Clays**: These can be soft to stiff, hard, brittle and cohesive. Normally they are relatively unpermeable and settle slowly under load. They are liable to shrinkage and swelling and have low shear strength. Clays frequently contain sulphates which attack concrete (made with Portland cement) and aggravate corrosion of ferrous metals.

- **Fill**: This can be composed of miscellaneous materials, e.g. mineral waste, rubble, organic waste, ect. It is necessary to pass through any fill with piles to reach firm strata or use raft foundations for lighter structures.

5.3. FOUNDATIONS AND RETAINING STRUCTURES

Foundations must be designed in such a way that they meet the following requirements:

- They must intercept loads and forces to which they are exposed from the building structure (walls, columns, slabs, etc.) and divert and spread them over an area large enough to utilize the maximum allowable bearing pressure of the soil. The forces mentioned here are compressional, tensional and horizontal forces involving friction and adhesion. Any load should be placed on the foundation in a balanced way, that is, concentrically to avoid bending moments induced by eccentric load (Fig. 247).

- They must be strong enough to prevent downward vertical loads shearing through the foundation (Fig. 248.

- They must withstand the tensional and shearing forces which are generated by the tendency of the foundation to bend upwards when exposed to a concentrated load from the structure above and the opposing resistance and pressure from the soil under (Fig. 249).

- They must accommodate movements of the ground due to shrinking or swelling characteristics of the soil or due to horizontal movements caused by earthtremors or earthquakes, or due to soil faults, unstable ground in areas with mining activities etc. All these movements can change the stresses within the foundation (Fig. 250).

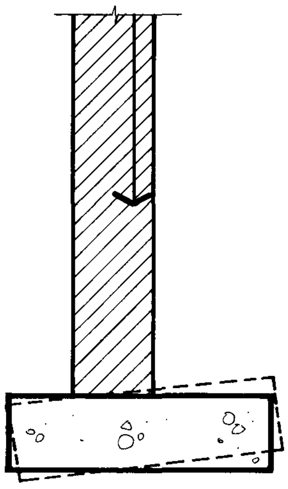


FIG. 247: **FAILURE DUE TO UNEVEN LOADING**

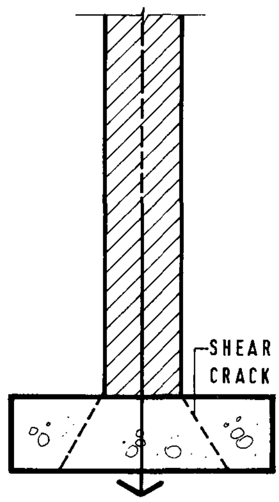


FIG. 248: **SHEAR FAILURE OF FOUNDATION**

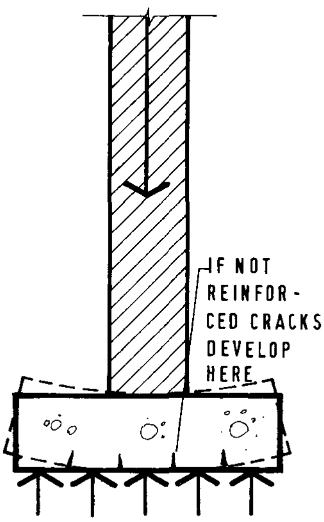


FIG. 249: **BENDING FAILURE**

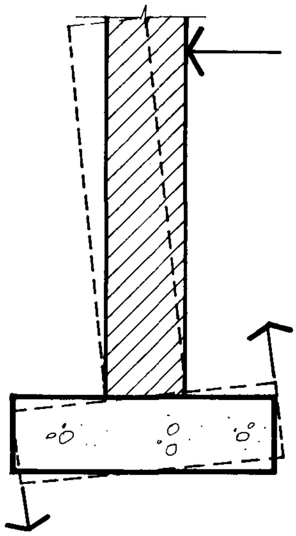


FIG. 250: **OVERTURNING DUE TO LATERAL FORCES**

(ADAPTED FROM "FOUNDATIONS" BY V.C. LAUNDER, MACMILLAN, LONDON)

As a general rule foundations should rather be laid deeper than lower, in order to reach good load-bearing soil. Under no circumstances should foundations be laid in soil containing humus or any other organic matter like roots etc. This layer may be much deeper than the normally accepted thickness of the immediate top soil (150mm). Even for low-cost houses built with mud walls it is advisable to build foundations below 400 to 450mm.

5.3.1 FOUNDATION TYPES

There are four main foundation types:

I. Strip foundations;
II. Pad foundations;
III. Raft foundations;
IV. Piled foundations.

A fifth type can be used in locations where the bearing capacity of the soil is low and the load of the building structure so great that a raft foundation would have been chosen but for the fact that the site is not large enough for the required size of raft to spread the load. In this case a so-called **"Buoyancy"** foundation can be used, which is a basement used like a huge tank on which the building "floats" (also described as tanked basement, Fig. 251). In the London clay tanked basements to a depth of 24m have been used in many buildings (e.g. London Hilton) containing several floors of underground car parks, service installations etc. In many West German towns underground parking in tanked basements is common in areas with clayey soils.

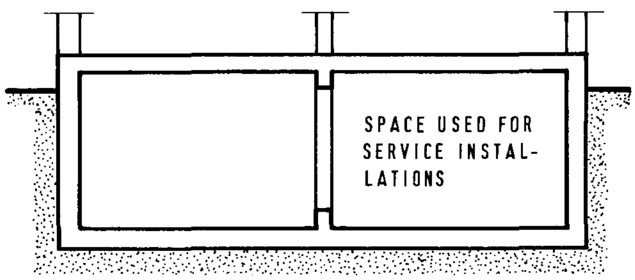


FIG. 251: **TANKED BASEMENT OR BUOYANCY FOUNDATION**

I. STRIP FOUNDATIONS (Fig. 252)

These consist of a continuous strip of mass concrete or reinforced concrete or other material like stones or bricks which rests on the soil at a depth and width depending on the bearing capacity and type of soil. This is the common foundation used for loadbearing wall structures on good and average bearing soils. Strips may also be designed to span or cantilever over "soft spots" in the ground.

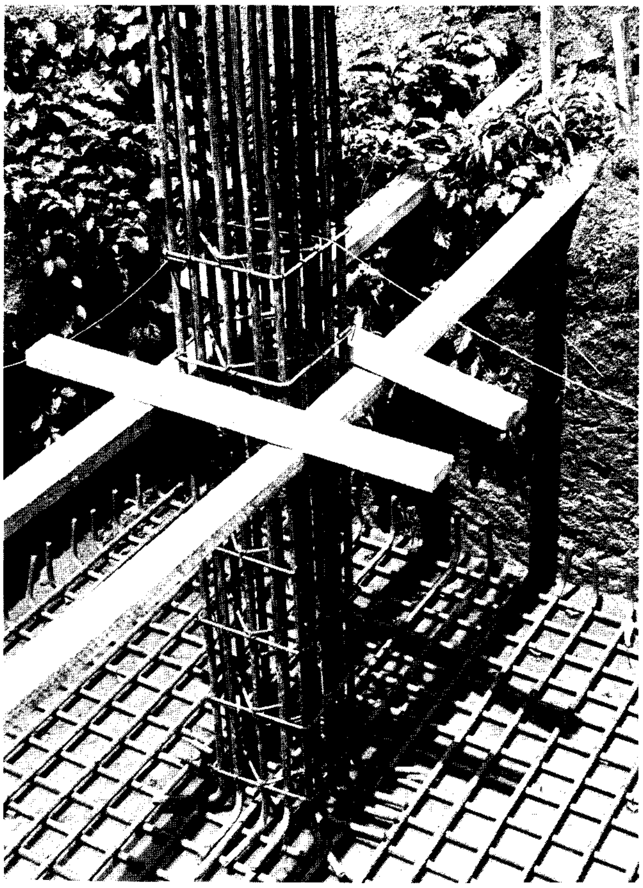
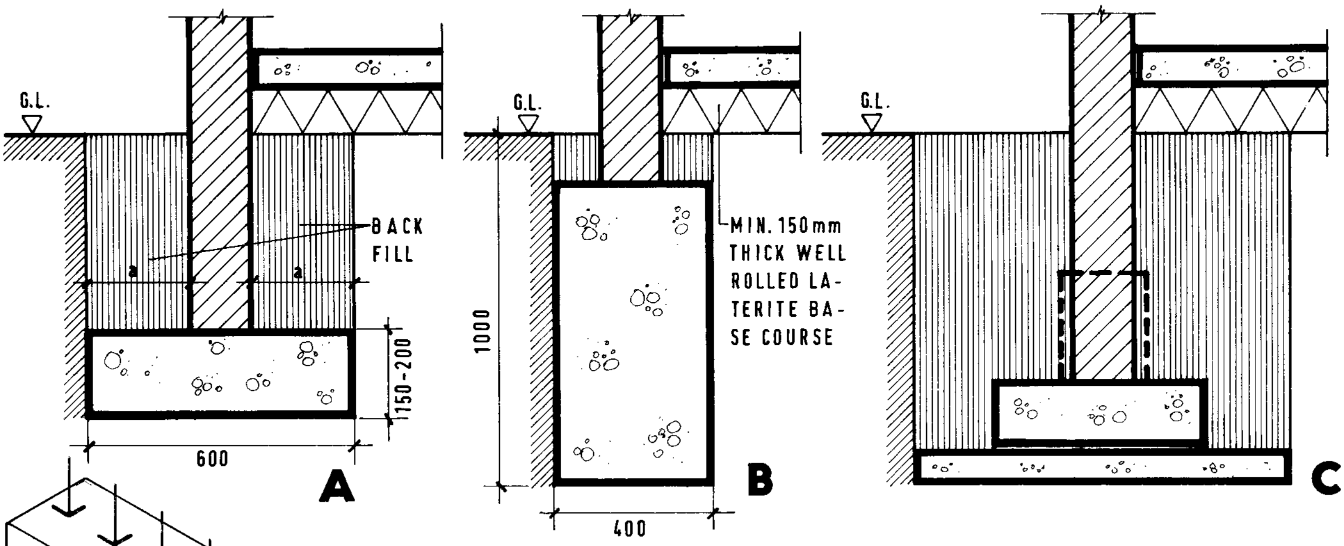
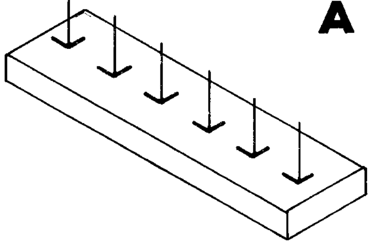


Fig. 254: Reinforcement in place showing starter bars of a pad foundation at the U.S.T. Library extension site, 1982. Architects: ARCHITECTURAL DESIGN PARTNERSHIP, Accra.

5.3.1 FOUNDATION TYPES





A LIGHTLY-LOADED SHALLOW STRIP FOUNDATION EXCAVATED BY HAND, NECESSITATING A FAIRLY WIDE TRENCH, ESPECIALLY IN LOOSE SOILS. DEPTH OF STRIP SHOULD BE MINIMUM 150 mm, BUT NOT LESS THAN a.

B LIGHTLY-LOADED DEEP AND NARROW STRIP FOUNDATION IN HARD OR STIFF CLAY, MECHANICALLY EXCAVATED. DEPTH OF STRIP ACCORDING TO SIDE FRICTION AND END BEARING.

C STRIP FOUNDATION WITH ADDITIONAL 75mm THICK BLINDING CONCRETE UNDER IN LOOSE SOIL. REINFORCED CONCRETE STRIP SHUTTERED. FOR LONGITUDINAL STRENGTH A CONCRETE T-BEAM IS SUGGESTED.

FIG. 252 : **STRIP FOUNDATIONS**

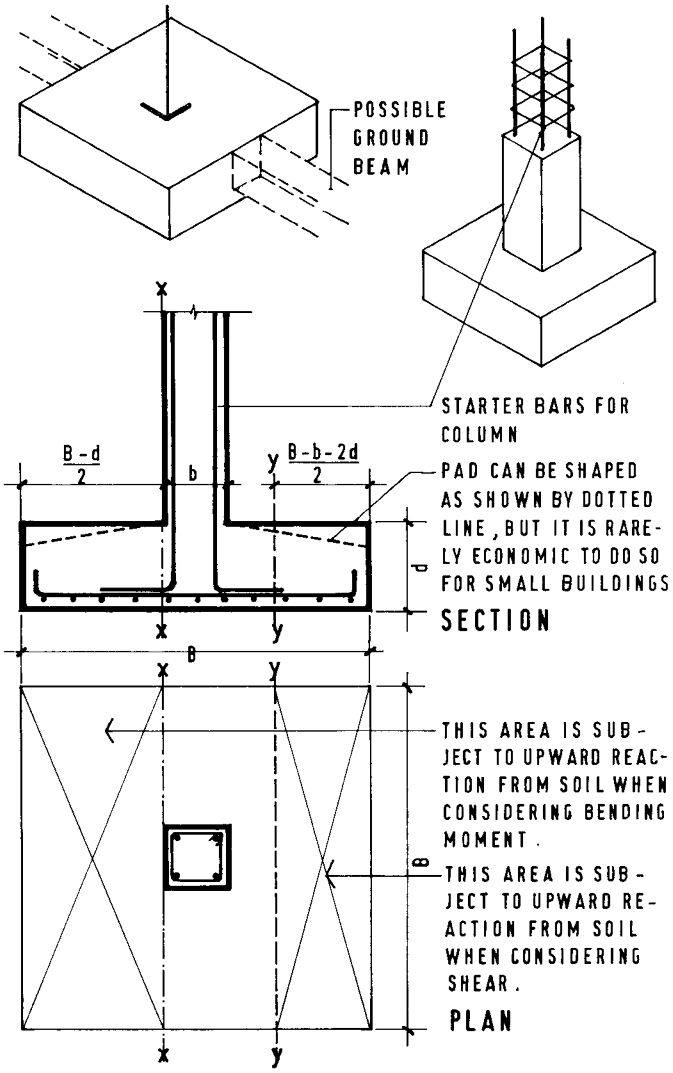


FIG. 253 : **PAD FOUNDATIONS** (ADAPTED FROM "FOUNDATIONS" BY V.C. LAUNDER, MACMILLAN, LONDON).

II. PAD FOUNDATIONS (Fig. 253)

These are usually square on plan, but may be rectangular near boundaries of a site. They are from reinforced concrete in order to spread heavy loads over a larger area. Pad foundations normally support columns and piers. They are also used in factories as foundations in areas where heavy machinery (with one main concentration of load) is placed (Fig. 254 *to* 256).

III. RAFT FOUNDATIONS (Fig. 257)

These consist of a continuous reinforced concrete slab under the whole building, taking up all the downward loads and distributing them over a large enough area to avoid overstressing the soil beyond its bearing capacity. Rafts are really two-way strip foundations. They are used:

- to found on poor and unstable ground, to limit total settlement and to minimize differential settlements;
- where it is necessary to provide a completely tied-together foundation system.

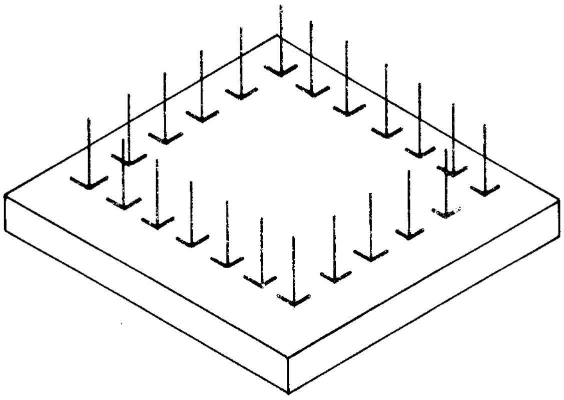
Raft foundations are particularly useful in areas of mining activity, in places where swallow holes might occur in the soil and in earthquake-prone zones. If soil conditions necessitate the use of rafts these may occasionally be supported by short or longer piles in addition.

For large buildings and greater loads the raft can be stiffened by ground beams under the walls forming an egg-crate grill under the slab. The space thus created can be utilized for service installations.

IV. PILED FOUNDATIONS (Fig. 258)

These are used in areas where settlement is greater than acceptable or unpredictable, but where load-bearing soil (rocks etc.) is found under the poorer soil at a depth where the use of piles would be economical. They are also used

5.3.1 FOUNDATION TYPES



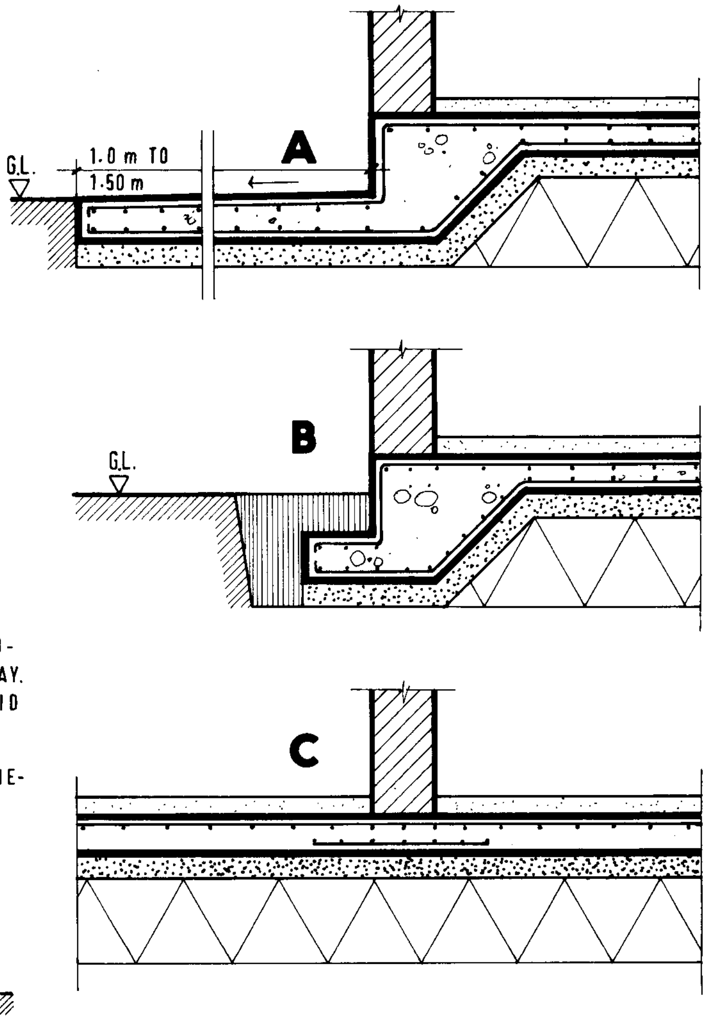


FIG. 257 : **RAFT FOUNDATIONS**

SOLID REINFORCED CONCRETE OR CELLULAR CONSTRUCTION, ANY SHAPE IN PLAN. FOR SMALL BUILDINGS 150 TO 225 mm THICKNESS OF RAFT. FOR LARGER BUILDINGS 225 TO 375 mm.

A AN APRON OF 1.0 TO 1.50 m WITH SLIGHT FALL IS DESIRABLY. BOTTOM STEEL REINFORCEMENT RESISTS SWELLING CLAY. A 75 mm THICK COARSE SAND OR GRAVEL BLINDING IS LAID UNDER RAFT.

B LIGHT REINFORCED CONCRETE RAFT FOUNDATION FOR DOMESTIC BUILDINGS.

C LIGHT BOTTOM STEEL REINFORCEMENT UNDER INTERIOR WALLS. TOP STEEL REINFORCEMENT FOR CRACK CONTROL.

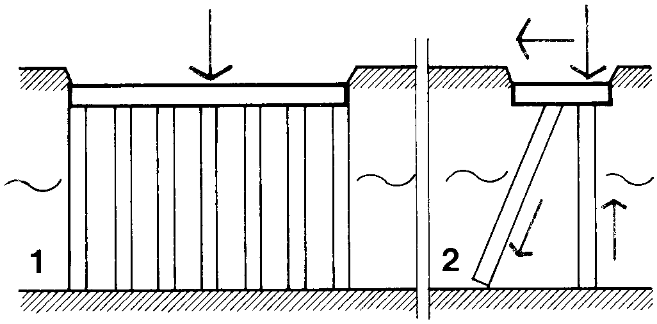
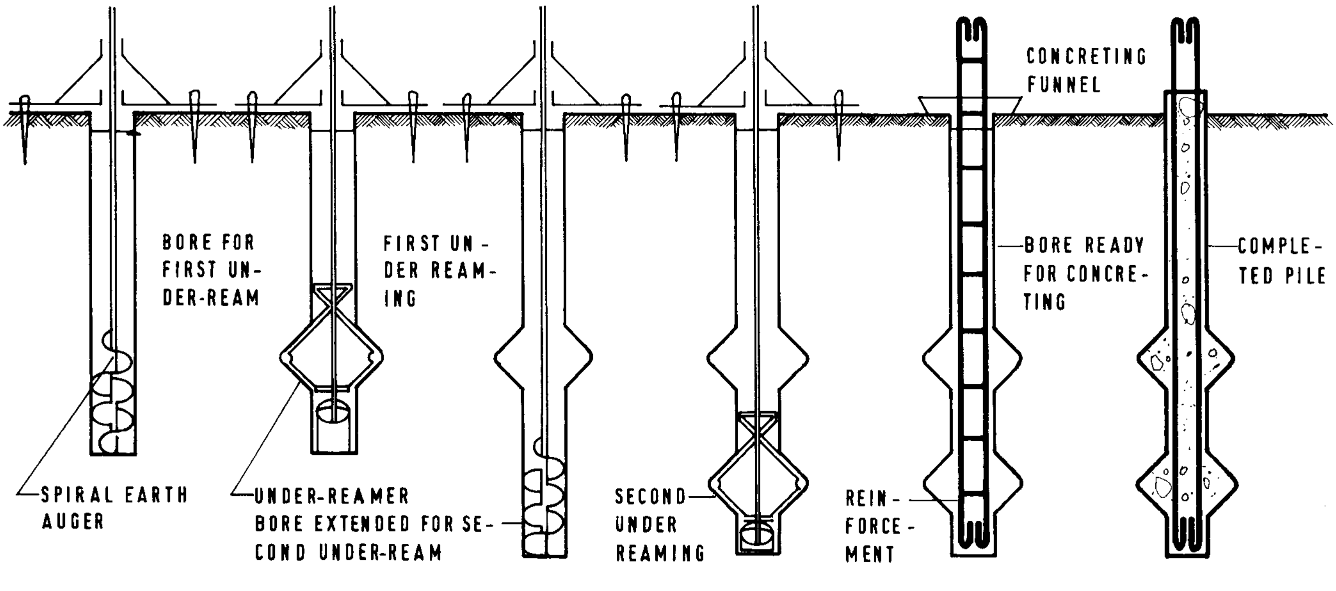


FIG. 258 : **PILED FOUNDATIONS**

1 TYPICAL GROUP OF PILES UNDER A REINFORCED CONCRETE PILE CAP. THERE MAY BE SEVERAL ROWS OF PILES EACH WAY.

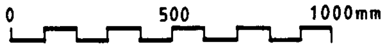
2 RAKING PILES TO RESIST LARGE HORIZONTAL LOADS.

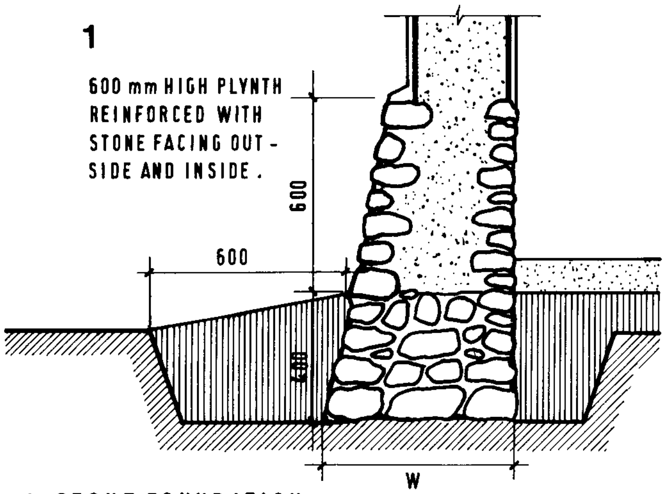
UNDER-REAMED PILE FOUNDATIONS HAVE BEEN USED SUCCESSFULLY IN INDIA FOR OVER 20 YEARS IN SOILS SUSCEPTIBLE TO EXPANSION AND SHRINKAGE. LENGTH OF UNDER-REAMED PILES RANGES FROM 3 TO 8 m. DIAMETER OF THE MANUALLY BORED SHAFT IS FROM 200 TO 500 mm. DIAMETER OF UNDER-REAMED BULB IS NORMALLY $2^1/_2$ TIMES THE SHAFT DIAMETER.



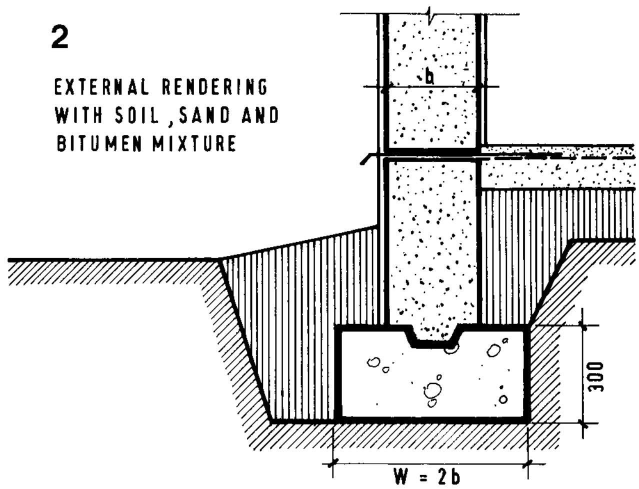
STAGES IN THE CONSTRUCTION OF MULTI UNDER REAMED PILES (FROM "FOUNDATIONS IN POOR SOILS INCLUDING EXPANSIVE CLAYS" BY P.L.DE, OVERSEAS BUILDING NOTES N° 179, APRIL 1978, B.R.E. GARSTON, WATFORD).

5.3.1 DIFFERENT FOUNDATION DETAILS

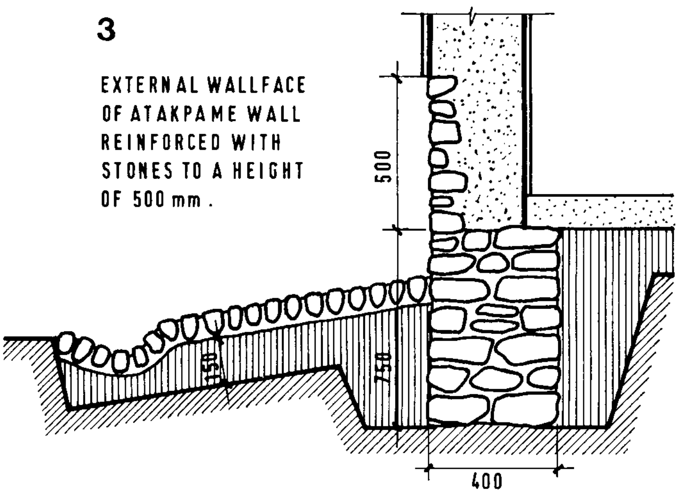




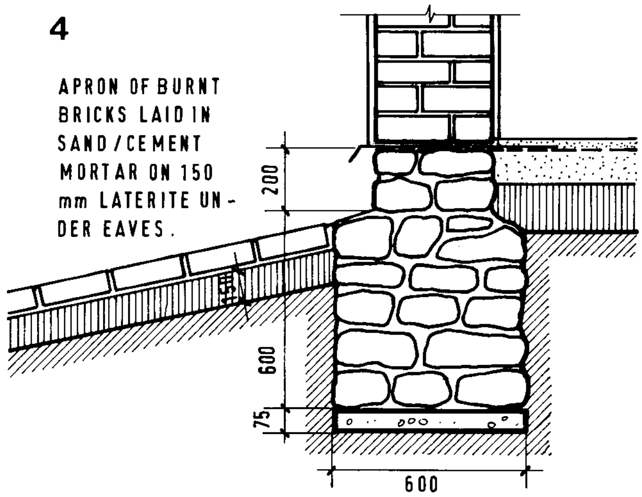
1 **STONE FOUNDATION** : WELL JOINTED WITH CEMENT SAND MORTAR. WIDTH 'W' DEPENDS ON THICKNESS OF WALL ABOVE WHICH CAN BE ATAKPAME OR WATTLE AND DAUB. WELL RAMMED CLAYEY LATERITE BACKFILL TO FALL AS APRON AROUND THE BUILDING.



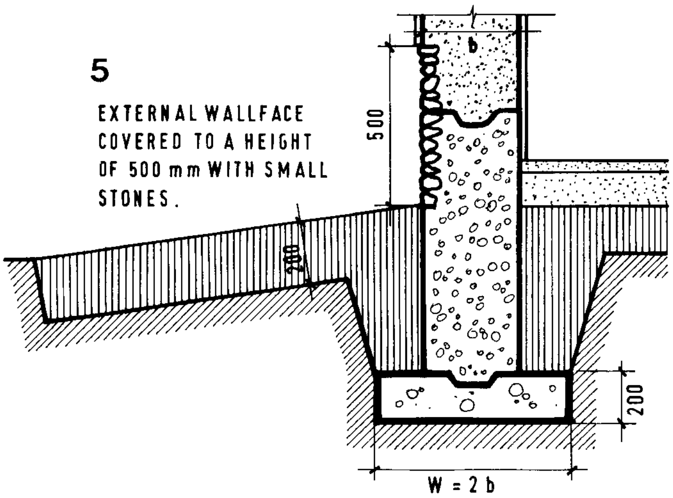
2 **CONCRETE STRIP FOUNDATION** : SUITABLE FOR ATAKPAME OR SUNDRIED BRICK WALLS. WELL RAMMED CLAYEY LATERITE BACKFILL AND BASECOURSE FOR 100 mm THICK MUD-FLOOR WITH SAND / BITUMEN SCREED. TERMITE SHIELD AND DAMPPROOF MEMBRANE WHERE NECESSARY.



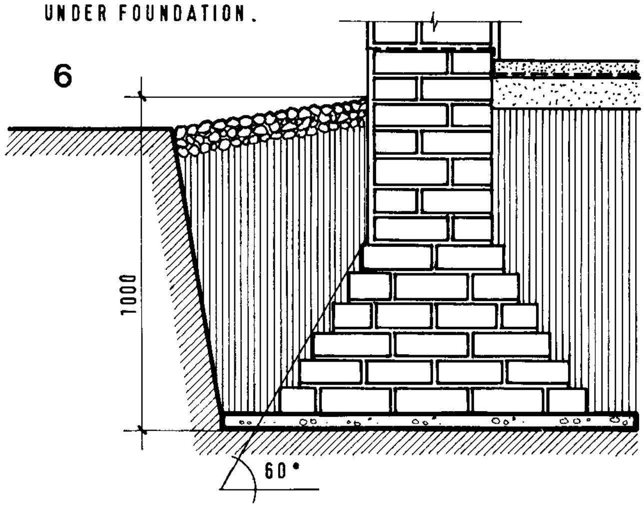
3 **STONE FOUNDATION** : JOINTS WELL FILLED WITH SAND-SOIL MORTAR WITH 5% BITUMEN CUTBACK MIXED IN. SUITABLE FOR ATAKPAME AND SUNDRIED BRICKWALLS. APRON OF STONES SET IN SAND / CLAY / BITUMEN MORTAR ON TOP OF 150 mm THICK WELL RAMMED LATERITE UNDER EAVES.



4 **STONE FOUNDATION** : JOINTS WELL FILLED WITH CEMENT SAND MORTAR, WITH A 200 mm HIGH STONE UPSTAND. SUITABLE FOR SUNDRIED AND BURNT BRICK WALLS. TERMITE SHIELD AND DAMPPROOF MEMBRANE WHERE NECESSARY UNDER FLOOR SCREED. 75 mm THICK CONCRETE BLINDING UNDER FOUNDATION.



5 **REINFORCED CONCRETE STRIP FOUNDATION** : WITH MASS CONCRETE FOUNDATION WALL OF UP TO 800 mm HEIGHT. SUITABLE FOR ATAKPAME, SUNDRIED BRICK AND BURNT BRICK WALLS. OUTSIDE APRON OF 200 mm THICK WELL RAMMED LATERITE LAID TO FALL UNDER EAVES.

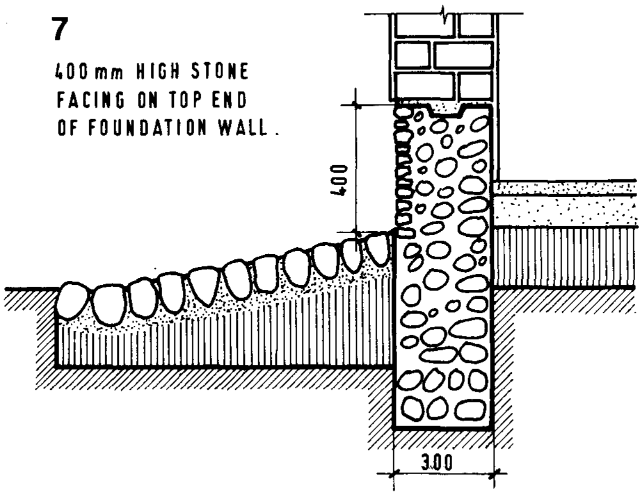


6 **BRICK FOUNDATION** : LAID IN BOND WITH CEMENT / SAND MORTAR ON 50 mm THICK CONCRETE BLINDING. SUITABLE FOR SUNDRIED AND BURNT BRICK WALLS. LATERITE BACK-FILL COVERED WITH 100 mm THICK LAYER OF GRAVEL LAID TO FALL AROUND BUILDING.

5.3.1 DIFFERENT FOUNDATION DETAILS

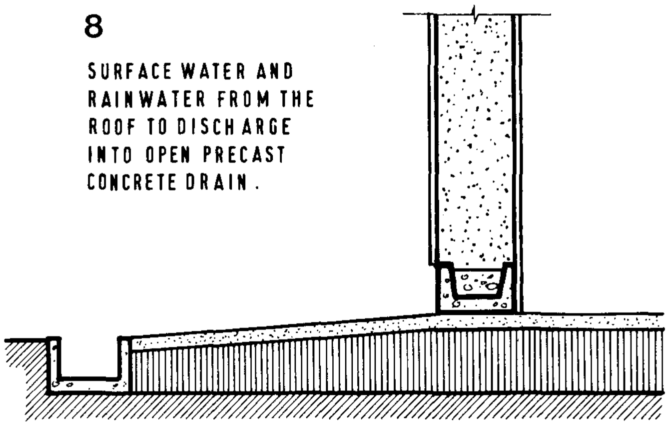
0 500 1000 mm

7



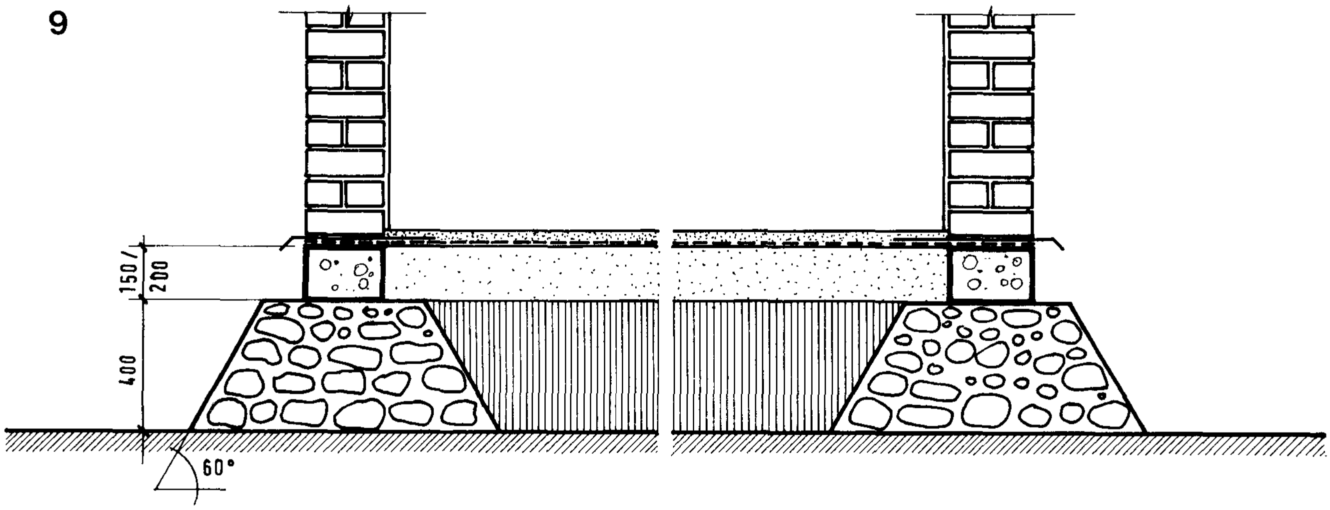
7 **NARROW STRIP FOUNDATION IN MASS CONCRETE,** SUPPORTING A BRICK WALL. CONCRETE MIX (IN PARTS): 1 CEMENT, 4 SAND, 6 SMALL STONES. APRON UNDER EAVES OF STONES SET IN SOIL / SAND / BITUMEN TO FALL.

8



8 **ATAKPAME WALL WITH PRECAST-U-BEAM BASE,** ON FLOOR OF 50 mm THICK SOIL / SAND / BITUMEN SCREED OR SAND / CEMENT SCREED ON MIN. 150 mm THICK RAMMED LATERITE WITH APRON UNDER EAVES. FROM " THE IMPROVED MUD WALL BUILDING " BY A.A.K. GBECKOR-KOVE, DEPARTMENT OF HOUSING AND PLANNING RESEARCH, FACULTY OF ARCHITECTURE, U.S.T., KUMASI.

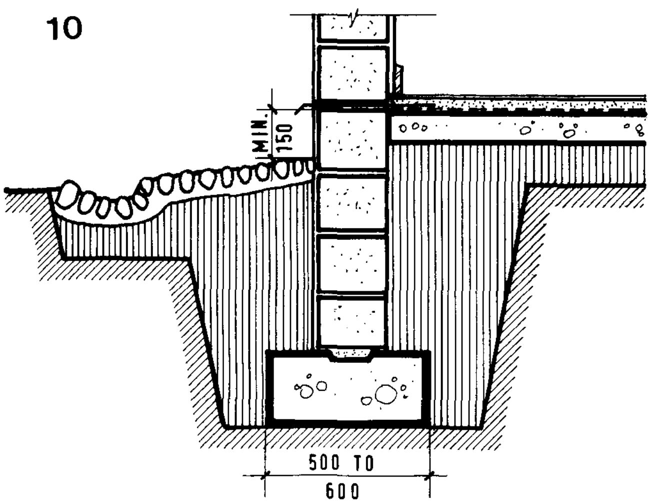
9



9 **RAISED CONCRETE BASE,** FOR SUNDRIED BRICKWORK. CONCRETE MIX (IN PARTS): 1 CEMENT, 4 SAND, 6 GRAVEL AND 10 SMALL STONES. 150 TO 200 mm HIGH CONCRETE UPSTAND ALL ROUND. SOIL / SAND / BITUMEN SCREED ON STABILIZED SOIL FLOOR AND LATERITE.

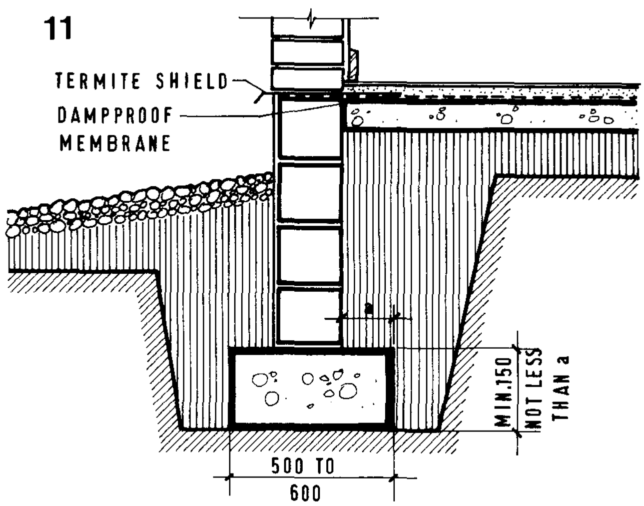
NOTE: DETAILS 1 TO 7 AND 9 ARE ADOPTED AND ALTERED FROM " GRÜNDUNG FÜR LOW-COST HOUSING " BY K. VORHAUER, GATE / GTZ M 6/6, 10/78.

10



10 **REINFORCED CONCRETE STRIP FOUNDATION,** WITH TEK-BLOCK FOUNDATION WALL, SUPPORTING TEK-BLOCK-WORK. STONES SET IN SAND / CEMENT MORTAR TO FALL AS APRON UNDER EAVES. TERMITE SHIELD AND DAMPPROOF MEMBRANE UNDER SCREED WHERE NECESSARY.

11

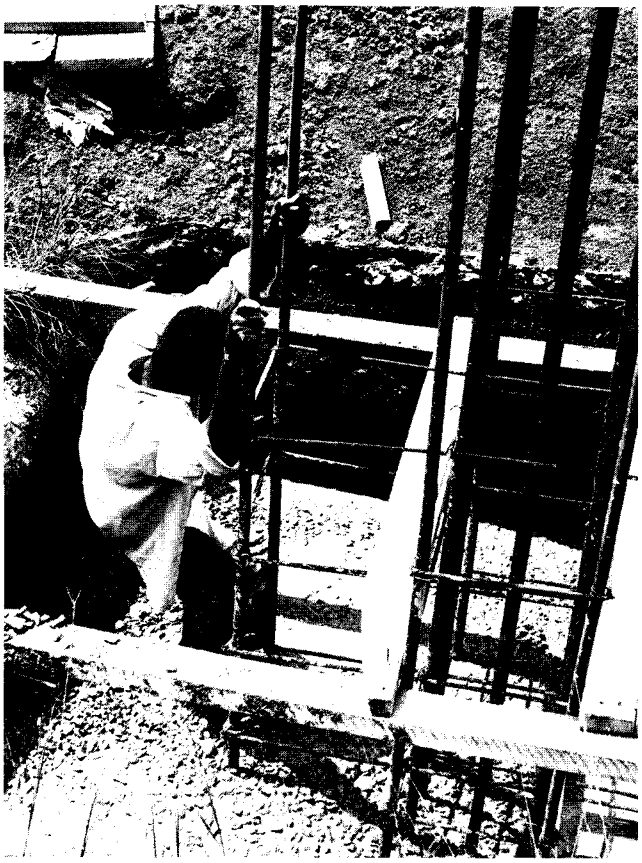


11 **REINFORCED CONCRETE STRIP FOUNDATION,** WITH BLOCKWORK FOUNDATION WALL SUPPORTING BURNT BRICK WALL. 100 mm THICK GRAVEL LAYER TO FALL AS APRON UNDER EAVES. REINFORCED CONCRETE FLOOR SLAB.

FROM: GRÜNDUNG FÜR LOW COST / SELF HELP HOUSING, BY K. VORHAUER, G.A.T.E., 10 / 78.

Fig. 255: Pouring concrete into a pad foundation, 1981.

Fig. 256: The completed pad foundation with starter bars for vertical column reinforcement, 1981.



in areas with expansive or shrinking soil, where the building has to be founded through water or where existing foundations must be strenghtened. A system of small diameter piles is also suitable for small buildings on a site where expansive soil overlies a hard stratum of high bearing capacity. In some tropical countries (e.g. Zimbabwe) aluminium tubes have been successfully used for such purpose.

Most piling systems are proprietary, they are designed and operated by specialist firms. New designs are continually developing.

REINFORCED CONCRETE FOUNDATIONS

If reinforced concrete foundations are used, it is important to ensure that the materials used are of satisfactory quality since the stability of a building depends largely on its foundations.

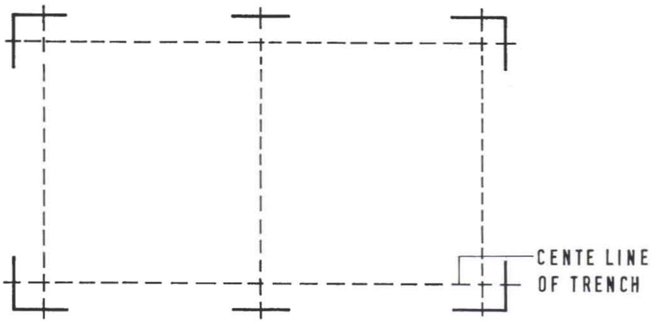
- **Concrete:** For high quality concrete the mix ratio should be 1 part cement, 1 part sand and 2 parts of coarse aggregate. For general use in a strip foundation the concrete mix should be 1:2:4 (1 part cement to 2 parts sand to 4 parts coarse aggregate), but not weaker than 1:3:6(5) for smaller buildings. Cement for concreting is normally Portland cement, but may be sulphate resisting cement or rapid hardening cement for special purposes. Reinforcement steel should be rolled bars from 6mm to 50mm in diameter according to the structural engineer's calculations, or welded steel mesh.

5.3.2 SETTING-OUT AND EXCAVATION

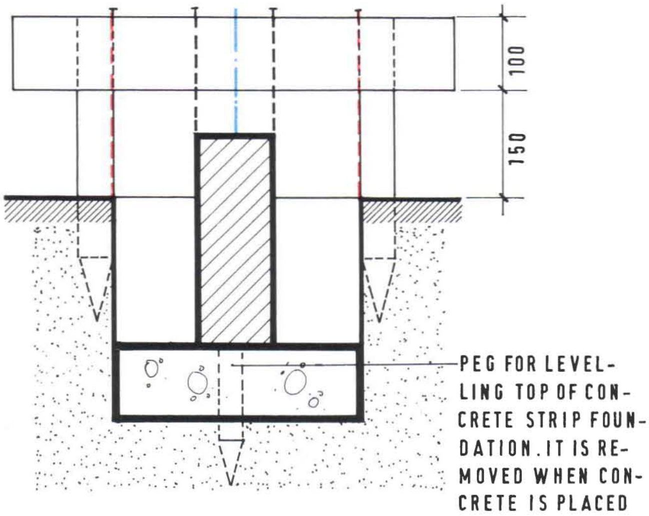
As already mentioned before the site which is to be used for the building must first be cleared of all vegetation, with particular reference to tree roots and stumps. Living vegetation has a tremendous force, even grass can force its way through concrete. This can be seen at the shoulders of the Tema- motorway, where thick bushels of grass are growing between the edge of the road concrete and the asphalted shoulders.

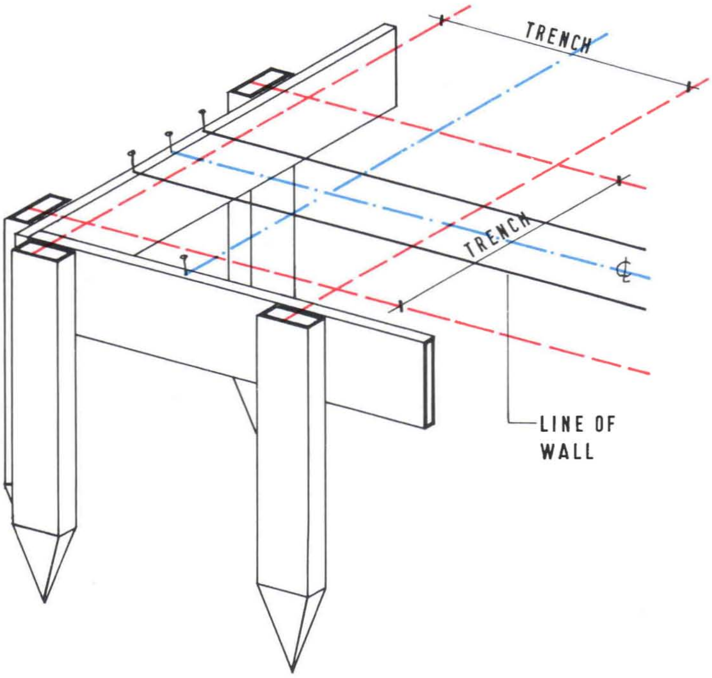
The preceding site survey should have taken note of existing trees and other vegetation on the site. The architect should always consider the importance of retaining grown trees on the site if they are not in the way of the building or even re-site the building, with the approval of the client, in order to save trees on the site, if that is possible. The humus-containing top soil must be removed and placed at a convenient place on the site from where it can later be used for landscaping. The approximate area of the building is then excavated to a depth of about 150mm. Rough profiles are set around the perimeters of the work. Accurate setting is required, for even the smallest error can be accumulative (Fig. 259). Setting-out must especially be accurate for building with a precast concrete panel system.

5.3.2 FIG. 259: SETTING-OUT AND EXCAVATION



LAYOUT SHOWING ARRANGEMENTS OF PROFILE BOARDS AND PEGS





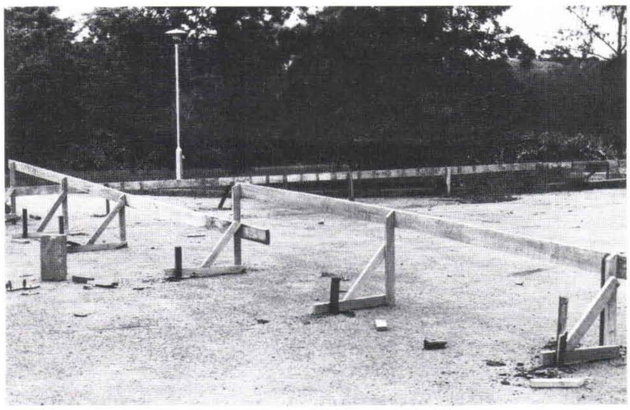
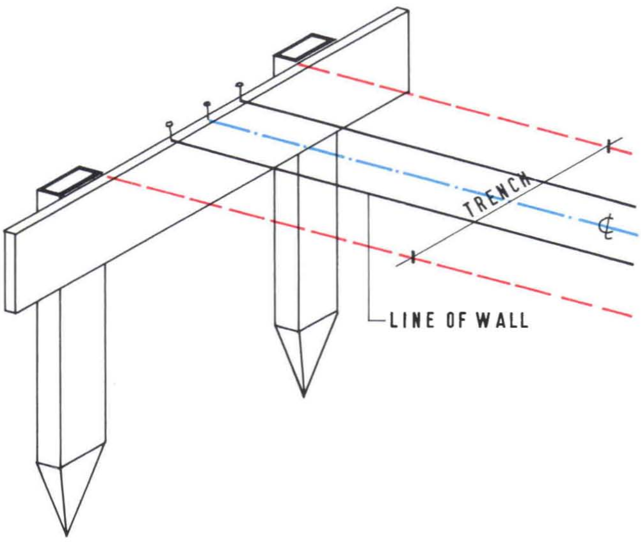
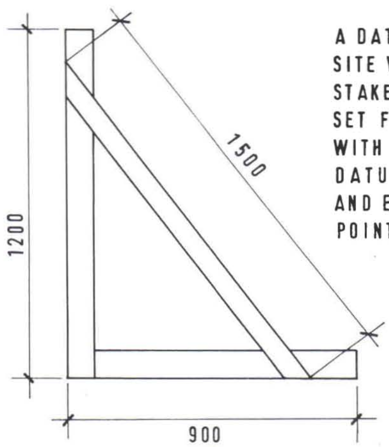


Fig. 259: Rough setting-out profiles at the U.S.T. Library extension site, 1981.



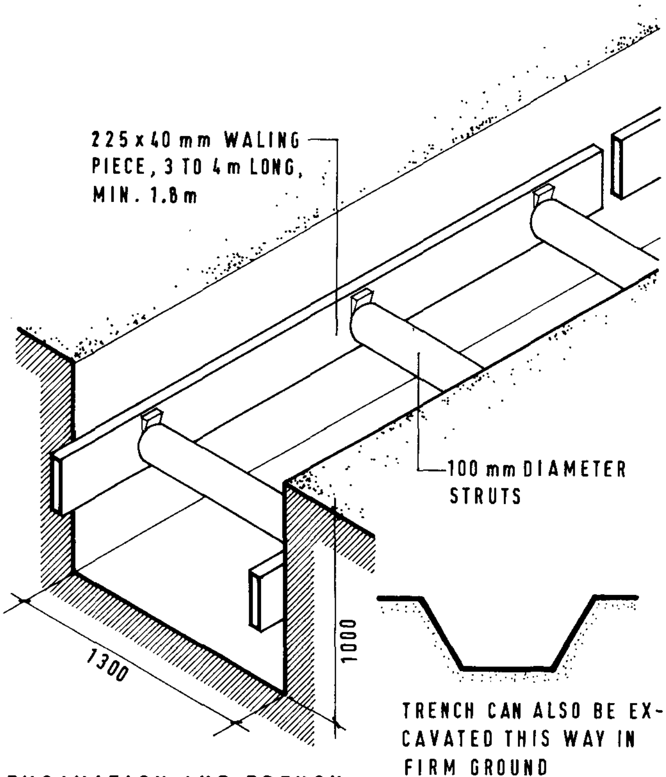
PROFILE BOARDS AND PEGS FOR CORNERS OF THE BUILDING AND AT POSITION OF INTERNAL LOAD-BEARING WALLS WITH STRIP FOUNDATION

A DATUM IS ESTABLISHED ON THE SITE WITH THE HELP OF A WOODEN STAKE, STEEL OR CONCRETE POST, SET FIRMLY IN A CONCRETE BASE, WITH THE TOP AS THE CHOSEN DATUM. ALL LEVELS ON THE SITE AND BUILDING RELATE TO THIS POINT.



A BUILDER'S SQUARE FOR SETTING OUT RIGHT ANGLES

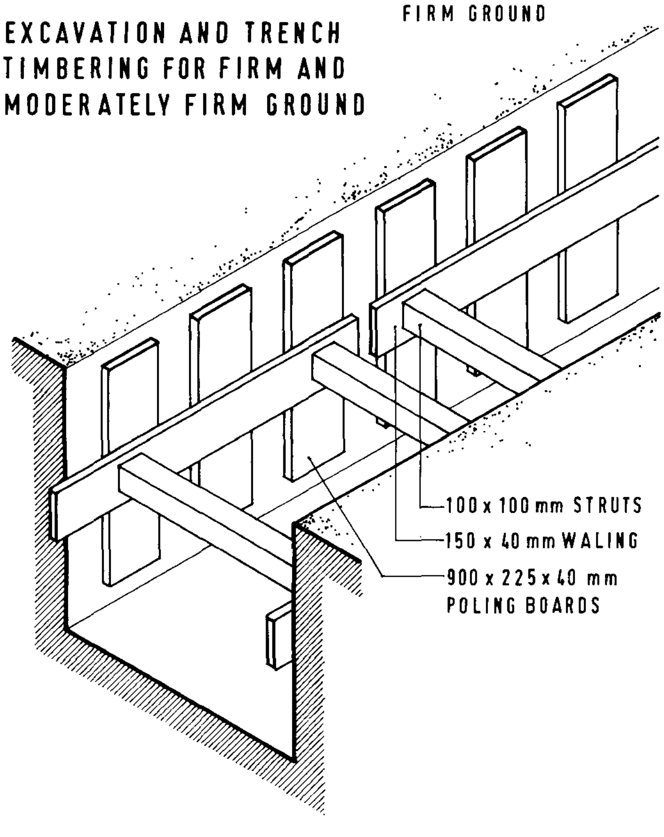
5.3.2 FIG.260 : TRENCH TIMBERING



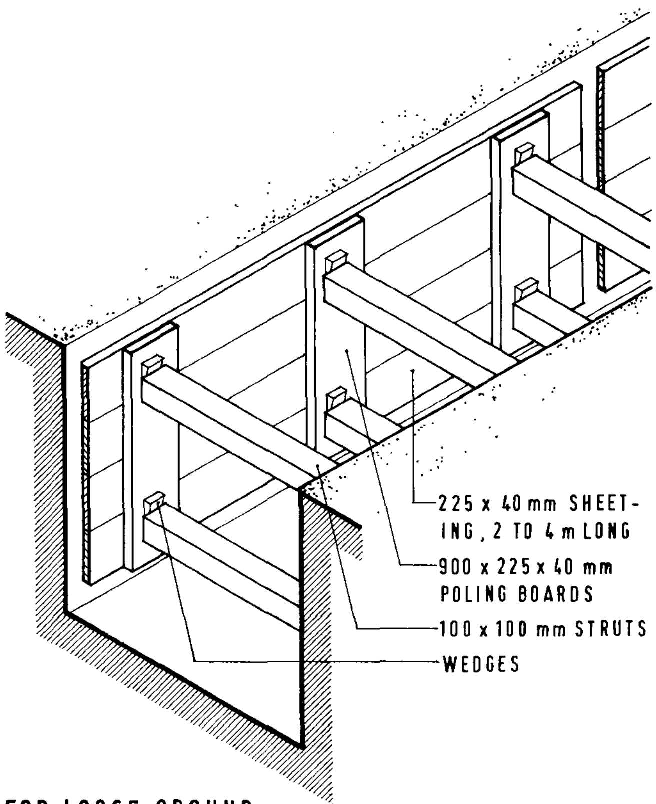
EXCAVATION AND TRENCH TIMBERING FOR FIRM AND MODERATELY FIRM GROUND

Excavations for structures up to 4-storeys will normally be done by hand with hand tools in most of the cases, depending on the conditions of the soil (Fig. 260). A lot of excavation work for larger structures is done by mechanical means: with scrapers, bulldozers, face shovels, toothed rippers, trench excavators with small-toothed buckets on a continuous belt etc.

On sloping sites it is important to consider the implications of the plan shape and floor levels for the excavation and foundations. Fig. 261 shows some proposed solutions for founding buildings on sloping sites. Table 17 shows suitable foundations for different soil types.



FOR MODERATELY FIRM GROUND



FOR LOOSE GROUND

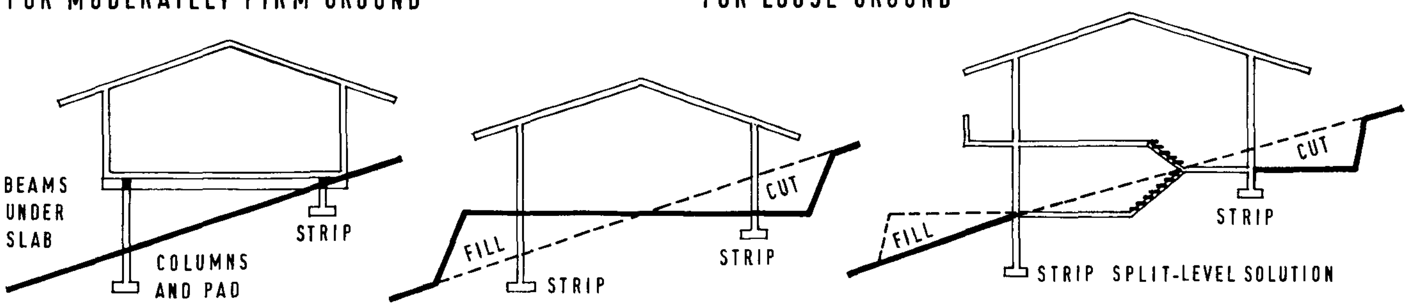


FIG. 261 : BUILDING ON SLOPING SITES

GROUND MUST BE FIRM. EXCAVATIONS MUST REACH DOWN TO LOAD-BEARING SOIL, OR PILING MUST BE USED FOR FOUNDATIONS.

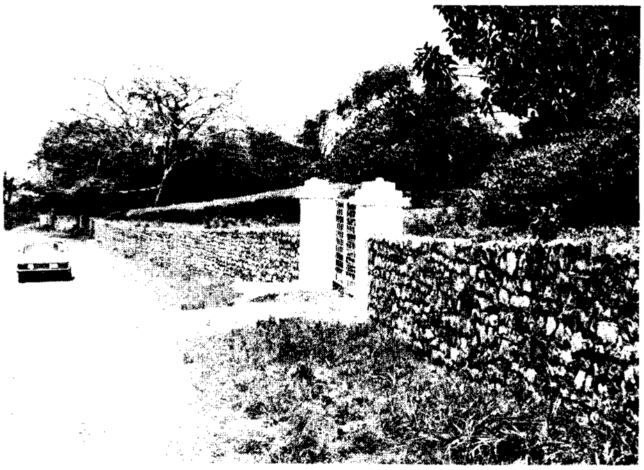


Fig. 262: Gravity retaining wall of stone; Mr. Turqui's residence, Aburi, 1980.

5.3.3 RETAINING WALLS AND REVETMENTS

Retaining walls are used to retain:

- **Solids:** Natural soil or fill of varying materials when a site is terraced.
- **Liquids:** Sea, river, reservoir walls.

A retaining structure must resist compression, tension, shear and bending, which are induced by all lateral and vertical forces to which it is exposed through the active pressure of the soil (or liquid) it retains. A retaining wall must be designed in such a way that it is stable, does not overturn, slide away or issue too large a pressure on the ground under its foundation.

There are two basic types of retaining structures.

- **Temporary Structures:** These are retaining structures which are upholding the sides of an excavation in loose ground (trench timbering) or temporary steel sheet piling for a foundation cast below the water table.

- **Permanent Structures:** Retaining walls and basement walls (Fig. 262).

Details of **basement** walls do not differ much from those explained on the detail drawing shown here. Further explanations would, however, go beyond the scope of this book and could form part of a textbook of more sophisticated construction technologies, listing multistorey structures (including tanked basements etc.).

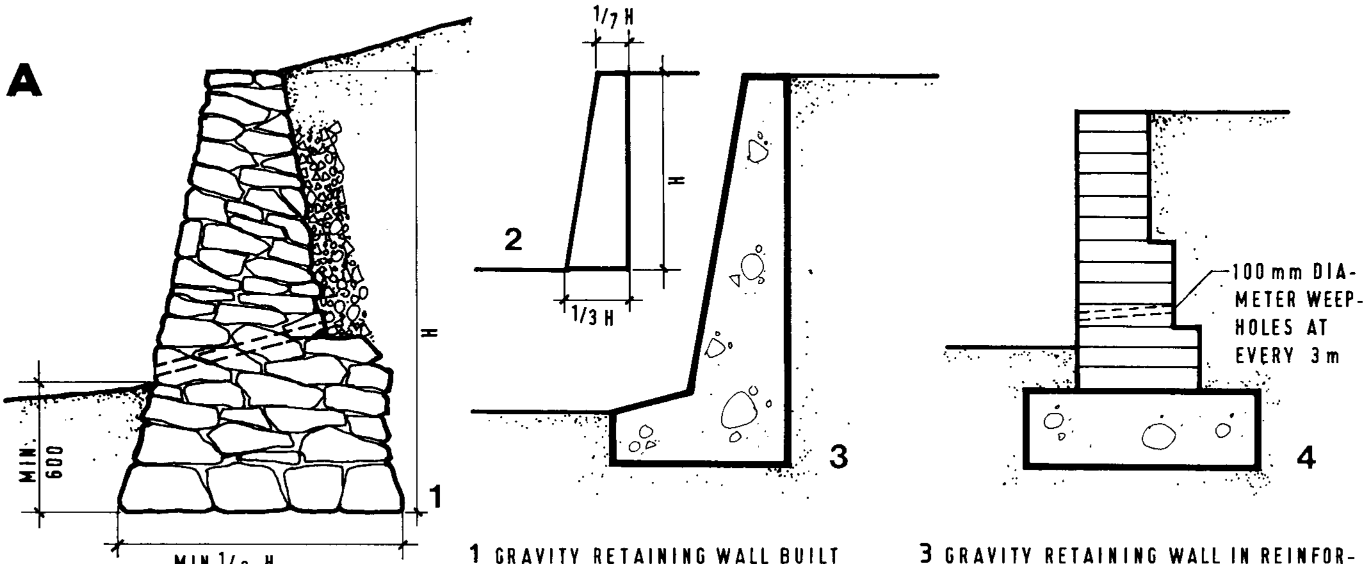
Table 17: Selecting suitable foundations for different soil types:

Type of Soil	Suitable Foundations	Remarks
Rocks (including semirocks e.g. chalk, shale)	Pads: For individual columns Strips: For walls or columns closely spaced in rows	Risk of swallow holes in limestone and chalk
Sands and Gravels (generally)	As for rocks: Pads and Strips Raft: For very heavy buildings	Foundations above water level may settle if subject to vibrations
Laterite (porous soil ranging from soft, earthy material to hard rocky material)	As for rocks: Pads and Strips, when soft Raft	
Loose Sands and Gravels (especially if near water table	Strips or Raft	Depends on bearing capacity of soil and settlement requirements
Clays and Silts (except as below)	Pads, Strips and Raft: For individual columns; Strips or Raft: For walls or closely spaced columns	Short bored piles may be advantageous for light buildings on clay
Clay (with shrinkage or swelling likely to appreciable depths)	Piling: To reach hard stratum. Piles to be connected with ground beams	Downhill creep may occur on slopes greater than 1 in 10. Piles must be reinforced in such areas.
Fill (existing or new)	Strips or Raft	Depends on load-bearing capacity and settlement requirements and needs very careful investigations. Foundations may have to be taken down to firm stratum below very poor and variable fill
Mining and other Subsidence Areas	Thin reinforced Rafts for individual houses with load-bearing walls	Rafts must be designed to resist tensile forces

(Source: "Soils and Foundations: 3" – Building Research Station, Digest 67, Second Series)

5.3.3 RETAINING WALLS AND REVETMENTS

A



A GRAVITY WALLS:

THESE ARE WALLS WHICH DEPEND FOR STABILITY ON THEIR OWN MASS AND DEAD WEIGHT. THEY ARE UP TO 2m IN HEIGHT.

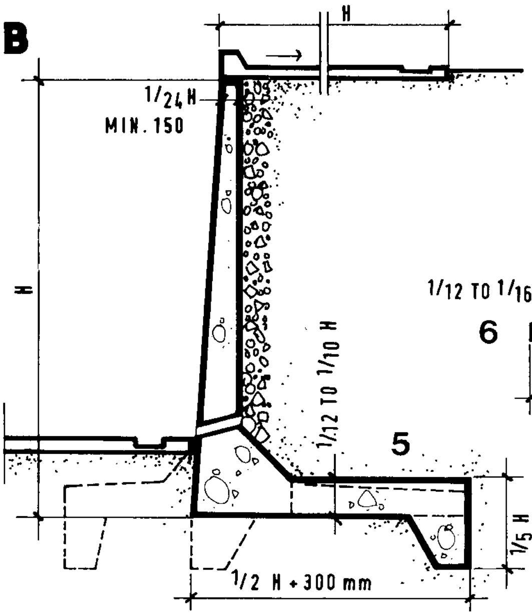
1 GRAVITY RETAINING WALL BUILT WITH STONES WITH GRANULAR BACK FILL AND 150 mm DIAMETER WEEP-HOLES AT 4m CENTRES. FACE OF WALL BATTERED 45° FOR DRY SET WALL OR 20° FOR WALLS SET IN MORTAR.

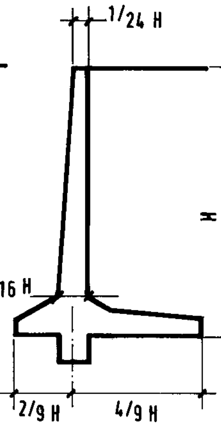
2 PROPORTIONS OF A GRAVITY WALL.

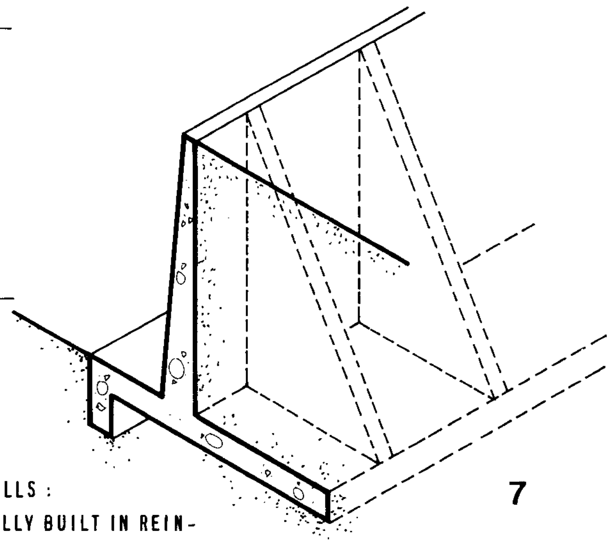
3 GRAVITY RETAINING WALL IN REINFORCED CONCRETE.

4 GRAVITY RETAINING WALL BUILT WITH BRICKS, SUITABLE FOR LOW HEIGHTS UP TO 1.5 m AND NO GREAT LATERAL PRESSURE. IF THE WALL IS TO BE HIGHER, IT SHOULD BE BATTERED AT MAX. 12° OR BUILT CURVED FROM BASE.

B







5 CANTILEVER WALLS:

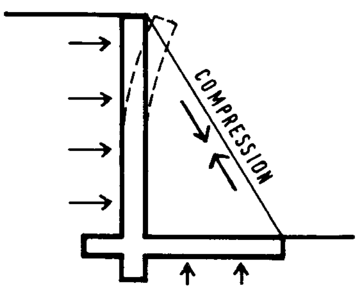
THESE ARE USUALLY BUILT IN REINFORCED CONCRETE WITH DIFFERENT CANTILEVERS AS SHOWN DOTTED. THEY ARE USED FOR HEIGHTS UP TO 7.5 m.

6 PROPORTIONS OF CANTILEVER WALL.

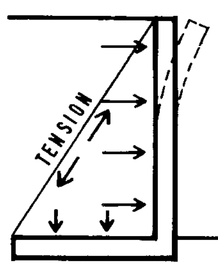
THESE ARE NORMALLY USED FOR RETAINING WALLS OF GREATER DEPTH AND HEIGHT WITH VERTICAL BUTTRESSES AND ADDITIONAL STIFFENING IN FORM OF HORIZONTAL RIBS.

B FLEXIBLE WALLS:

THESE WALLS ARE DESIGNED IN SUCH A WAY THAT THEY ACT AS A CANTILEVER, BEAM OR ARCH BETWEEN FIXED SUPPORTS.



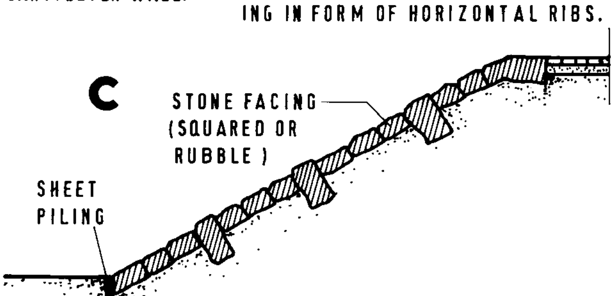
BUTTRESS
(IN COMPRESSION)



COUNTERFORT
(IN TENSION)

FROM "FOUNDATIONS" BY V.C. LAUNDER, MACMILLAN, LONDON.

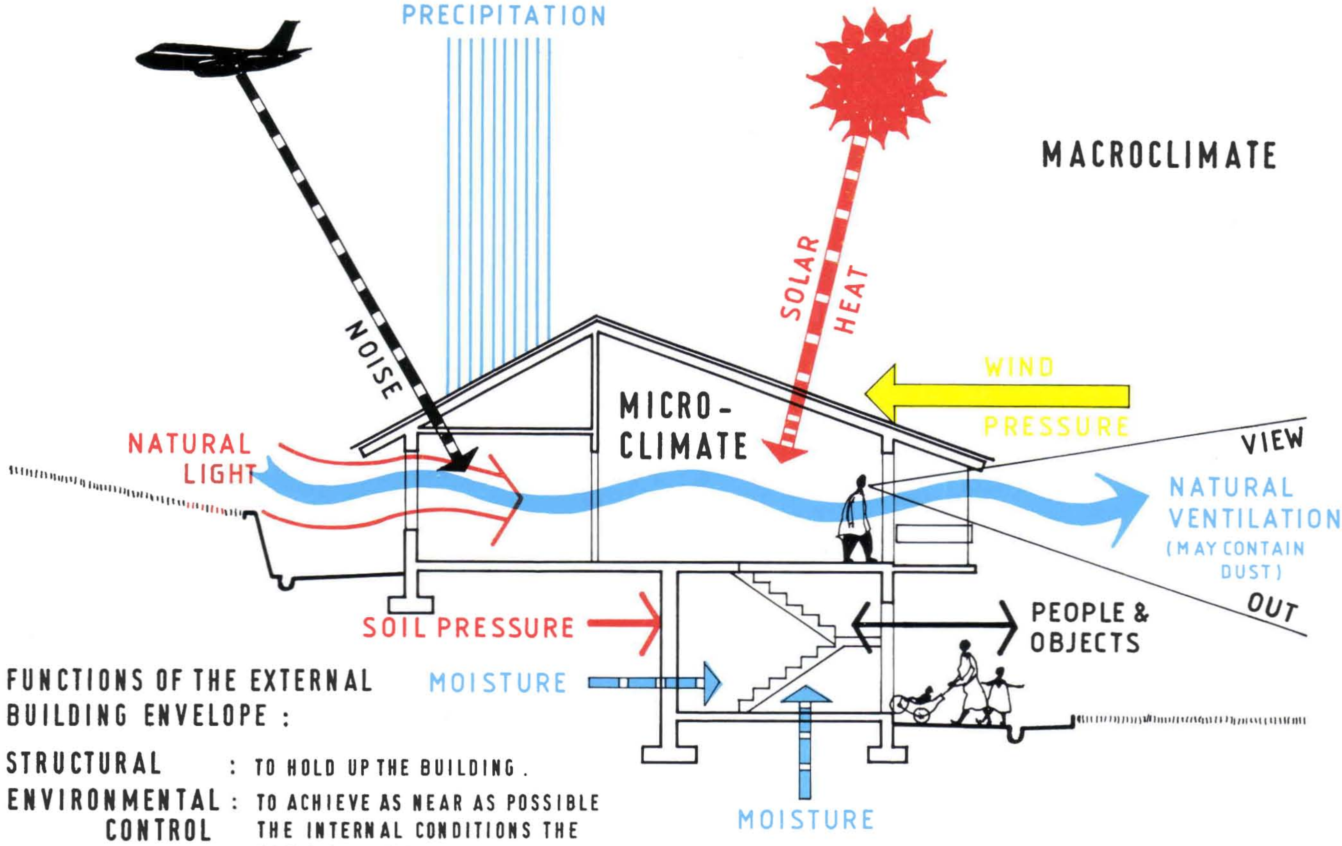
C



C REVETMENTS:

THESE ARE SURFACINGS OF SOIL BANKS OR CUTTINGS WITH STONES, BRICKS OR CONCRETE TO RETAIN AND STABILIZE THE SOIL AND TO PREVENT EROSION. FOR LANDSCAPING; RESEROIR WALLS.

5.4 THE BUILDING FIG. 263



FUNCTIONS OF THE EXTERNAL BUILDING ENVELOPE:

STRUCTURAL	: TO HOLD UP THE BUILDING.
ENVIRONMENTAL CONTROL	: TO ACHIEVE AS NEAR AS POSSIBLE THE INTERNAL CONDITIONS THE USERS REQUIRE.
VISUAL	: TO HAVE A BEAUTIFUL APPEARANCE WHICH CONTRIBUTES TO A PLEASANT LAND- OR TOWNSCAPE.
SECURITY	: TO PROVIDE SECURITY FOR ITS OCCUPANTS.

ADAPTED FROM "A.J.-HANDBOOK OF BUILDING ENCLOSURE" BY A.J. ELDER AND M.VANDENBERG, THE ARCHITECTURAL PRESS LTD., LONDON.

A building can be compared with a huge envelope enclosing spaces with specific functions for the varying activities, needs and the comfort of its occupants therein.

This envelope has to fulfil its own functions. As Figure 263 explains, the envelope acts as a selective filter which separates the internal spaces from the external environment. Each and every part of the envelope's structure has to be designed and detailed in such a way that it helps to produce, as nearly as possible, the internal conditions in the building which are required by its users. If this is achieved, the various aspects of the external macroclimate will be modified to create a more acceptable internal microclimate. The internal subdividing elements in turn must be designed so that they reduce sound transmission from space to space to a minimum, that they provide privacy where necessary and that they allow easy circulation.

Next to the structural function of the external building envelope, the holding up of the building, the most important function is its environmental control. The designer must be familiar with the local climate in any given situation, with the prevailing conditions of precipitation, humidity, air movement, air temperature, intensity of solar radiation and light. Careful analysis of climatic data is required in order to make the correct decisions on:

- Shape, orientation and spacing of buildings;
- Plan form and dimension of rooms;
- Fabric of walls, floors and roofs;
- Size and materials used for doors and windows;
- Treatment of external surfaces.

The meteorological services will supply the necessary climatic data, e.g. monthly mean, maximum and minimum temperatures, daily and annual ranges of temperatures and humidity, average duration of bright sunshine and measurements of rain and wind. Comfort zones, expressed in acceptable temperatures and humidity, and desired natural air movement (control of ventilation without the necessity of mechanical cooling installations) have to be established for each area with different climatic conditions in tropical countries. It has been observed that inhabitants of tropical areas prefer somewhat higher temperatures than those living in areas with hot summers and cold winters. In general, comfort limits are higher for the day and lower for the night.
For each of the climate types which may be experienced in tropical environments, it is necessary to specifically design and detail parts of the external envelope.

Hot, Humid Climate:

Indoor comfort is largely dependent on control of air movement and radiant heat. Maximum air movement past the body must be encouraged to ensure rapid evaporation of sweat from the skin. Solar heat must be prevented from reaching the building occupants either directly through doors and windows or indirectly by heating the structure, then re-radiating the heat to the occupants or warming the indoor air. The building fabric which was exposed to solar radiation during the day must cool quickly after sunset to give maximum night-time comfort. These requirements call for a light, well-insulated construction of walls and roofs (which should shade most of the building facades during the most intensive sun radiation, about 10 o'clock to 16 o'clock), reflective surfaces, correct shading devices and design for good breeze penetration (not just at head level when sitting).

Hot, Dry Climate:

Areas with this climate have high day temperature, low night temperature and low humidity. There are also large diurnal and annual ranges of temperature with little air movement except for local thermal winds and dust storms. The passage of solar heath through walls, doors, windows and roofs should be slowed down so that it is out of phase with the daily heating and cooling of the outside environment. To achieve this the fabric of a building must be slow to heat up. As little heat as possible must be permitted to penetrate through external openings. Good shading of walls and openings, "umbrella" roof design, reflective colouring of unshaded out-door surfaces and very effective insulative outer construction are needed to provide indoor comfort during the day. Maximum night comfort on the other hand requires a light construction which can cool rapidly after sunset.

Composite Climate:

Buildings in such areas with a combination of the two climates have to satisfy the needs of the hot dry periods, as well as those of the warm humid periods. Many of the requirements and objectives for the hot dry and warm humid areas are compatible. Where apparently incompatible needs arise, it becomes necessary to compare the length and intensity of various seasons and to study their detailed features in order to find design data that make an integrated solution possible.

5.4.1 BASIC DESIGN DECISIONS

I. FOR BUILDINGS IN WARM HUMID CLIMATES:

- **Orientation**: North-South (Northeast-Southwest, depending on the prevailing winds, if any) for habitable rooms.
- **Layout**: Loose and well spaced to allow for air movement through and around buildings.
- **Internal Plan**: Single-banked rooms to allow for maximum use of natural cross-ventilation.
- **External Walls and Roof**: Thin, insulated.
- **External Openings:** Large, from ceiling to floor (but protected).
- **Outside Surfaces**: Where not shaded, reflective.
- **Internal Walls**: Thin, perforated or with fixed timber louvres, etc.

Special protection is needed against heavy rains (especially in rainforest areas where rain periods are more extensive), insects and termites.

II. FOR BUILDINGS IN HOT DRY CLIMATES:

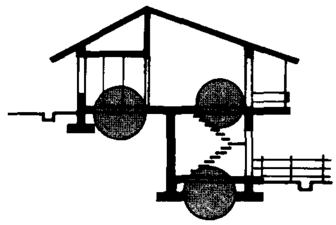
- **Orientation**: North-South for habitable rooms.
- **Layout**: Compact planning to allow the buildings to shade each other.
- **Internal Plan**: Rooms grouped around and opening up on to courtyards.
- **External Walls and Roof**: Of dense materials (stabilized soil, bricks, blocks), insulated, "umbrella" roof design (See 5.4.7 **Roof Structures and Finishes**).
- **External Openings**: Small, to be placed high, together with low openings to help create vertical ventilation (stack effect).
- **Outside Surfaces**: Where not shaded, reflective. Courtyards to have shaded floors in front of rooms.
- **Internal Walls**: Of dense materials.

External circulation should, if possible, be shaded. Special protection is necessary against dust storms, heavy thunder storms during the rainy season (normally accompanied by very strong winds and torrential rains in hot dry zones with one annual rainy season), insects and termites.

In tropical areas (which extend roughly between the Tropics of Cancer and Capricorn and slightly beyond) walls facing east and west receive most radiation from the direct rays of the sun and should be protected against this. Rectangular buildings should be placed on an axis as near to east-west as practicable with openings for access, ventilation and light on the north and south (the longer walls). Walls should be completely shaded where possible. All openings into buildings must be shaded from the direct entry of the sun's rays. Since it is rather difficult and expensive to completely shade the east and west walls the buildings should be designed such that these walls have no openings as already mentioned. Solar charts are normally available in the meteorological services of tropical countries to calculate the angles of the sun's rays so that the architect is in a position to design the correct overhang of the roof structure or shading devices (See 5.4.6 **Sun Shading**).

Many houses built with traditional building methods in tropical countries have been "naturally conditioned" as a result of repeated cycles of trial and error. They embody the experience of generations of builders. It is however, not advisable to simply copy the traditional solutions which may have been developed under conditions that have ceased to exist or may have been developed to fulfill certain needs that can better be met by other means nowadays. One must also remember that in some traditional buildings climatic comfort was often subordinated to other requirements, particularly security. A wisely used appropriate technology should make it possible to arrive at better and more economic solutions fulfilling the "modern" user's needs and requirements.

5.4.2 FLOORS AND FLOOR FINISHES



This section will describe the lowest floors which can be built at three different levels, as (1) a **Basement,** (2) at **Ground Level,** and (3) **Suspended** (above ground level) or **Raised** (which creates an open ground floor space) and the **Upper Floors** (which separate storeys of a building).

Historically the lowest floor at **Ground Level** has been the most common position, from beaten earth with animal skins or woven mats spread over it, through finishes from stone slabs, burnt clay tiles on a sand bed, to the concrete slab on rolled hard-core at ground level.
Recessing a building into the ground, as is the case when constructing a **Basement,** creates many structural and operational difficulties with accompanying problems of water exclusion. Except in special circumstances construction of basements should be avoided in tropical developing countries. With the growing urban centres and rising values of land properties the construction of multi-storey structures, however, may justify the additional expense of the construction of basements for use as storage areas, for service installations or for underground car parking.

Raising a building above the ground level is a characteristic technique of modern architecture, expecially for high-rise buildings, with vehicle circulation and parking at ground floor level. In vernacular buildings floors at ground level were raised as protection against floods, insects and rats.

5.4.2.1 FUNCTIONS OF FLOORS

I. Structural Support: To provide a level surface which is capable of supporting people, furniture, equipment and internal partitions. The floor should safely support its own weight (dead weight) and any superimposed load. The floor finish contributes to the support function by protecting the structural floor surface from wear and abrasion and at the same time providing a safe surface for the users.

II. Environmental Control: The most important function in this respect is water exclusion from the interior of the building. One can achieve this with two methods:

- By providing an air-gap (cavity) or a ventilated space under the floor;
- By providing an impervious barrier in form of a damp-proof membrane in or under the floor or under the screed, and a damp-proof course in the external wall at floor level.

Other functions of the floor, as part of environmental control, are to reduce noise transmission and to provide sufficient thermal insulation. Noise transmission will be a problem in raised and upper floors. In airconditioned areas floors should be insulated as well as walls to prevent a gain of heat from unconditioned rooms below or above. Cold stores must have insulation as an integral part of ceiling and floor (as well as wall) construction.

III. Durability: Another important function of all floors is that they must be durable. Their life expectancy should be that of the whole structure of the building. Surface wear depends on the quality and behaviour of the floor finishes, that is the selected coverings.

At ground level there are two types of floors:

- **Solid Floors**: These are continuously supported on the ground itself. As already mentioned, the traditional floors were of beaten earth or natural stones or clay bricks laid directly on the earth. The modern designer invariably uses concrete to form a solid floor slab with a large variety of different floor finishes.
- **Suspended Floors**: These are supported from the foundation system (but raised floors and upper floors span between supporting structures). If elevated well above ground level, the space below can be utilized.

The choice between the two depends on:

- The desired ground floor level in relation to the existing site level;
- The load bearing capacity of the ground;
- The foundation design;
- The anticipated superimposed loads on the floor;
- The availability and cost of suitable back fill.

If the site is flat and the bearing capacity of the ground good, a solid floor with only a nominal (normally 150 mm thick) layer of well rolled laterite or hardcore (where this is available) is cheaper than a suspended floor. In areas with a poor load bearing capacity of the soil, a suspended floor is the obvious choice, as it is also for piled foundations. In moist areas with heavy rainfall the ground floor level should be about 300 mm to 400 mm above the existing site level. The required fill in such cases would be rather expensive. In this case, which will most probably apply to many areas of tropical developing countries, a suspended floor should be chosen (Fig. 264).

5.4.2.2 SOLID CONCRETE FLOOR

At ground level this has the function of transmitting the superimposed load directly to the supporting ground, and in addition spreading point loads so that the bearing capacity of the ground is not exceeded. A solid concrete floor has to be built in such a way that it can easily receive the required floor finish. The thickness of the slab is decided after the necessary soil investigations give sufficient information on the existing soil conditions. It is normally between 100 and 150 mm. Concrete mixture is (in parts) 1 part cement to 2 parts sand to 4 parts coarse aggregate. For domestic floors on stable ground a mix ratio of 1:3:6 is sufficient. The slab is normally reinforced with mild steel square mesh or according to the structural engineer's specifications. The slab is cast in situ on top of a well rolled or rammed base course and fill (Fig. 265). The bay sizes are usually determined by the room sizes of the building. For domestic works these do not normally exceed 3 to 5 m, which allows the slab to be cast in one go. For larger rooms, bay sizes, when casting, are between 3 to 5 and 5 to 7 m.

BASE COURSE AND FILL

All solid concrete floors are laid on a base course of well rolled laterite or hardcore (where this is available). The thickness of the base course should not be less than 150 mm or the thickness of the amount of surface soil

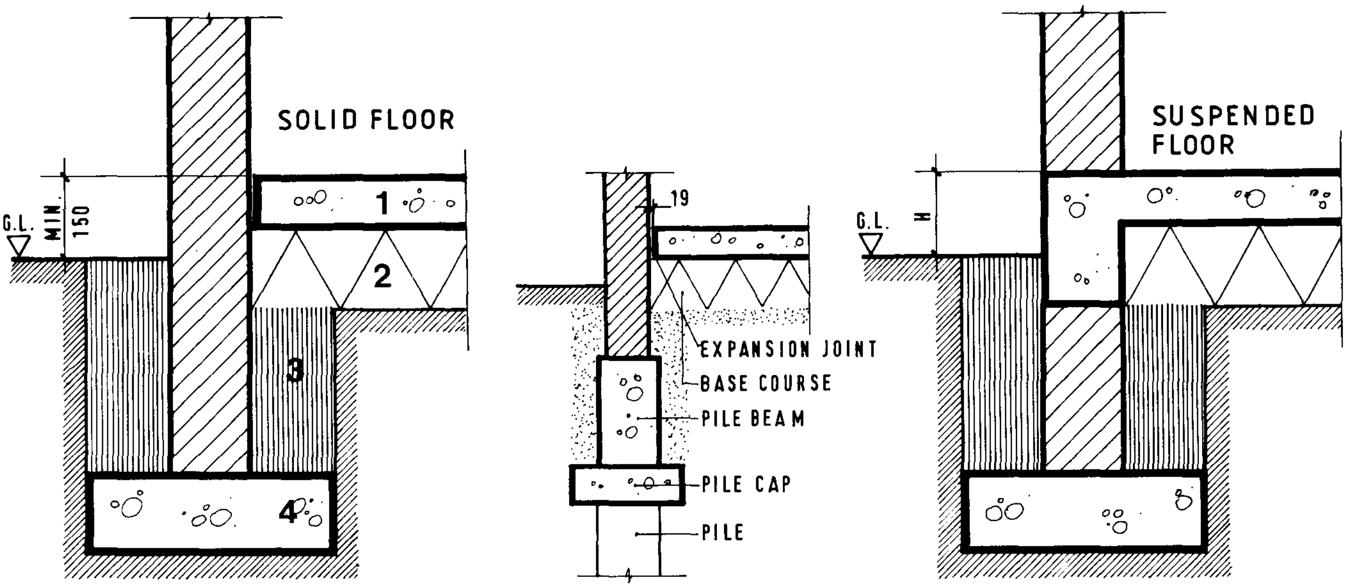
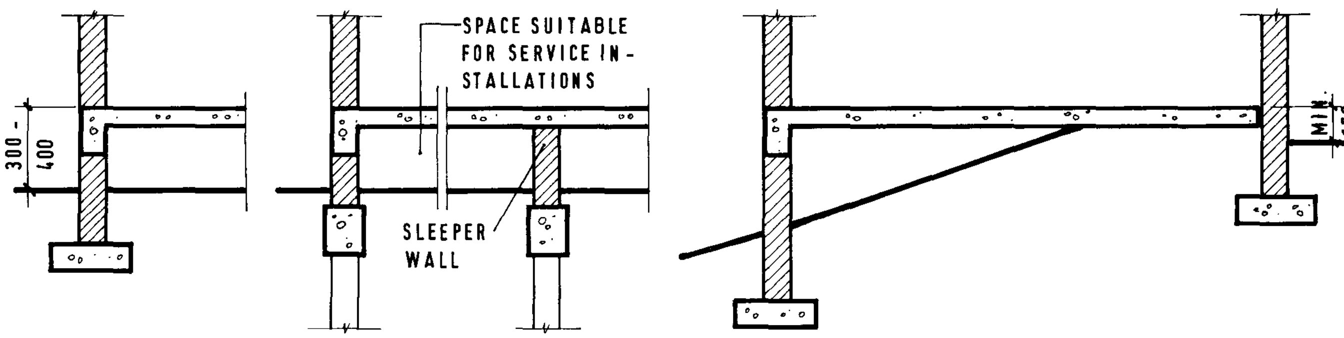


FIG. 264 : **SOLID AND SUSPENDED FLOOR**

1 REINFORCED CONCRETE FLOOR SLAB ;
2 BASE COURSE OF MIN. 150 mm THICK WELL ROLLED OR RAMMED LATERITE OR SUITABLE HARD CORE ;
3 HARD, WELL COMPACTED FILL TO AVOID SETTLEMENT;
4 FOUNDATION.

THE POINT BETWEEN THE REINFORCED CONCRETE SLAB AND THE EXTERNAL WALL CAN ABSORB EXPANSION AND CONTRACTION. IT IS ALSO A POINT WHERE DIFFERENTIAL SETTLEMENT MAY OCCUR AS IN THE CASE OF A GROUND-SUPPORTED SLAB ADJACENT TO A PILE-SUPPORTED WALL. A SUSPENDED FLOOR SHOULD BE USED IN THIS CASE.

H IN MOIST AREAS WITH HEAVY RAINFALLS HEIGHT H FROM G.L. (GROUND LEVEL) TO THE TOP OF THE FLOOR SLAB SHOULD BE 300 TO 400 mm.



SUSPENDED FLOOR IN MOIST CONDITIONS WITH STRIP FOUNDATIONS ON GOOD LOAD BEARING SOIL.

SUSPENDED FLOOR ON PILED FOUNDATION WITH A PILE BEAM GRID AT GROUND LEVEL AND SLEEPER WALLS.

IF THE GROUND FLOOR ON A SLOPING SITE IS NOT ARRANGED AT SPLIT LEVELS, THE FLOOR IS A SUSPENDED SLAB AT THE SLOPING END AND A SOLID FLOOR SLAB ON THE FLAT GROUND.

which has been excavated to remove all organic growth. The base course fulfills the following functions:

- It provides the correct surface and required level for the structural floor;
- It acts together with the structural floor in spreading point loads over a greater area;
- It restricts or reduces capillary movement of water from the ground upwards;
- It provides additional insulation.

The base course and fill material must be free of organic matter and of sulphates; it should be thorougly compacted (with a smooth-wheeled roller, hand or power rammers). The top of the fill or base course can be blinded with a final layer of finer material e.g. sand.

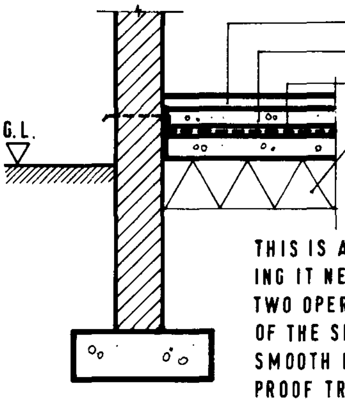
DAMP-PROOF BARRIER (Fig. 266)

In moist conditions this should be incorporated in solid floors to prevent rising damp from affecting the floor finish and entering the building. There are two ways of fixing this barrier:

- As **Damp-proof Membranes** (D.P.M.): From polythene, light-gauge P.V.C. sheeting or a 3mm thick hot bitumen layer under or between the floor slab or under the screed;
- As **Damp-proof Course** (D.P.C.): From the same material, in the external wall.

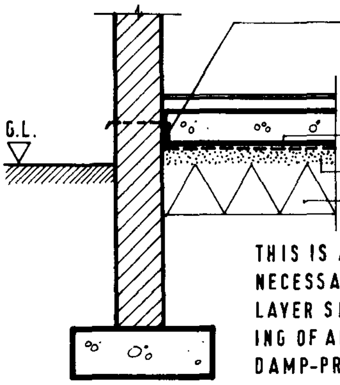
5.4.2.3 SUSPENDED FLOORS

If constructed near the ground level, a suspended floor which is supported from the foundation system performs more or less the same function as solid ground floors. If it is elevated well above the ground level, the space below can be utilized for service installations etc. A suspended timber floor (as detailed in part 4.9.3 **Timber and Timber**



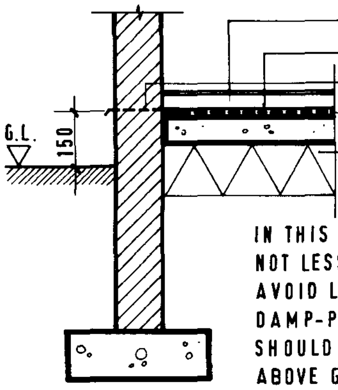
THIS IS AN EXPENSIVE METHOD, MAKING IT NECESSARY TO LAY THE SLAB IN TWO OPERATIONS. THE LOWER PORTION OF THE SLAB MUST BE BROUGHT TO A SMOOTH FINISH TO RECEIVE THE DAMP-PROOF TREATMENT.

SANDWICH MEMBRANE :



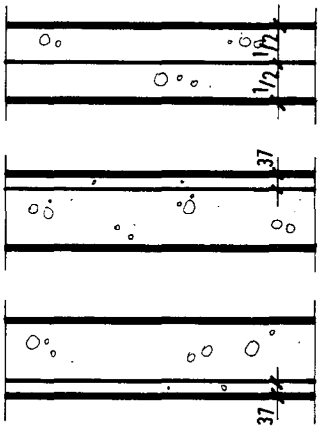
THIS IS A VERY POPULAR METHOD. IT IS NECESSARY TO FINISH THE BASE COURSE LAYER SMOOTHLY WITH A SAND BLINDING OF ABOUT 40 mm TO RECEIVE THE DAMP-PROOF MEMBRANE.

DAMP-PROOF MEMBRANE BELOW SLAB :



IN THIS CASE THE SCREED SHOULD BE NOT LESS THAN 50 mm THICK TO AVOID LIFTING UP OF THE SCREED. THE DAMP-PROOF COURSE IN THE WALL SHOULD NOT BE LESS THAN 150 mm ABOVE G.L.

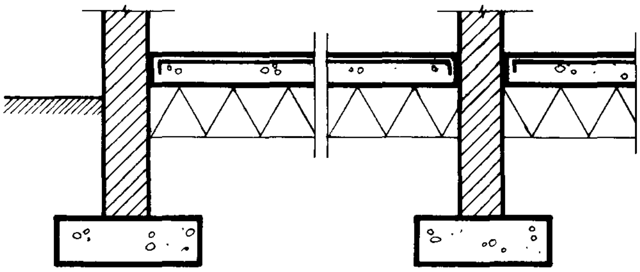
DAMP-PROOF MEMBRANE ABOVE SLAB AND BELOW THE SCREED :



REINFORCEMENT PLACED IN THE CENTRE OF THE SLAB TO COUNTERACT CONVEX AND CONCAVE BENDING. EFFECTIVE DEPTH OF SLAB REDUCED.

TOP REINFORCEMENT OF SOLID GROUND-SUPPORTED FLOOR SLAB. MINIMUM CONCRETE COVER 37 mm.

BOTTOM REINFORCEMENT OF SUSPENDED FLOOR SLAB. ALSO UNDER PARTITION WALL IN CASE A RAFT FOUNDATION IS USED AS GROUND FLOOR SLAB.



SOLID FLOOR

SUSPENDED FLOOR

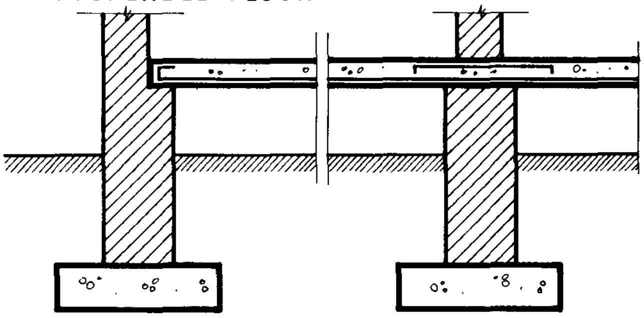
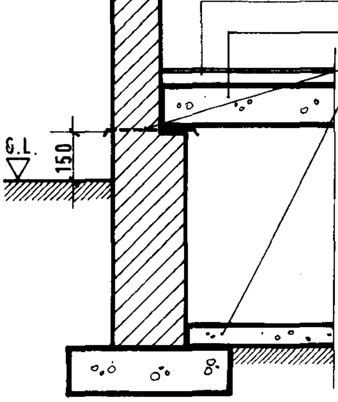
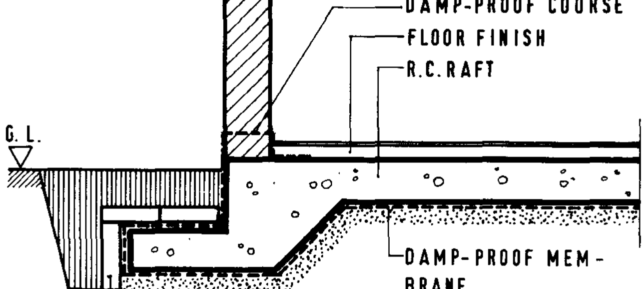


FIG. 265 : **POSITION OF REINFORCEMENT IN SOLID AND SUSPENDED FLOOR SLABS.**



IF THE SUSPENDED FLOOR IS LAID ABOVE A SPACE USING SITE CONCRETE TO COVER THE GROUND BELOW THE SPACE, THERE IS NO NEED FOR A DAMP-PROOF MEMBRANE.

DAMP-PROOF COURSE BELOW A SUSPENDED FLOOR SLAB :



DAMP-PROOF MEMBRANE BELOW RAFT :

FIG. 266 : **DAMP-PROOF BARRIERS**

Frame Construction, Floor Construction and Finishes) can be cheaper than a solid concrete slab, especially in timber housing and also in small buildings, especially on sloping sites. In the case of a suspended floor the wall and floor are both supported from one and the same foundation system; the question of any differential settlement does not arise here. In case of a suspended timber floor with brick or block walls as external walls, a protective layer of sand blinding (with a damp-proof membrane) or oversite concrete (about 100mm thick without damp-proof membrane) is necessary (Fig. 267).

5.4.2.4 UPPER FLOORS

These span between supporting structures, reinforced concrete frames (columns and beams) or loadbearing walls.

Relatively poor load carrying capacity limits the use of suspended timber floors to buildings not higher than two or three storeys. An upper timber floor has, moreover, to be constructed in such a way that sound transmission is reduced to an acceptable minimum.

A suspended reinforced concrete floor can be cast monolithically in situ or it can be formed of a series of pre-cast units. The in situ floor forms an integral part of the structural framework of the building (columns, beams, walls) so that the floor, in turn, adds to and forms part of the structural stability and strength of the building. Holes for service-pipes, conduits and ducts can easily be incorporated in the floor design. Pre-cast units are more useful for multiple regular layouts, e.g. flats, offices, with a great deal of repetition of floor areas.

For two- or three-storey structures the beam and slab system is usually chosen in tropical developing countries. Although an in situ slab needs a lot of formwork to support the concrete until it has set and matured, labour costs are low, so the time-cost factor, dictating the coice of a construction system in industrialized countries, does not apply. Flush slabs, incorporating the beam, can be useful for spans up to 4.5m in spaces with limited headroom. For multi-storey structures with columns and supported beams far apart, a normal reinforced concrete slab would become very thick and heavy. In this case intermediate beams can be placed between the main supporting beam, forming a grid of 1m to 1m. The "waffle-grid" floor slab, which is supported like this, is normally quite thin (Fig. 268).
One of the disadvantages of an in situ reinforced concrete slab is its weight. By using hollow pre-cast units (from burnt clay or concrete) the weight of the slab can be considerably reduced.

- **Burnt Clay Units (Hollow Pots):** These units should contain some vitrifying materials. Their surfaces are smooth and hard after burning. Formwork for casting is the same as for a reinforced concrete slab. The hollow pots are placed in line on the formwork with a space of 75mm between each line. Mild steel reinforcement (2 of 10mm diameter) is laid in the space between the pots on small pieces of broken clay tiles. Concrete is then cast and compacted between the pots and in a 50mm thick layer on top of them. A variety of different "pot floors" have been designed and many are proprietary systems, but any wellfired clay hollow pot of a size approximately 300 × 300 × 75 to 200mm thick with good indentions and grooves to provide a "key" for the concrete cast around the pot could be used. A hollow pot slab is quite ideal for domestic floors, flats, offices, shops and for floors which do not have to support heavy loads.
- **Pre-cast Concrete Floors:** These factory-made floor units do not need formwork. They can be hoisted into position, and immediately support the loads for which they are designed. As with any prefabricated unit, close supervision during the factory production process guarantees a finished product of high quality and accuracy, with the correct concrete mix and finish, completely cured. Their disadvantages are that, for the most economic construction, a certain standardization of the unit sizes is desirable, a condition which is not yet met in most of the tropical developing countries.
As with the hollow pots, pre-cast concrete floor units are offered in many proprietary systems, which can be grouped into two categories:
- **Pre-cast Reinforced Concrete Beams:** These are laid between supports and in turn support hollow filler blocks with an in situ screed on top;

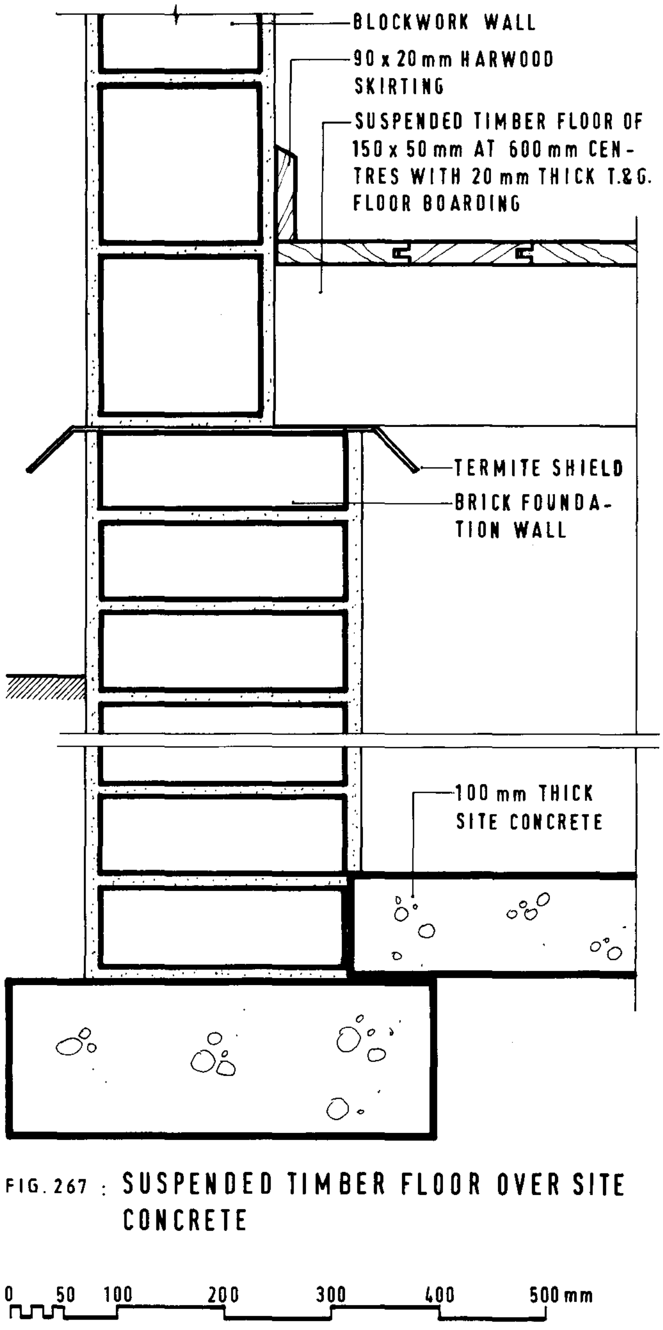
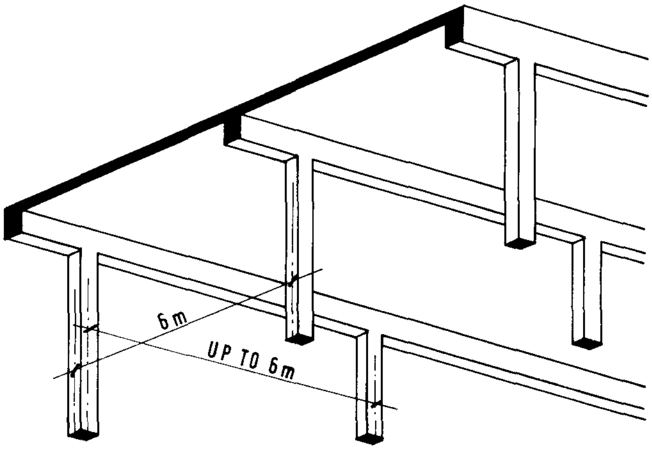
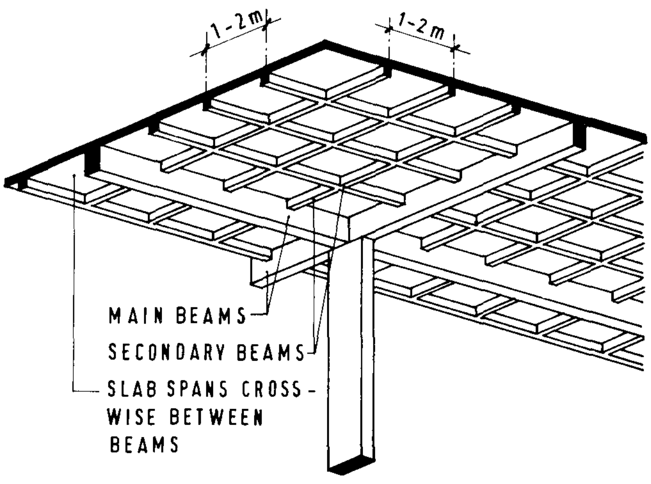


FIG. 267 : SUSPENDED TIMBER FLOOR OVER SITE CONCRETE



BEAMS AND SLAB : MAXIMUM SPAN IN EITHER DIRECTION 6 METRES.



WAFFLE-GRID SLAB : MAIN BEAMS SUPPORTED BY COLUMNS, SECONDARY BEAMS BETWEEN MAIN BEAMS.

FIG. 268 : **REINFORCED CONCRETE UPPER FLOORS**
FROM "FLOORS" BY G. HALE, ESSENCE BOOKS ON BUILDING, THE MACMILLAN PRESS LTD., LONDON.

- **Hollow Pre-cast Reinforced Concrete Slabs**: These are laid side by side between supports with an in situ screed or concrete topping. One of the common pre-cast concrete units is the so-called Bison-slab designed by Messrs. Concrete Limited, England, using foamed plastic cores to form voids in the pre-cast unit, thus reducing the thickness and therefore decreasing the weight of the unit. Bison slabs are produced from 3m to 15m lengths, 400 to 1200mm widths and 100 to 200mm thicknesses. Pre-stressed units are also manufactured.

5.4.2.5 FLOOR FINISHES

Floor finishes are the finishing layers over or coverings of the structural floor. Their functions are:

- To have a high wearing resistance and long life span;
- To provide a safe, non-slip and easy-to-clean surface of the floor;
- To increase the structural floor's fire-, insect- and termite resistance;
- To reduce sound transmission and to provide insulation;
- To contribute to the aesthetic effect of the interior of a building (this is more important in sparesely furnished areas like galleries and foyers, where a large proportion of the floor area is exposed and therefore influences the total aesthetic appearance of the room);
- To have a high enough degree of flexibility, so as not to be affected by slight shrinkage, settlement or thermal movement in the structural floor (or sub-floor).

SCREEDS

These are used in many cases as an intermediate element (or sub-floor) in the form of a cement-based layer to provide a level surface for the final finish. They are normally used in conjunction with a concrete floor, for which they fulfil principal functions:

- They provide a smooth surface for other finishing materials (thin tiles, sheets and wood blocks or mosaic flooring panels);
- They restore a damaged surface of the concrete floor. Screeds are normally applied late in the construction programme, after all rough work has been completed;
- They accommodate shallow service ducts, piping or conduits for electrical power and communications (Fig. 269);
- They lessen sound transmission (in upper floors).

Screeds are normally dense cement-aggregate mixtures (coarse sand) in the ratio of 1:3 or 1:4 (one part Portland cement to 3 or 4 parts coarse sand). Screeds of more than 40mm thickness should be mixed with an additional graded aggregate to form a fine concrete.

There are three ways of laying screeds:

- On new (green) concrete, forming a monolithic slab;
- On cured concrete;
- On an old concrete surface (Fig. 270).

Laying of screeds is done in rectangular bays which should not exceed 15m^2 in large areas (or $3x = 2y$, x being the width of the bay). A 25mm thick screed is cured in one month, only then should the final finish be laid on top.

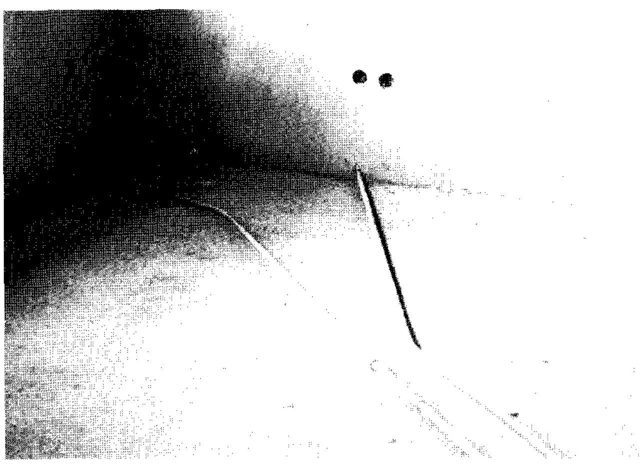


Fig. 269: Service conduits on floor slab before screeding, U.S.T. Medical School site, 1982. Project Office, Faculty of Architecture, U.S.T.

A screed can form a finish by itself, if it is applied in a thickness of up to 75mm (rather as a fine aggregate concrete, with aggregate from 9mm down) for factory and warehouse use. A surface hardener (solution of *Calcium Chloride* or *Sodium Silicate*) can improve its wearing resistance. Its appearance, however, is rather dull, it is easily stained and has a hard, but noisy surface. Another screed used mainly in factories, warehouses, storerooms etc. is the so-called granolithic screed, a screed with an aggregate of fine granite chippings. If laid on green concrete to a thickness of 20mm, it matures together with the concrete into a hardwearing monolithic floor. If the concrete is cured, the screed applied should be 40mm thick or more. Unless used together with pigmented cement, the finished floor is of unattractive appearance, but when painted with different types of floors paints (normally light grey or terracotta red) the finished surface can receive floor polish and makes this type of floor and its maintenance quite cheap. Again, this is a hard, but noisy floor.

Floor finishings can be grouped into four main groups:

I. **Hard Monolithic Floors** (with expansion joints or panelling joints);
II. **Hard Tiled floors;**
III. **Resilient Floors**: Thin tiles and sheets, carpets and wood flooring;
IV. **Special Floors**: Sound-proof floors, spring floors, cavity floors, special industrial floors.

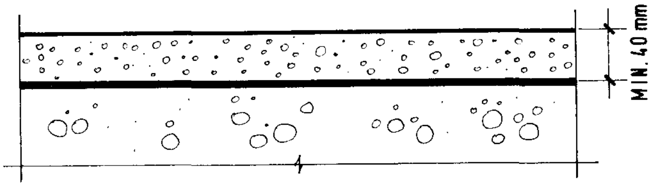
I. HARD MONOLITHIC FLOORS

Screeds, concrete floor finish and granolithic screed have already been described. The other finishes in this group are:

- **In-situ Terrazzo**: This floor finish consists of an aggregate of crushed marble (or any other suitable substitute with a thickness of 1 to 10mm) which is laid on a screeded bed of not less than 20mm thickness into which plastic dividing strips are anchored (or strips of brass, copper or ebonite). The bays or panels should not exceed 1.2 m^2. The terrazzo topping of about 15mm thickness should be laid whilst the screed is still green (normally within 3 hours), after which both are compacted together and trowelled smooth. After the terrazzo is cured (which takes the same time as the curing of ordinary screed, one month), the surface of the terrazzo will receive the final finish in a grinding process which is carried out with power operated machines using abrasives. Terrazzo is a hard finish of no resilience, a totally non-combustible material, but not insulative. It has very good wearing qualities. If it is highly polished, it is slippery when wet. With different coloured chippings a very attractive floor of different patterns can be designed (Fig. 271 *and* 272).
- **Mastic Asphalt and Pitch Mastic**: These are finishes based on asphaltic bitumen with rock aggregates and silica aggregates bonded with coal or pitch. Where these materials are available, the floor finishes are very useful in factories, dairies, breweries, battery rooms, cold stores or warehouses. Both finishes are spread hot (180–210°C) and laid in thicknesses from 16 to 25mm depending on the anticipated traffic. A 16mm thick layer is suitable for domestic floors and office floors with light traffic (in colours of red, brown and green; normal colour is black). The finish can be polished glossy or matt (produced by a final dressing of fine sand or stone dust or carborundum grit to make it non-slip). If used on the ground floor the damp-proof membrane can be omitted. The floor finish is water- and vapour-proof.
- **Epoxy Resin**: This floor finish is based on polymer compositions which can be spread thinly onto a concrete or screeded sub-floor. It is a hard and very tough finish, but very expensive. Epoxies are thin (about 3mm thick); they are compounded of a resin and hardener mixed 1:1 together with appropriate fillers (*Aluminium oxide* or different types and sizes of mineral fillers). They cure in a short time (3 days to one week) and are resistant to all chemical liquids and water. Their main use is in laboratories.

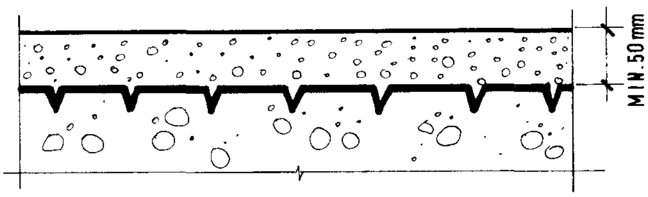
ON NEW CONCRETE :

THE SCREED IS LAID WITHIN 3 HOURS OF LAYING THE FLOOR SLAB, THE BASE CONCRETE IS STILL "GREEN". THIS SYSTEM IS USED IN SMALL AREAS WHERE NO SERVICES ARE BEDDED INTO THE SCREED.



ON CURED CONCRETE :

THE NORMAL WAY OF LAYING SCREED IS ON CURED CONCRETE. SERVICE CONDUITS CAN BE LAID ON TO THE HARDENED CONCRETE SLAB BEFORE THE SCREED IS LAID. THE SLAB SURFACE MUST BE LEFT SUITABLY ROUGHENED TO RECEIVE THE SCREED.



ON OLD CONCRETE :

SCREED IS LAID ON OLD CONCRETE IN THE SAME WAY AS ON CURED CONCRETE. THE SLAB SURFACE MUST BE FREE OF ANTI-BONDING SUBSTANCES (GREASE, OIL) AND WELL HACKED BEFORE THE SCREED IS LAID.

FIG. 270 : LAYING OF SCREED

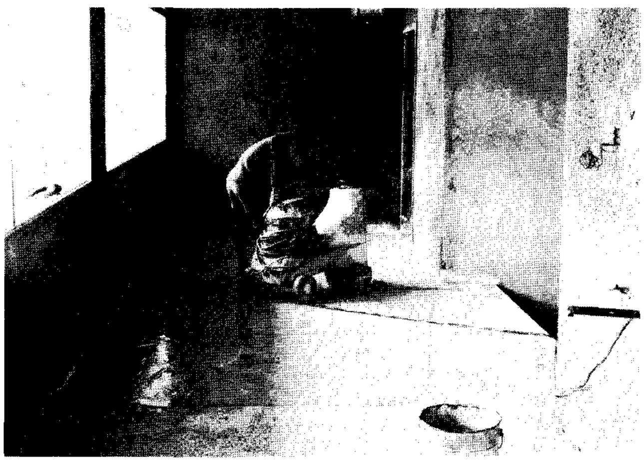


Fig. 271: Polishing of in situ terrazzo floor in the office wing of the Parliament House extensions, Accra, 1971.

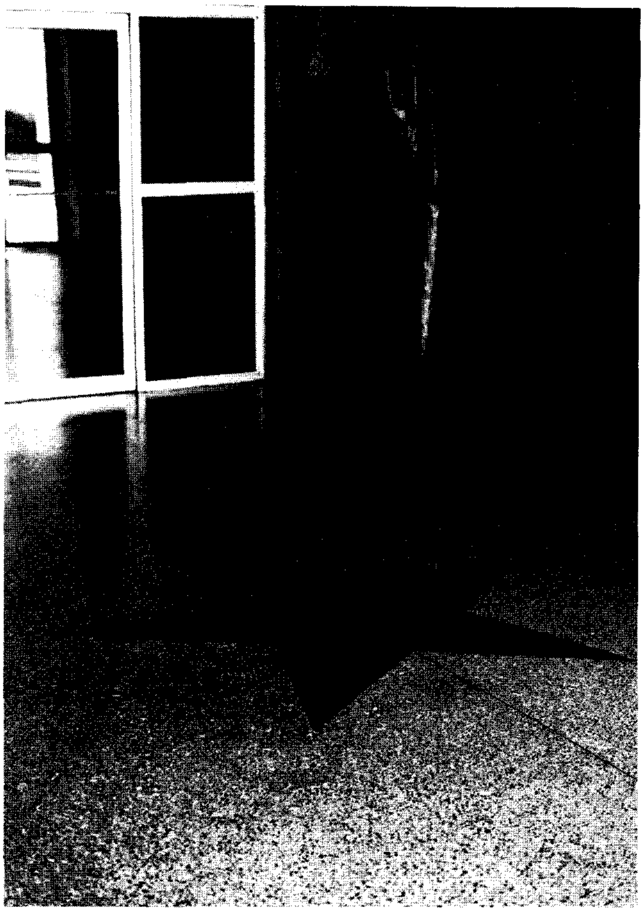


Fig. 272: The in situ terrazzo floor in the entrance hall of Parliament House, Accra, 1971. Architect: HANNAH SCHRECKENBACH.

II. HARD TILED FLOORS

These include all hard materials laid in separate pieces on a screed or thin or thick mortar bed of cement sand mortar (mix of 1:3) from 10 to 20mm thickness, thinner than the tile itself.

- **Concrete and Terrazzo Tiles**: These are produced in sizes from 100mm × 100mm to 450 × 450mm and in thicknesses from 15mm to 35mm. The most common terrazzo tile size is 300 × 300 × 15. These tiles are laid on cement sand mortar onto a clean and well-wetted concrete sub-floor (Fig. 273).
- **Quarry and Clay Tiles**: The word "quarries" derives from the French word carre = square. Quarry tiles (normally from 100mm square to 300mm square and in thicknesses from 16mm to 40mm) are made from unrefined clays pressed into dies and burnt hard in kilns. They have a pleasant rustic appearance with a rough surface and are normally in colours of different shades of reds, browns and buffs. Clay tiles are made from refined clays to a much greater accuracy and fired at a higher temperature (1000 to 1200°C) which results in smooth and even tiles in sizes from 75mm square to 150mm square by 10 to 12.5mm thick. Clay tiles can be produced with smooth, grooved or studded surfaces (Fig. 274). They are normally keyed underneath to bond well with the mortar bed (normally 20mm thick cement sand mortar). Quarry and clay tiles have a tendency to expand when wet. It is therefore necessary to provide expansion joints passing through the full depth of the tile and bedding at every 7m centres.
- **Ceramic (or Vitreous) glazed Tiles and Mosaic**: Vitreous tiles are clay tiles which are burnt at temperatures higher than 1200°C and incorporate calcium, flint and feldspar. They are virtually unaffected by oils and chemicals and are impervious. Surfaces can be made nonslip by graining or studs. They are produced in sizes from 100 × 100mm to 150mm square and 4 to 16mm thick and used in laboratories, breweries, bathrooms, toilets, kitchens, etc. Mosaic consists of highly fired clay or glass in smaller units, about 20 to 25mm square which are attached to sheets of thick paper in squares of 300mm. They are fixed similar to vitreous tiles on a cement mortar bed upside down, after which the backing paper is soaked off. Mosaics are used for decorative floors etc.

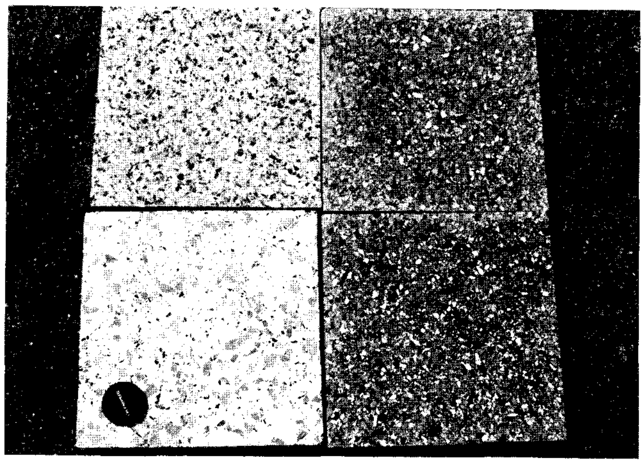


Fig. 273: Terrazzo tiles (A. Lang Ltd., Tema).

- **Natural Materials**: These are stone flags and marble slabs and used for purely decorative flooring or utilitarian floors taking heavy traffic (mainly outdoors). Bedding depends on out- or indoor application.

III. RESILIENT FLOORS

- **Thin Tiles or Sheets**: These floor finishes, especially the plastic sheet and tile materials have developed mostly after World War II:

(a) **Rubber**: Natural rubber is a traditional flooring material (synthetic rubber also) and one of the best. Rubber sheets are 3.2, 4.8, 6.4mm thick and produced in rolls of 900 to 1800mm widths. A full range of plain or mottled colours is available. Rubber flooring is fixed with rubber-based adhesives to any suitable, smooth sub-floor. It has excellent wearing properties and is non-slip. Thicker grades are used in hospital corridors. The material is sound absorbing. It is resistant to surface water and weak acids, but susceptible to fats, oils and grease.

(b) **Linoleum**: A plastic mass is prepared from cork granules and wood powder as fillers together with oxidized linseed oil and pressed as a smooth sheet onto a jute canvas backing (or on to bitumen saturated felt paper). The flooring can be produced as tiles from 2.5 to 3.2mm thickness or sheets from 1.4 to 6mm thickness and 1800mm to 2000mm widths. Colours can be printed on to the linoleum or incorporated during the production process. It is a quiet, hardwearing, easy to maintain resilient flooring material, which is resistant to oils, fats and weak acids.

(c) **Cork**: Granulated cork is compressed and baked into blocks, bonded with natural resins. Tiles are cut from the blocks to a thickness of 4.5mm upwards and 300 × 450mm in size. To prevent dirt absorption a suitable surface sealer should be used. Cork tiles are sound absorbing, hard-wearing and of pleasant appearance.

Fig. 274: Ceramic floor tiles (PLATT, Stoke-on-Trent, England).

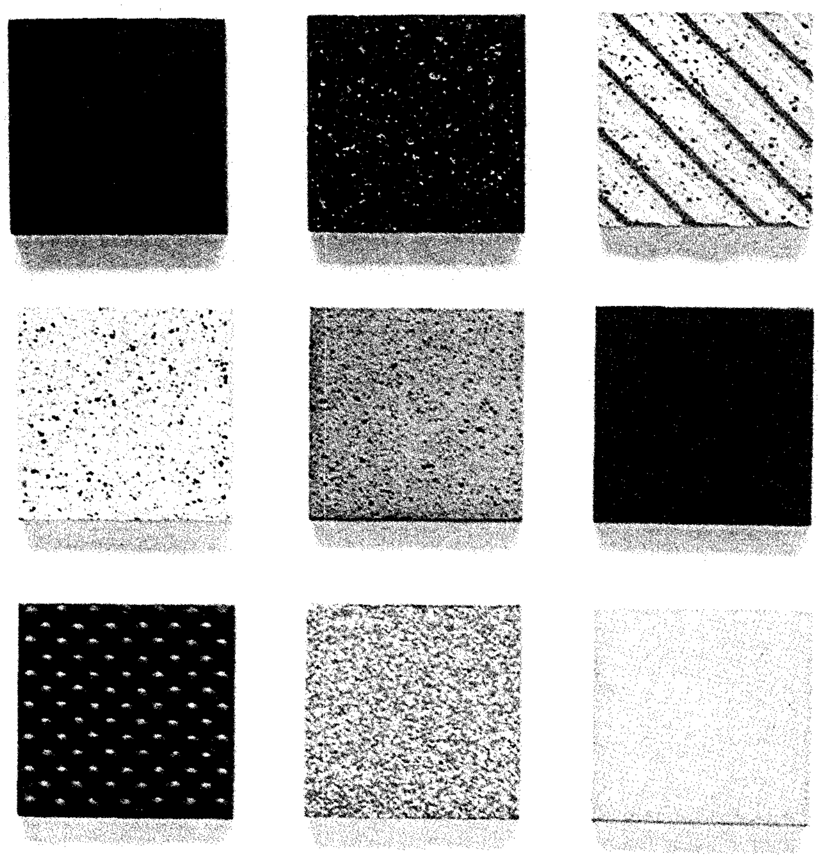
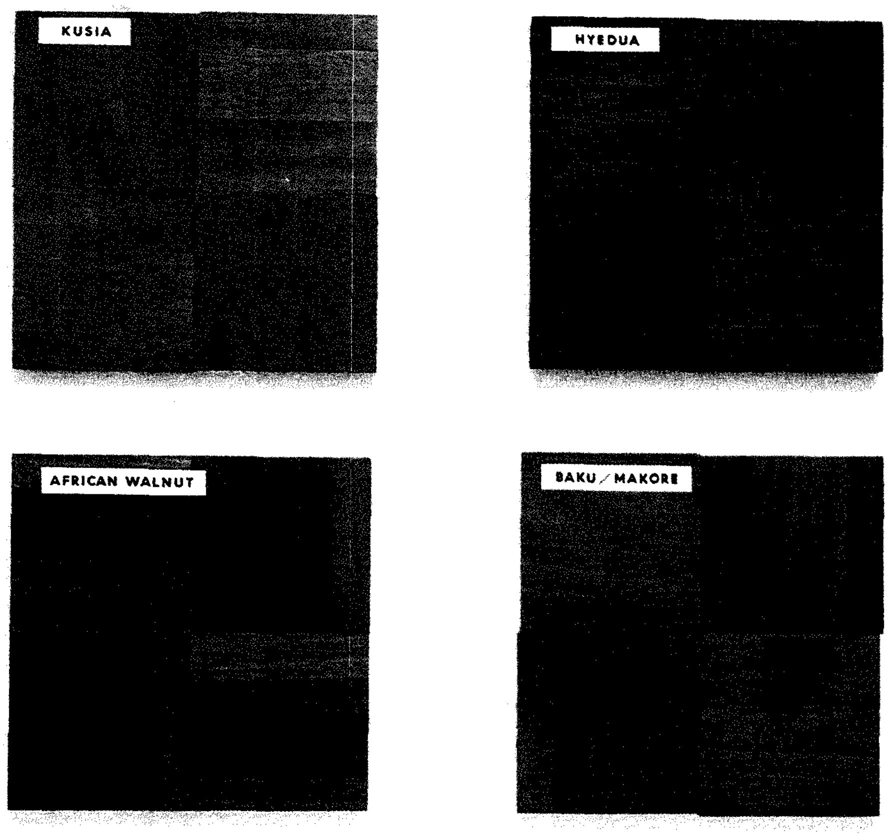


Fig. 278: Mosaic wood flooring panels, made by A.T.P. Ltd. (Samreboi), 1970.



Thick cork tiles are used as insulation materials in cold stores. Cork granules can also be bonded with linseed oil to a jute canvas backing, 3.2 to 4.5mm thick and about 1800mm wide and used as sheet flooring similar to linoleum (surface sealing is essential).

(d) **Flexible P.V.C. Sheets and Tiles**: These are based on *Polyvinyl chlorid resin.* The higher the P.V.C. resin content, the greater the flexibility of the material. A smooth base is necessary, application to the base is always by adhesives. This flooring material is produced in an unlimited colour range, its performance and durability has been well proved for many years. Tiles are normally 300 × 300 × 2mm thick. Sheets are about 2400mm wide. This flooring material is highly resistant to wear and chemical corrosion, it has good non-slip properties and is widely used in domestic buildings, restaurants, shops, offices, hotels and hospitals etc.

(e) **Thermoplastic Tiles**: These are based on mineral asphalt or pitch containing plastic resin additives. Normal domestic grades are about 1mm thick. They are quite brittle at normal temperatures.

(f) **Vinyl Asbestos Tiles**: These were developed from the thermoplastic tiles using only P.V.C. resin as binder and asbestos fibre with mineral fillers and pigments as base. As with the thermoplastic tiles these must be warmed before fixing with bituminous adhesives on to a smooth surface (Fig. 275).

(g) **Fitted Carpets** (from wall to wall): These are used as floor covering in a wide variety of materials (wool, nylon, acrylic, rayon, sisal etc.) or a mixture of them (e.g. 80% wool + 20% nylon etc.). Carpets require a flat, dry and even sub-floor. At ground floor level a damp-proof membrane must be incorporated in the sub-floor. Carpets are always laid on an underlay from synthetic fibres, felt or foamed rubber latex, if they do not have an integral foam latex backing. Fixing of carpets, done by trained experts, is either by nailing or hooking on to a special gripfast strip (smooth edge) around the room's perimeter or by adhesive. Whilst laying, the carpet material (which should be moth-proof and non-creep) must be properly stretched. Fitted carpets which are very resilient, quiet and insulative, are used in living rooms, hotels, reading rooms of libraries, board rooms etc. (Fig. 276).

(h) **Wood Flooring**: Wood, being an organic material, makes a very beautiful floor surface, which has also a degree of resilience and good wearing and insulative characteristics. Since the principal risk involved in the use of wood floors is shrinkage, timber used for flooring must be properly kiln-dried to the required moisture content. (Continued on page 191).

The following pages show details of different floors and floor finishes.

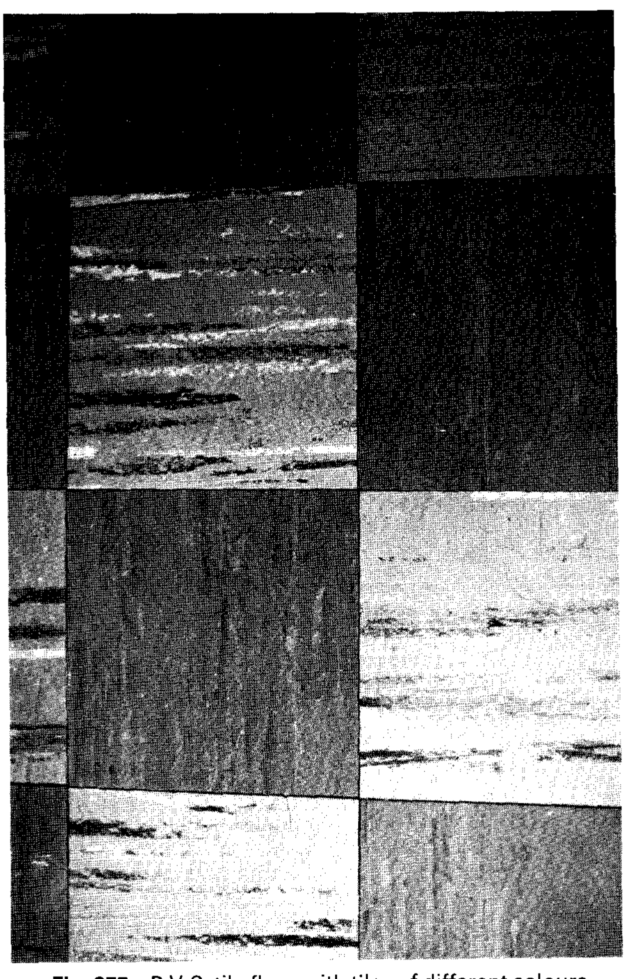
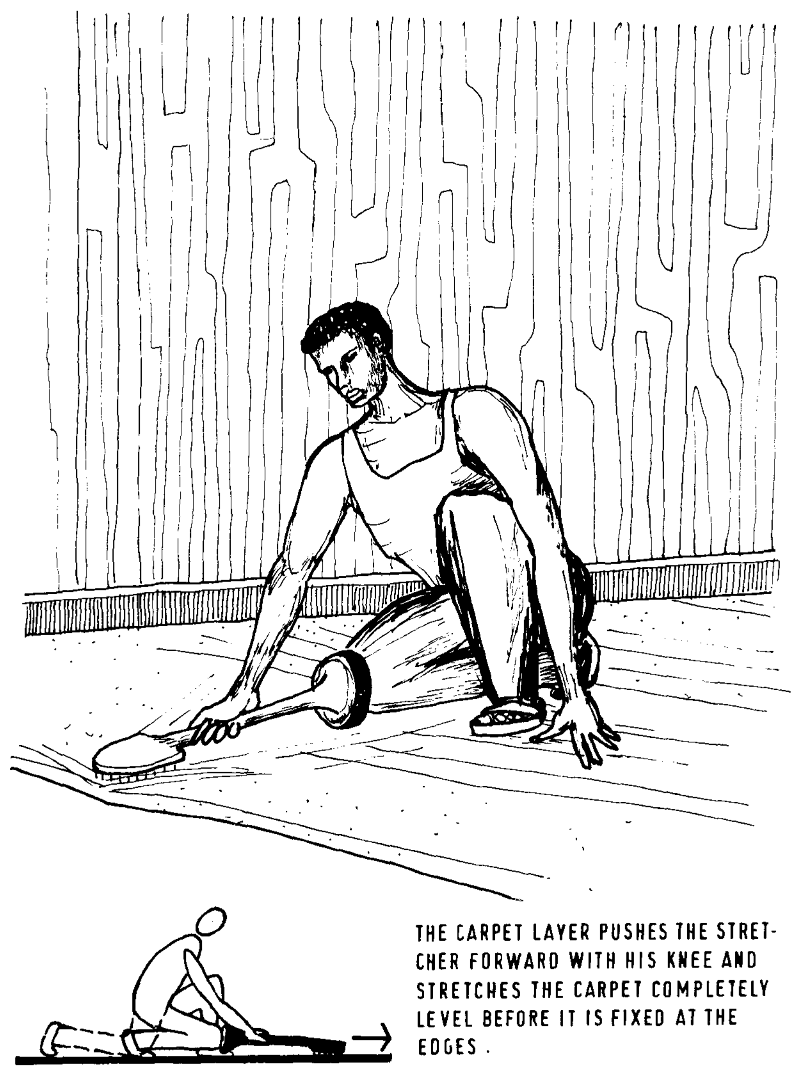


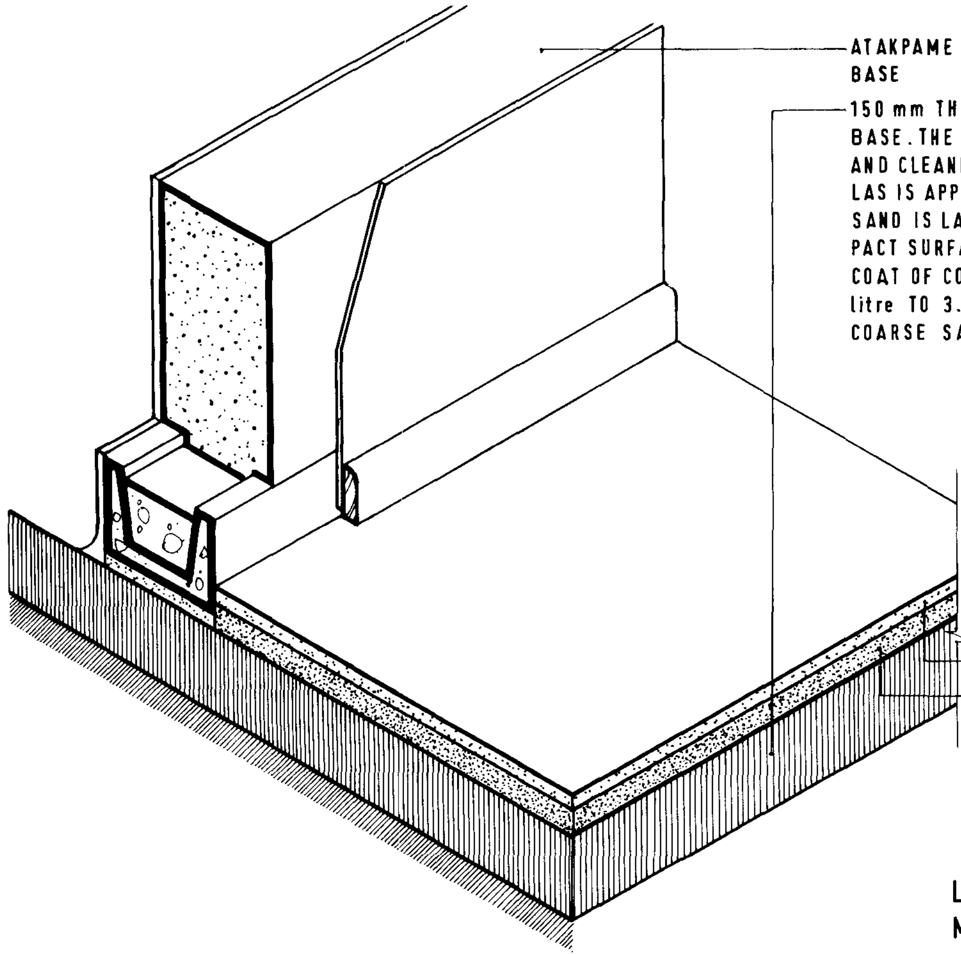
Fig. 275: P.V.C. tile floor with tiles of different colours.



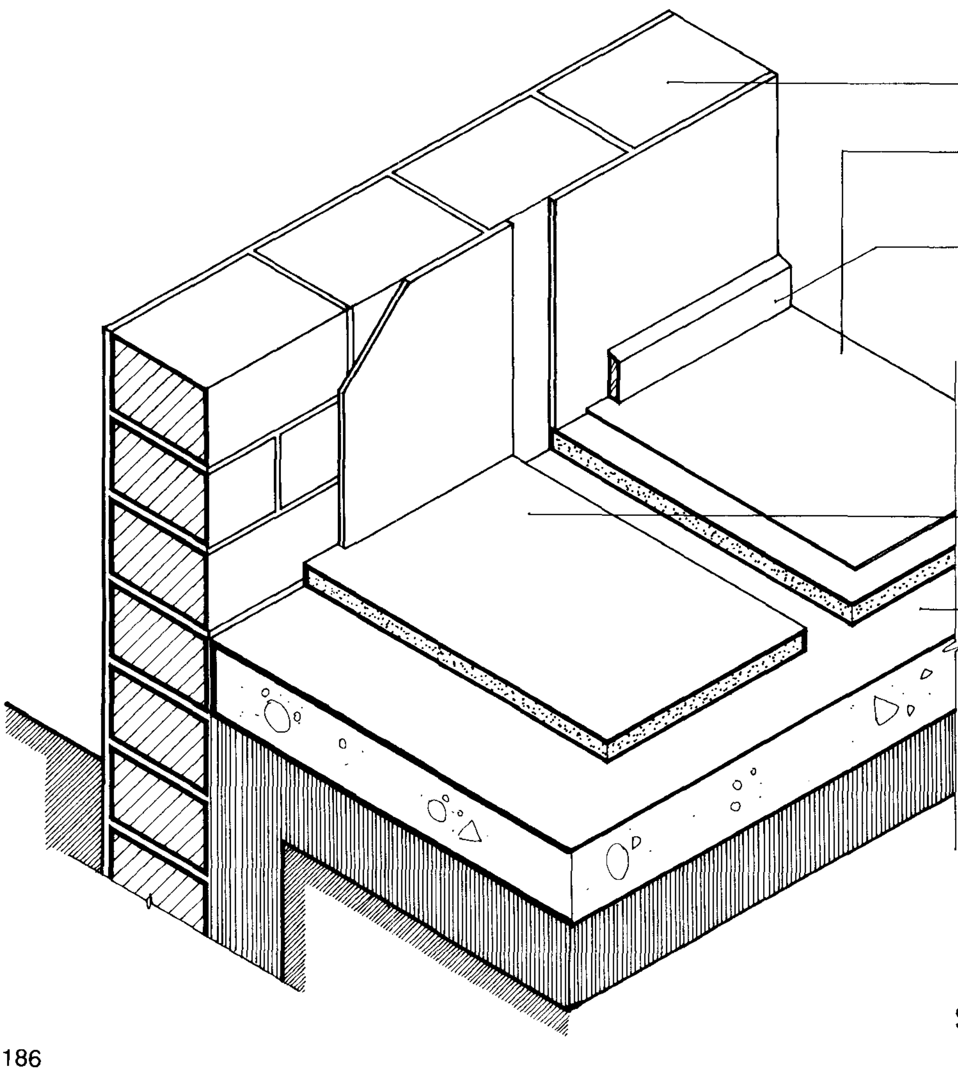
THE CARPET LAYER PUSHES THE STRETCHER FORWARD WITH HIS KNEE AND STRETCHES THE CARPET COMPLETELY LEVEL BEFORE IT IS FIXED AT THE EDGES.

FIG. 276 : FITTED CARPETS

5.4.2 FLOORS AND FLOOR FINISHES

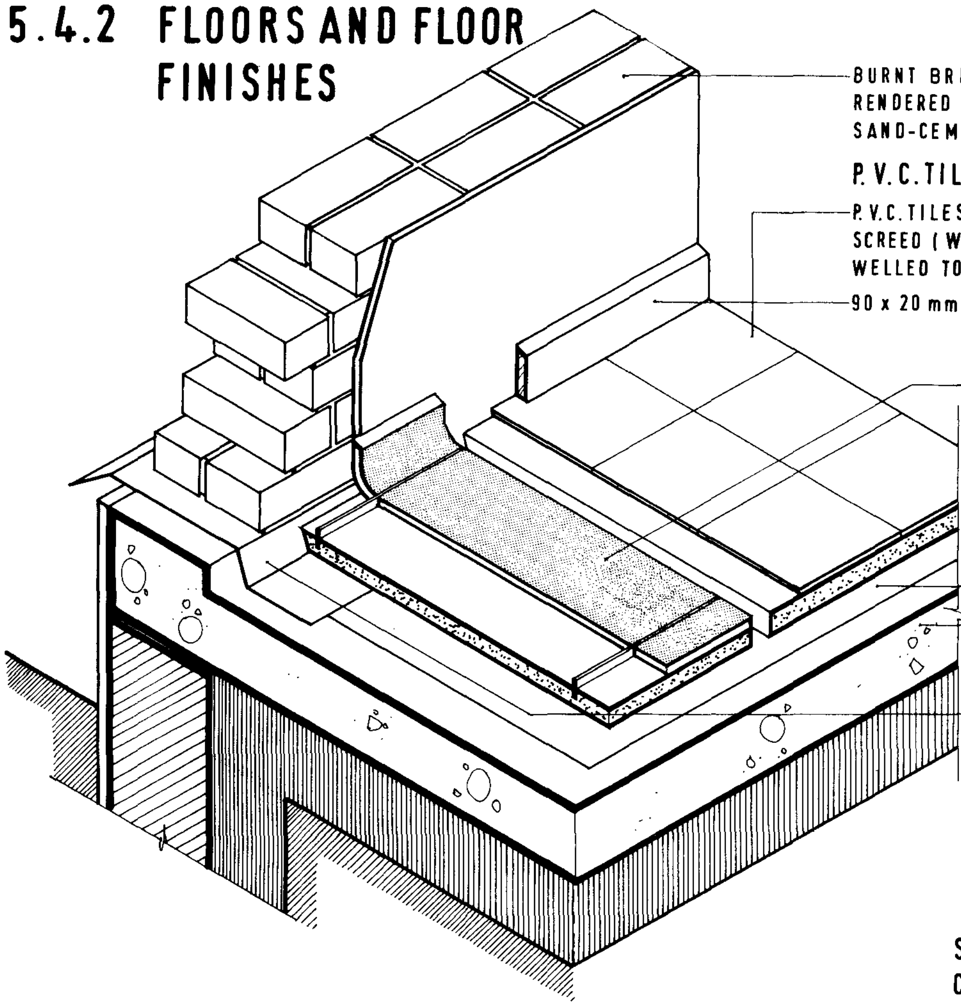


LOW-COST FLOOR FOR ATAKPAME OR SOIL BLOCK HOUSE



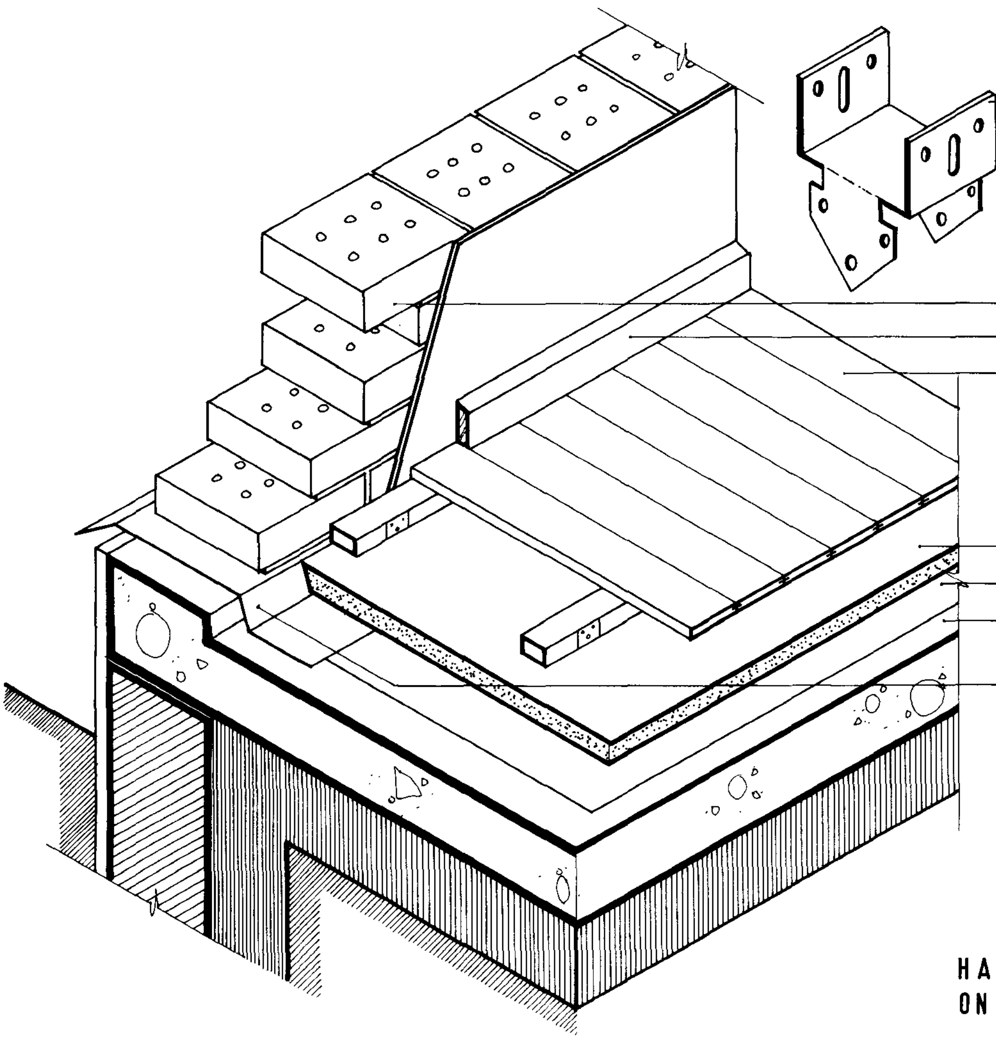
SOLID CONCRETE FLOOR

5.4.2 FLOORS AND FLOOR FINISHES



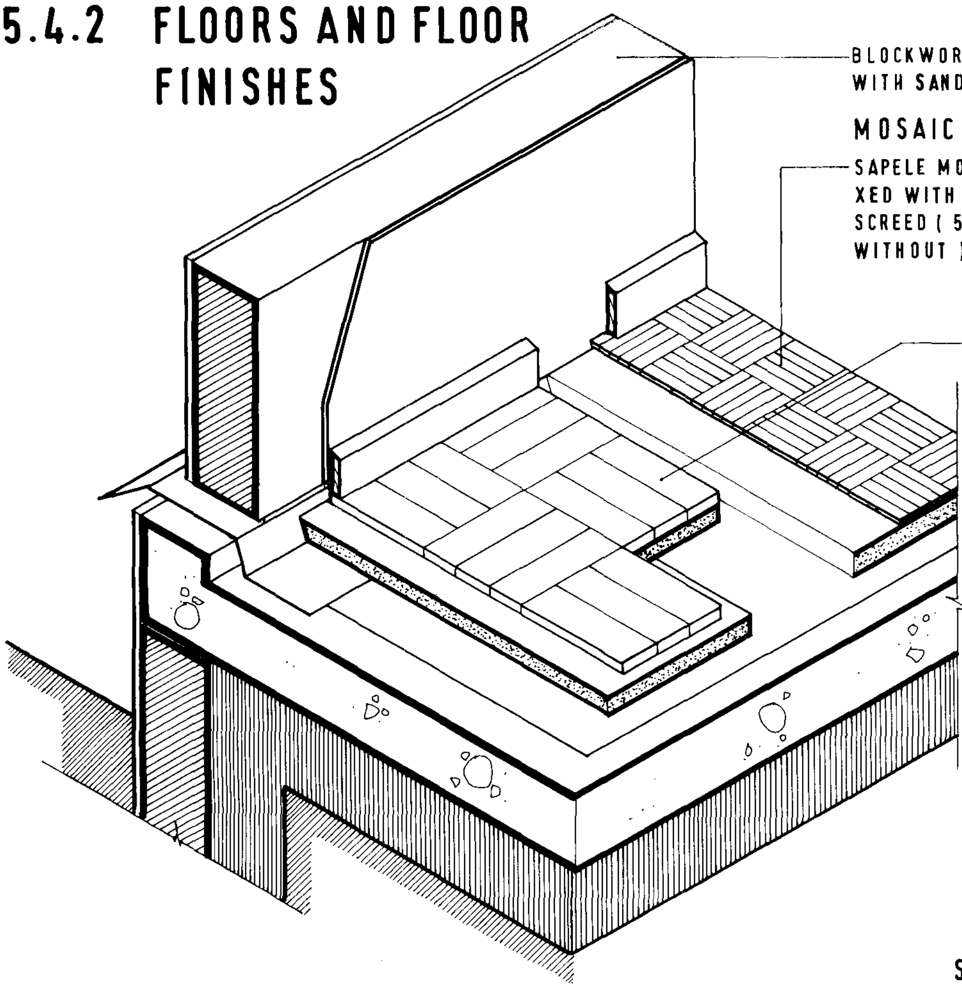
SUSPENDED REINFORCED CONCRETE FLOOR

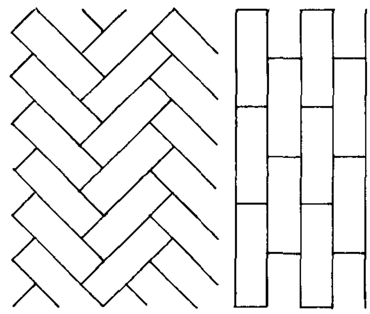
FIG.277: GALVANIZED PRESSED STEEL FLOOR CLIPS SET 600 mm APART INTO THE SCREED. (FROM :"FLOORS" BY G.HALE, MACMILLAN PRESS LTD.LONDON)



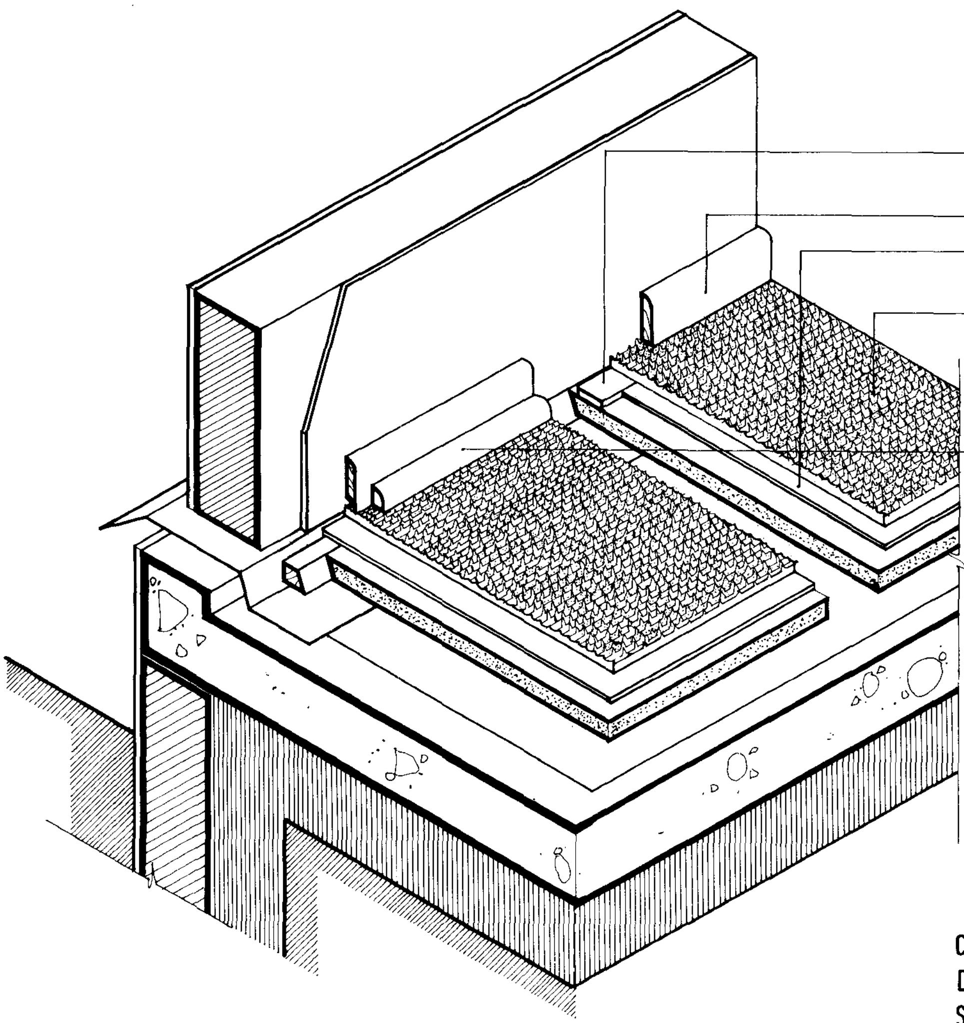
HARDWOOD STRIP FLOORING ON SUSPENDED CONCRETE FLOOR

5.4.2 FLOORS AND FLOOR FINISHES



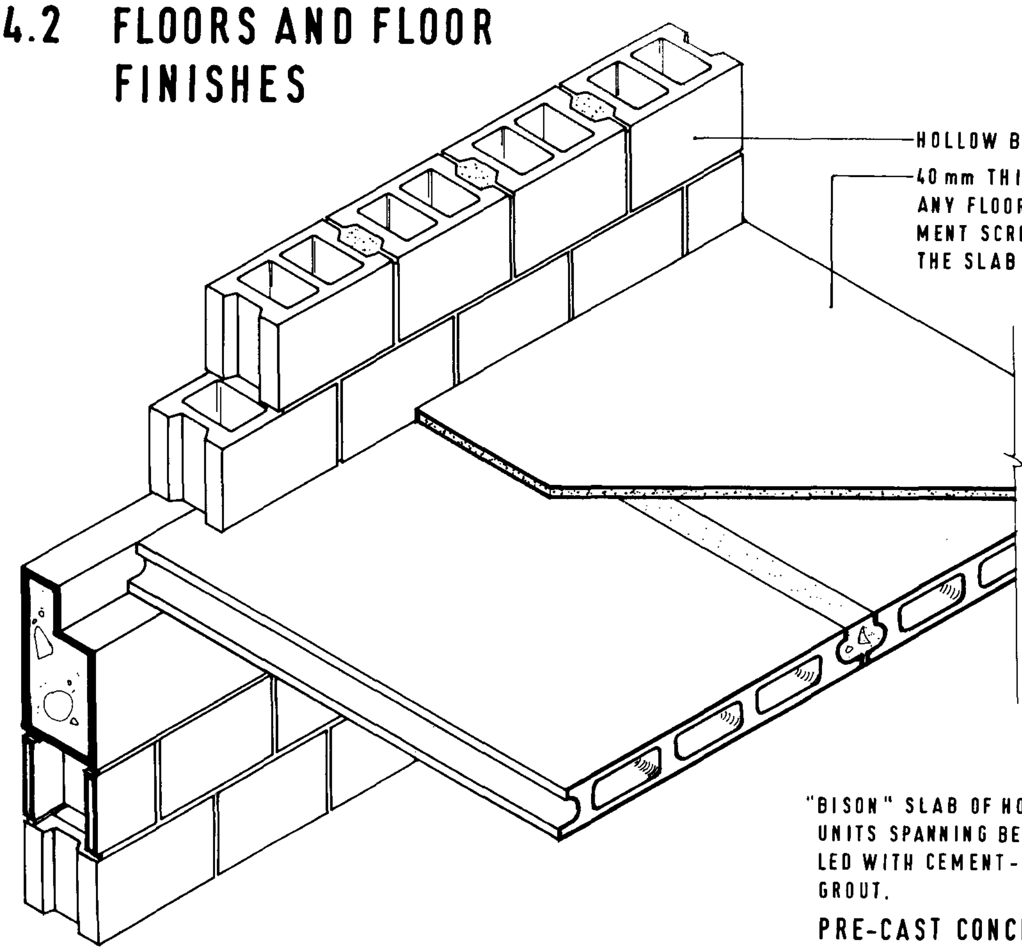


SUSPENDED CONCRETE FLOOR



CLOSE CARPETING ON SUSPENDED REINFORCED CONCRETE SLAB AT GROUND FLOOR LEVEL

5.4.2 FLOORS AND FLOOR FINISHES

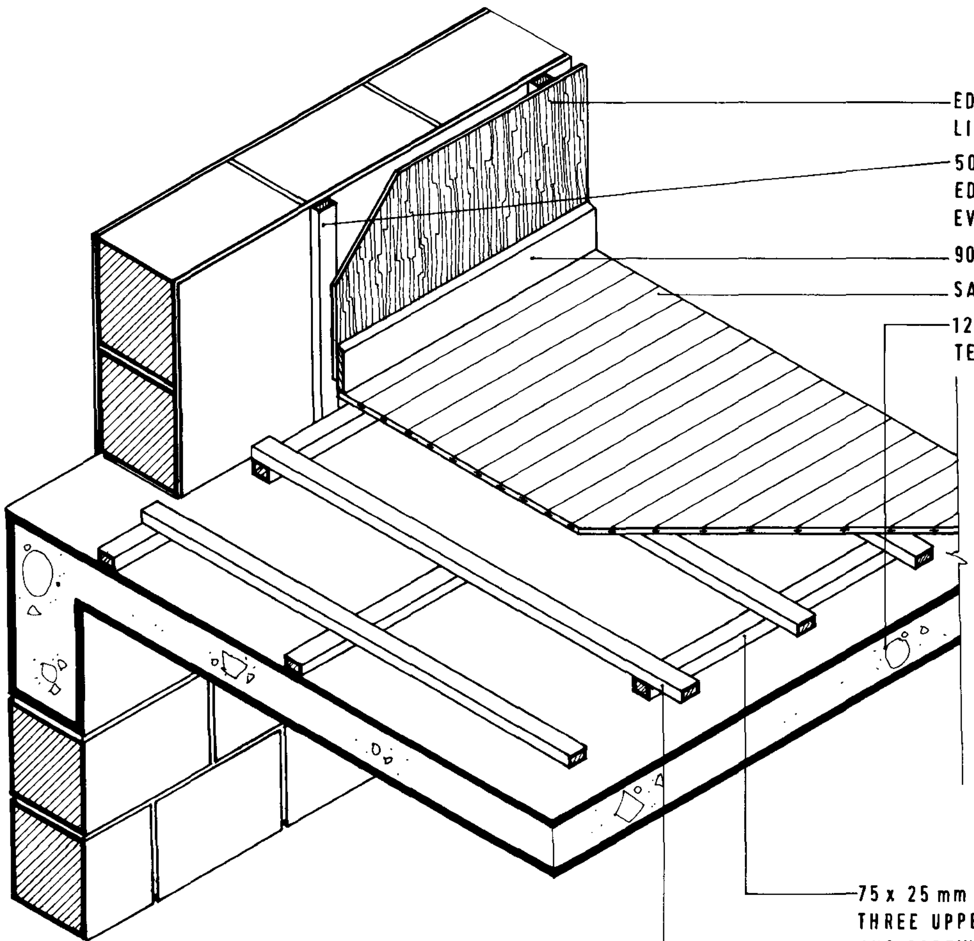


HOLLOW BLOCKWORK WALL

40 mm THICK GRANOLITHIC SCREED, ANY FLOOR FINISH USING SAND-CEMENT SCREED CAN BE USED ON TOP OF THE SLAB.

"BISON" SLAB OF HOLLOW PRE-CAST CONCRETE UNITS SPANNING BETWEEN BEAMS. JOINTS FILLED WITH CEMENT-SAND SCREED AND CEMENT GROUT.

PRE-CAST CONCRETE UPPER FLOOR



EDINAM VENEERED PLYWOOD PANELLING

50 x 15 mm PANELLING BATTENS FIXED TO PLASTERED BLOCKWORK WALL EVERY 600 mm

90 x 20 mm SAPELE SKIRTING

SAPELE T. AND G. FLOOR BOARDING

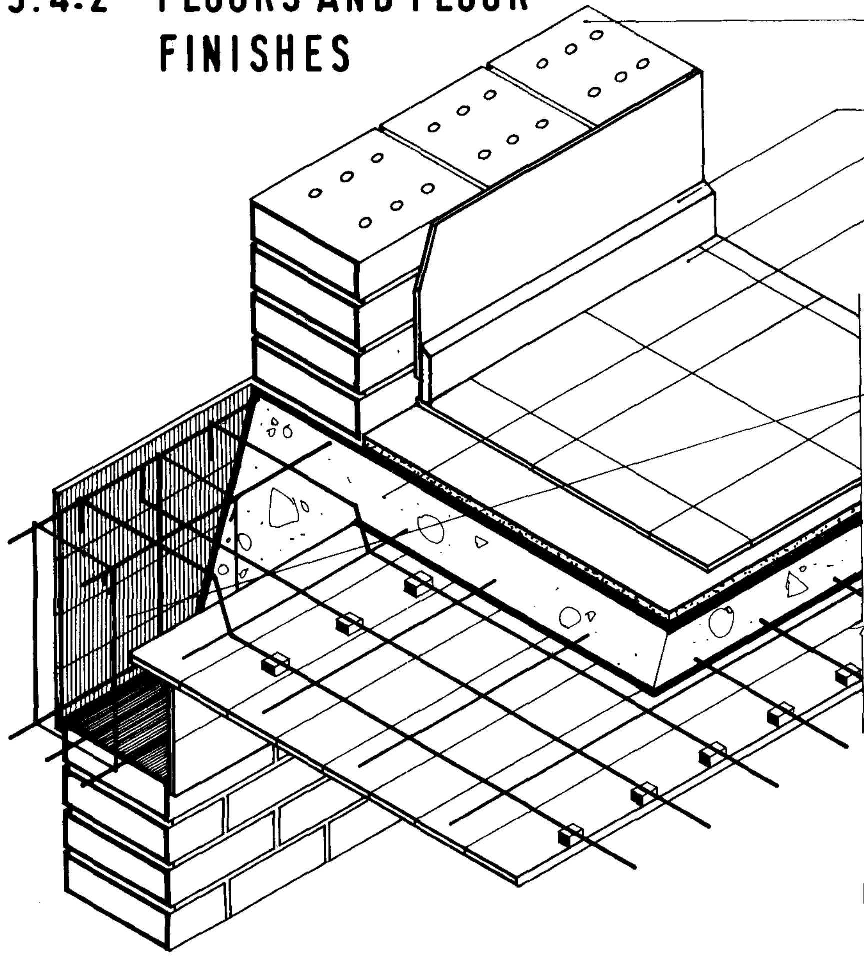
125 mm THICK REINFORCED CONCRETE SLAB

75 x 25 mm LOWER BEARERS LAID, ONE FOR THREE UPPER BATTENS, AT 900 mm CENTRES AND SCREWED TO PLUGS SET INTO THE CONCRETE.

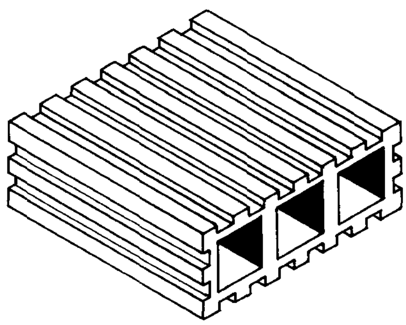
75 x 30 mm UPPER BATTENS LAID AT 450 mm CENTRES.

BATTEN SPRING FLOOR - ADAPTED FROM "FLOORS" BY G. HALE, ESSENCE BOOKS ON BUILDING, THE MACMILLAN PRESS LTD., LONDON.

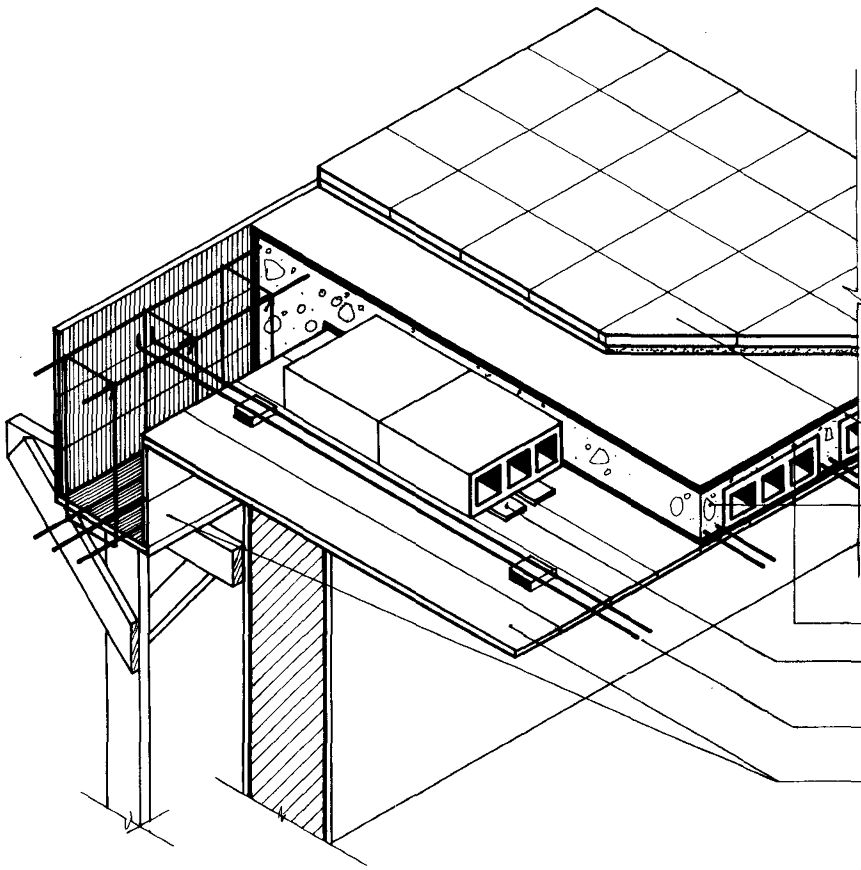
5.4.2 FLOORS AND FLOOR FINISHES



IN-SITU REINFORCED CONCRETE UPPER FLOOR



DETAIL OF A BURNT HOLLOW CLAY POT, 300 x 300 x 100, WITH GROOVES ALL ROUND



HOLLOW POT FLOOR OF A FIRST FLOOR VERANDAH

There are two types of timber flooring:

- **Boards and Strips:** These span between timber joists and are therefore a structural material as well as a finish. They require a good quality hardwood, which has been preservative-treated against termites and insects. Both boards and strips are normally fixed tongued and grooved. The actual covering width is usual 13mm less than the nominal width (10mm for the tongue, 3mm gap). Standard sizes vary, nominal widths are from 75mm to 150mm with thicknesses from 20 to 25mm. Boards and strips are normally fixed to the joists at no more than 450mm centres or to preservative-treated wooden bearers which are set into the screed or on to the concrete slab with the help of floors clips (Fig. 277). At ground floor level it is necessary to provide a damp-proof membrane between the timber flooring and sub-floor.
- **Blocks:** These are made from hardwood. Since they are comparatively small in size, they can be produced from off-cuts or cut timber which is useless for other purposes. Blocks are normally made in widths up to 90mm and in lengths from 150mm to 380mm and 20 to 30mm thick. Allowance should be made for sanding down and finishing the blocks of about 2 to 3mm. They are tongued and grooved all round and laid in a variety of patterns, herring-bone, basket weave, brick bond, on a solid level sub-floor, normally screed. They are fixed to the subfloor with latex-bitumen emulsion adhesive. For special rustic and hard-wearing surfaces thick blocks (from 60 to 115mm thick and 75mm wide by 225mm long) can be used after they have been pressure-impregnated with *Creosote.* Specially selected kiln-dried decorative hardwood blocks from 6.5mm to 9.5mm thickness, pressed on to a backing to form panels of up to 600mm (normally in basket weave pattern) are known as **Parquet**. Parqueting panels are laid directly on to a suitable even subfloor and fixed with adhesives. Small rectangular hardwood strips forming panels of 230 × 230 × 9mm are known as **Mosaic Wood Flooring** panels. They can produce a beautiful and hard-wearing floor finish (Fig. 278).

IV. SPECIAL FLOORS

These are floors which are required to have a very high degree of resilience, like floors intended for dancing in restaurants, discotheques or in school or sport gymnasiums. Such floors can either be fully sprung or semi-sprung, incorporating special springs which allow the sub-floor to deflect when in use or using resilient rubber, fibre or nylon pads under the floor covering (which at the same time serve as sound insulation). For sound-proofing a floor a simple method can be adopted. The galvanized floor clips with which battens (to which the floor boards are nailed) are fixed to the screed can have rubber insulators incorporated.
Cavity floors are useful for buildings in which computers are used and other complex services. Since most of the cavity or "elevated" floors are proprietary systems, produced by specialist manufacturers to their own design and specifications, they would have to be imported to developing countries as well as some of the different types of metal floors which may be needed in different industries. It would go beyond the scope of this book to detail such floors.

NOTE : COST LIMITS DIFFER FROM PLACE TO PLACE. IT WILL BE NECESSARY TO COMPARE COSTS OF SIMILAR BUILDINGS BEFORE ESTABLISHING THESE LIMITS.

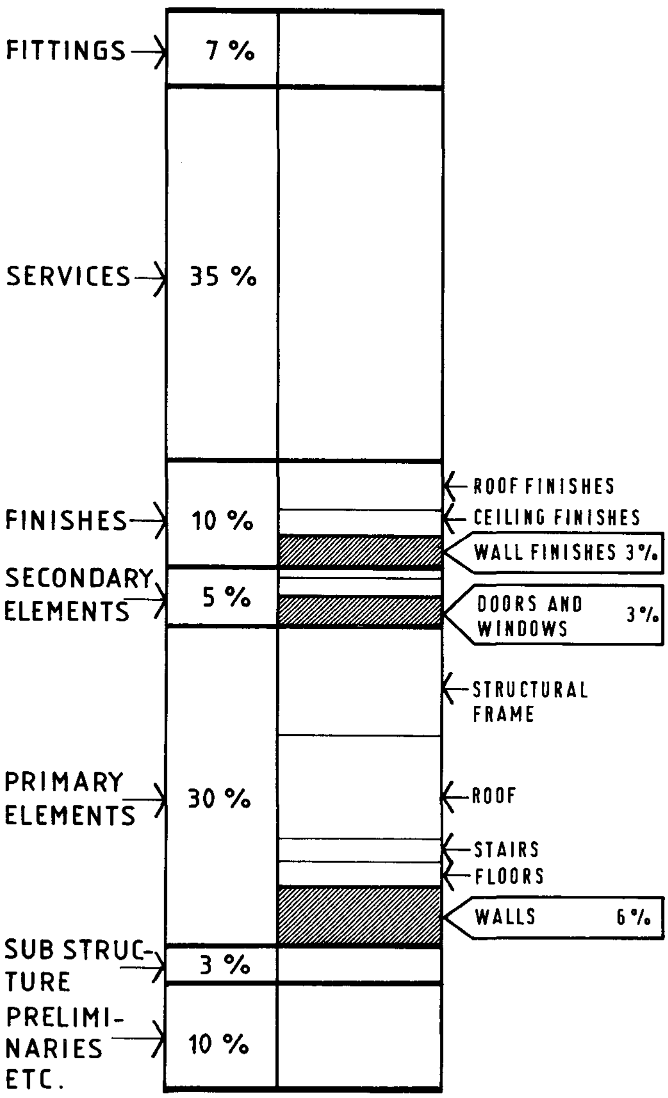
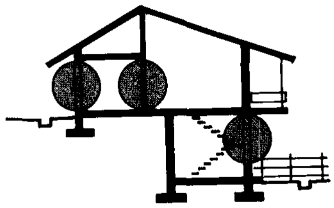


TABLE 18 : **COST LIMITS FOR DIFFERENT BUILDING ELEMENTS - WALL ELEMENTS**. ADAPTED FROM "A.J. HANDBOOK OF BUILDING ENCLOSURE" BY A.J. ELDER AND M. VANDENBERG (EXTERNAL WALLS 2, PARA. 3.02 TO 3.03), THE ARCHITECTURAL PRESS, LONDON.

5.4.3 WALLS AND WALL FINISHES



The external walls of a building, which are part of the structural system, at the same time define the outside and inside spaces. Walls, more than any other of the building elements, contribute to the aesthetic appearance of the building, especially within the urban context (streetscape, townscape). In the static societies of the past the traditional builder had to take very few design decisions; he worked within the constraints which the available materials and technologies imposed on him. With the advanced societies a greater element of specialization and differentiation developed. The builder of today has a much wider choice of different wall building methods and many design options.

The designer has to consider certain data before he can design walls so that they fulfil their functions. He will study the requirements of the occupants, their number and types (do not forget the physically disabled), the nature and duration of occupancy and the activities of the occupants. He will collect the necessary climatic data of the area (air temperature, humidity, rainfall, prevailing winds, noise, pollution, daylight). He will study the availability of local building materials, of skilled and unskilled labour and the technologies with which the workers are familiar. He will make a careful cost analysis, breaking down the estimated total costs of the building into smaller parts for each element of the building in order to achieve a well-balanced distribution of available funds. Previously constructed buildings of similar design can be a guide for such analysis (Table 18). He will finally study the local statutory regulations (structural requirements etc.).

5.4.3.1 PERFORMANCE REQUIREMENTS OF EXTERNAL WALLS

I. **Environmental Control**: The external wall is the barrier between the external macro- and the internal microclimate. It must be built in such a way that it contributes to the thermal comfort of the occupants inside the building. It must be designed so that its openings admit the required amount of ventilation and daylight.

II. **Structural Support:** The major structural function of load-bearing walls is to support the weight of the structure above the walls, as well as their own weight and loads imposed in them through the floor, the occupants and furniture. External walls must also be constructed so that they can distribute wind loads and resist oblique forces (earthquake etc.). They contribute, in addition, to the general stiffness of the structure.

III. **Aesthetic Requirements:** The external walls of a building, as mentioned before, should contribute to the visual satisfaction of those who will use the building and those who will see it from the outside as part and parcel of the surrounding street or townscape. A building in a rural setting should satisfy the same requirements.

IV. **Security**: External walls (and more so the windows and doors fixed into them) should provide the necessary security against unauthorized and forced entry.

5.4.3.2 FUNCTIONS OF INTERNAL WALLS AND PARTITIONS

Internal walls are part of the internal subdivision of the building, dividing internal spaces.

Internal load-bearing walls are part of the structural system, and their main function is similar to that of the load-bearing external walls, providing the necessary structural support for the building, the live loads and other forces and loads to which they are exposed. Non-load-bearing internal walls can be built lighter, so long as they fulfil the function of providing the necessary privacy for the occupants (noise exclusion) and are strong enough to receive the required finishes, loads (e.g. wash basins etc.), services (cables, pipes etc.) and other fixings. Demountable partitions, which are used in offices, conference, lecture rooms etc. are normally proprietary designs, which in some cases include an integrated ceiling design together with the partition. All internal walls have to satisfy fire resistance requirements. These regulations, which may differ from country to country, are all based upon the principle of preserving life in case of a fire outbreak. The designer will include necessary means of escape in the design and also divide the internal space in a building so as to stop the fire spreading easily.

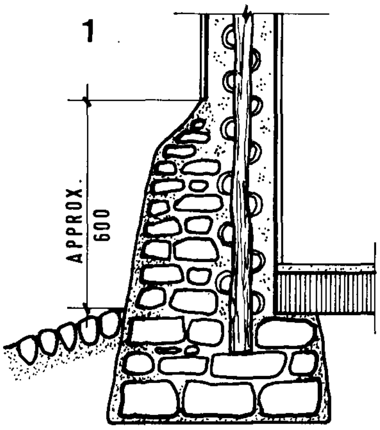
5.4.3.3 TYPES OF WALLS

Most of the solid walls built in tropical countries are single-leaf walls, due to the fact that no heating is normally required inside the building. In dry arid zones with very low night temperatures during the dry season an internal open fire-place may be required in the living area for the occupants' comfort. A solid brick or stabilized soil block wall without cavities provides the necessary thermal comfort conditions for the high day and low night temperatures in these areas.

Timber walls have already been described in part 4. This part deals with the following wall types:

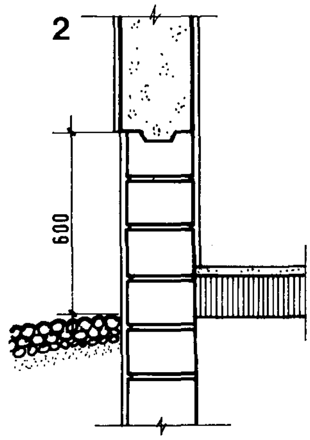
– **Rammed Laterite or Soil Walls** (Fig. 279):

These are suitable for expandable low-cost compound houses types of 5 to 7 rooms or more in a rural setting. A certain accommodation standard is achieved if vented indirect pit latrines (V.I.P. latrines) and showers fed by on overhead water-tank can be incorporated in the compound design, as well as a shelter for domestic animals. In most areas of tropical developing countries suitable soil will be available for use in an improved Atakpame-method. Walls are constructed on foundations (shown in 5.3.1) or provided, where possible, with a reinforced concrete ring beam at the floor, window- and door-lintel and roof level from pre-cast U-shaped beam units. Wall thickness is normally 300 mm at ground beam level, tapering to 230 mm at top ring beam level, or 230 mm throughout the wall.
It is very necessary to protect the base of the structure, since it is here that the trouble starts in the form of erosion and decay (through insufficient rain and termite protec-



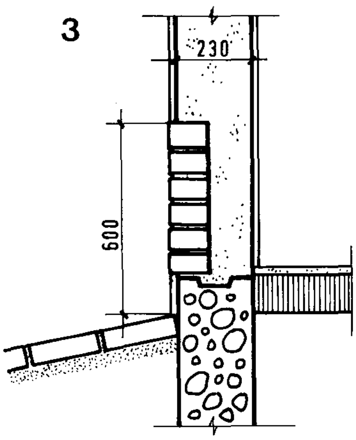
THE WALL IS ERECTED ON A 600 x 300 mm STONE FOUNDATION. THE EXTERNAL BASE OF THE WALL IS REINFORCED WITH STONES SLOPING TOWARDS THE TOP TO PREVENT GOATS FROM CLIMBING UP. STONES OF WALL BASE AND FOUNDATION ARE COVERED WITH SAND-CEMENT MORTAR. FOR ONE HOUSE OF 8 x 5 m ABOUT 3 BAGS OF CEMENT ARE REQIRED FOR THIS WORK.

1 WATTLE AND DAUB WALL WITH REINFORCED STONE BASE



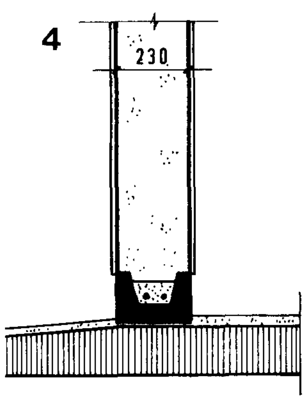
THE WALL IS ERECTED ON A FOUNDATION AND BASE WALL OF STABILIZED LATERITE-SOIL BLOCKS PRESSED WITH THE TEK-BLOCK PRESS. BLOCKS OF TOP LAYER ARE KEYED TO GIVE GOOD BOND TO THE MUD WALL ABOVE. BASE WALL IS RENDERED WITH SAND-CEMENT PLASTER OUTSIDE. WALL 1 & 2 ARE PLASTERED WITH A SOIL-SAND AND 5 % BITUMEN CUTBACK MIXTURE.

2 ATAKPAME WALL WITH STABILIZED SOILBLOCK FOUNDATION AND BASE WALL



THE WALL IS ERECTED ON A MASS CONCRETE FOUNDATION WALL. THE BASE OF THE WALL IS REINFORCED WITH BURNT BRICKS UP TO A HEIGHT OF 600 mm. THE WALL IS RENDERED WITH A SOIL-SAND AND 5 % BITUMEN CUTBACK MIXTURE IN AND OUTSIDE.

3 ATAKPAME WALL WITH REINFORCED BRICK BASE ON MASS CONCRETE FOUNDATION WALL



THE WALL IS ERECTED ON PRE-CAST CONCRETE U-BEAM UNITS WHICH ACT AS BASE RING BEAM. THE UNITS ARE REINFORCED WITH TWO BARS AND FILLED WITH CONCRETE. THE WALLS ARE RENDERED AS 3. IT IS ESSENTIAL FOR THIS ARRANGEMENT TO HAVE A LARGE ROOF OVERHANG AT THE EAVES AND AN OUTSIDE APRON TO FALL WITH SAND-CEMENT-BITUMEN SCREED.

4 ATAKPAME WALL WITH CONCRETE BASE BEAM

FIG. 279: RAMMED LATERITE AND SOIL WALLS

tion) or abrasion (through goats rubbing themselves on the walls). Apart from a large roof overhang and solid aprons (of stone, rammed gravel or laterite) laid to fall under the eaves to guarantee a quick run-off of rainwater from the surface, a base of stone or brick cladding or of stabilized laterite blocks (part of the foundation wall) up to 600mm high or higher according to local requirements, together with waterproof plasters, gives a suitable protection to the wall at ground level.

Atakpame walls must be built slowly. One layer of approximately 600mm height per day allows the swish material to dry sufficiently in order to receive the next layer. During wall construction the correct number of wooden plugs must be inserted for fastening of window, door frames and partitions. In order to make an Atakpame structure resistance to earthquake and typhoon the following design recommendations should be followed:

(a) Structures built with rammed laterite should not be higher than one storey, the wall height should not exceed 2.40m;
(b) Bases of the walls should be protected from moisture in the adjacent soil or from splashing surface water;
(c) Structures should have a lightweight roof, which is well anchored into the top ring beam for protection against strong winds;
(d) No wall section should exceed 4m in length before a dividing wall (which acts as buttress) is arranged;
(e) There should be tie-beams at base and wall-top level.

– **Brick Walls:**

Burnt brick or soil bricks may be hand-moulded or machine-pressed and wire-cut. Clay bricks are then burnt in a kiln. Soil bricks are left to dry outside. A number of small and large-scale brick factories (also producing roofing tiles) have been set up in Ghana. In the absence of standards a variety of different sizes and forms of bricks are produced (Fig. 280).

In order to provide a stable wall, which can distribute any loads carried over the complete wall and which is strong enough to provide lateral stability and resistance to side thrust, a brick wall is bonded with adequate lap. A number of different bonding techniques are known, the **Stretcher, English** and **Flemish** bonds are the most common and also suitable bonds (Fig. 281).

Mortar used for laying the bricks is a mixture of sand and a hydraulic binder (cement or lime) formed into a mass with water. The mortar for brick joints must be of good quality. The resistance of the joint may be affected by various factors: the type and quantity of cement or lime, the plasticity of the mortar, the rate at which water is absorbed by the brick (or block) and the quality of workmanship. Joints must be well filled with mortar (both horizontal and vertical). The mix proportions recommended are for ordinary standard and good quality brickwork from 1:2 (by volume) to 1:5 (with 1:3 for brickwork in external walls and 1:4 and 1:5 for ordinary and coarse brickwork which is not subject to stresses). In earthquake zones it is important to provide good interlocking between brickwalls and reinforced concrete confining members (length of the bonding key should not exceed one fourth of a brick between the wall and column). It is advisable to erect the brick wall first and then to concrete to columns and tie-beam in order to form a proper anchorage between the brickwork and reinforced concrete framework. If an externally fairfaced brick wall is required (without plaster finish), the positioning of windows and door openings must be carefully detailed. These openings should be situated so that breaking up of bricks in too many places is avoided (Fig. 282).

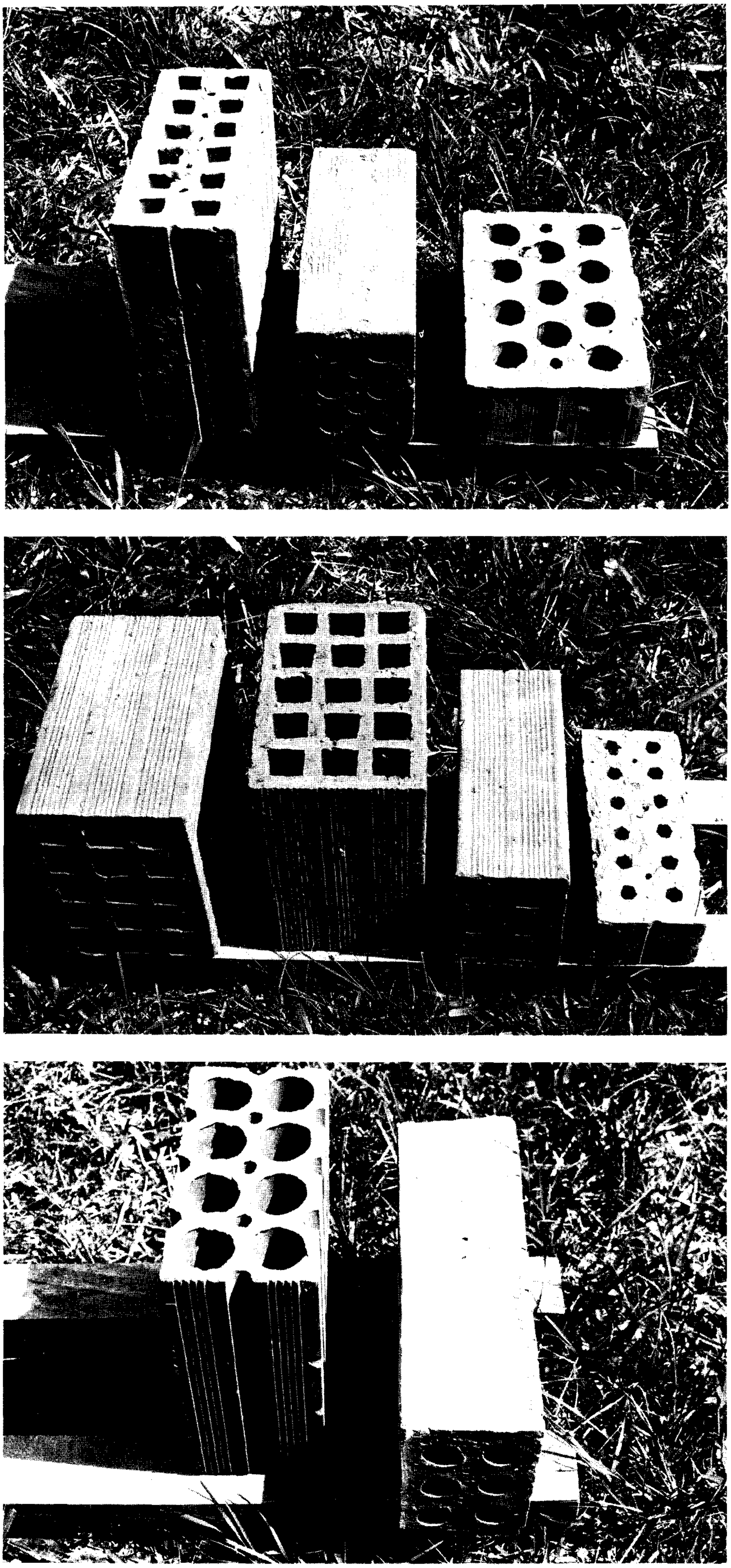
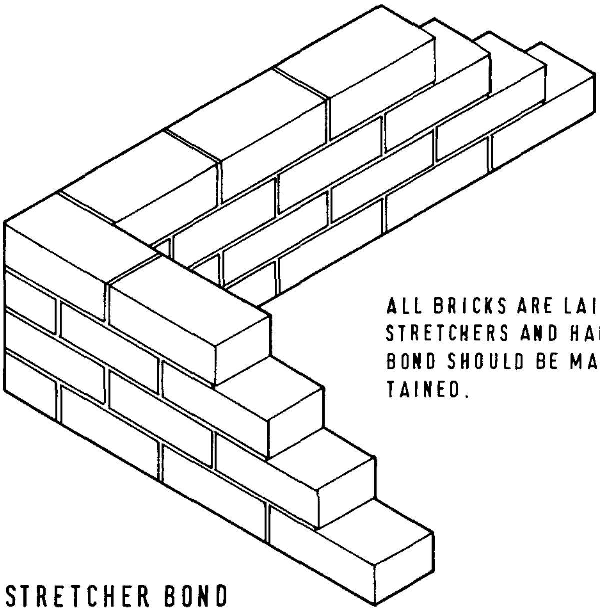
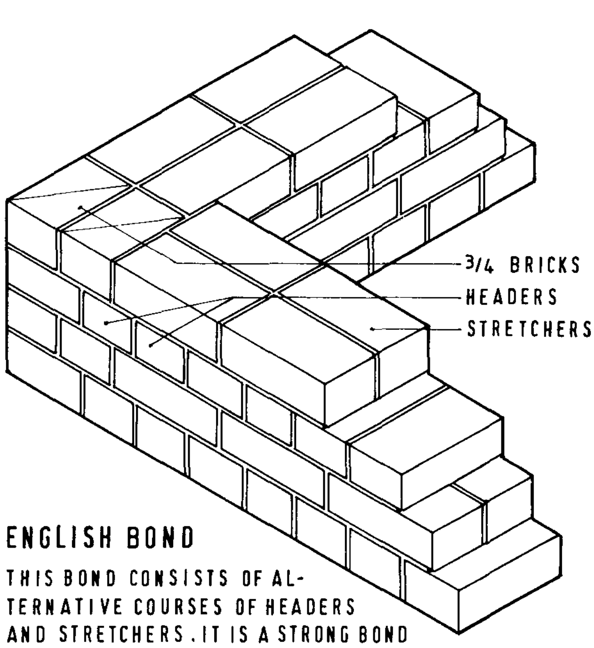


Fig. 280: Different types of bricks made in Ghana (G.I.H.O.C. Brick and Tile Co. Ltd., Prampram Brick and Tile Company Ltd., Volta Brick and Tile Ltd.), 1982.

5.4.3 WALLS AND WALL FINISHES

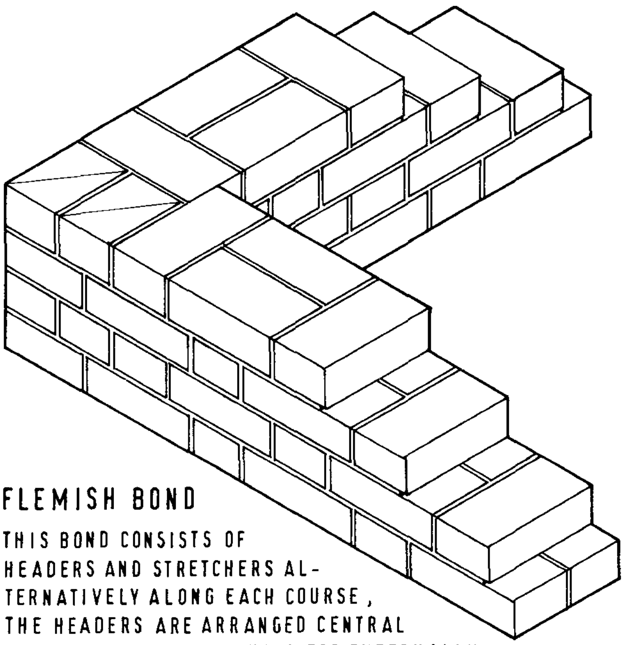


STRETCHER BOND
(OR HALF BOND)



ENGLISH BOND

THIS BOND CONSISTS OF ALTERNATIVE COURSES OF HEADERS AND STRETCHERS. IT IS A STRONG BOND FOR A LOAD BEARING WALL.



FLEMISH BOND

THIS BOND CONSISTS OF HEADERS AND STRETCHERS ALTERNATIVELY ALONG EACH COURSE, THE HEADERS ARE ARRANGED CENTRAL OVER THE STRETCHERS. USED FOR EXTERNALLY FAIRFACED, LOAD BEARING WALLS.

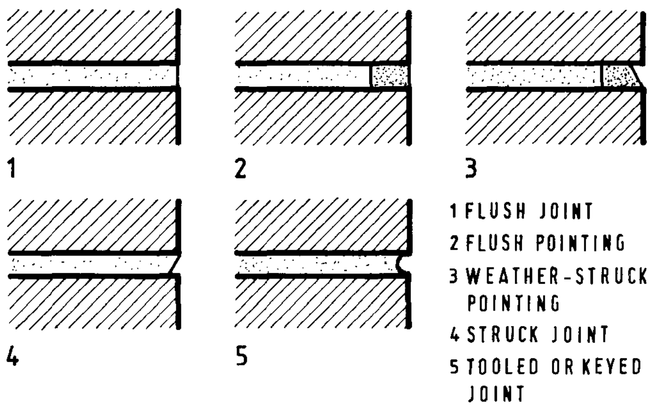
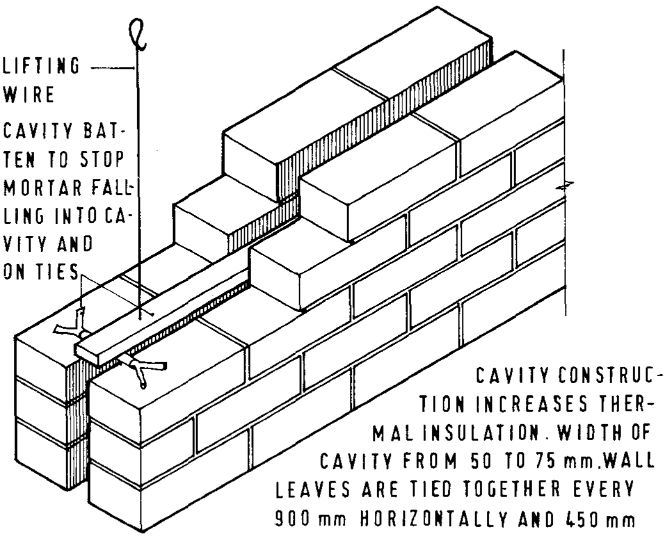


FIG. 281 : **BRICK BONDS, JOINTING AND POINTING**

FOR POINTING JOINTS ARE RAKED TO A DEPTH OF ABOUT 15 TO 20 mm AND SUBSEQUENTLY REFILLED WITH A SELECTED MORTAR FOR THE REQUIRED APPEARANCE OF THE FAIRFACED WALL. THE MORTAR CAN BE MIXED WITH COLOUR.

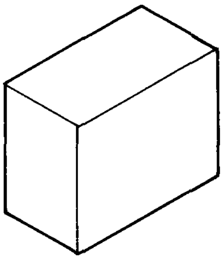


CAVITY CONSTRUCTION INCREASES THERMAL INSULATION. WIDTH OF CAVITY FROM 50 TO 75 mm. WALL LEAVES ARE TIED TOGETHER EVERY 900 mm HORIZONTALLY AND 450 mm VERTICALLY WITH GALVANIZED TWISTED STEEL, WIRE OR PLASTIC TIES.

CAVITY WALL

Fig. 282: External fairfaced brick wall, C.S.I.R. Library building (under construction), Accra, 1982. Architects: V. MAHADEVAN (Head, Consultancy & Development Division, B.R.R.I., Kumasi).

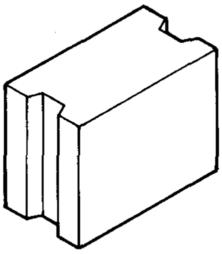
5.4.3 WALLS AND WALL FINISHES



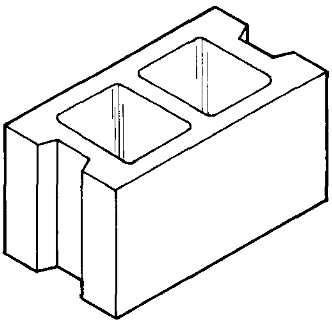
SOLID, PLAIN BLOCK

LENGTH : 300 TO 450 mm
WIDTH : 100 TO 225 mm
HEIGHT : 225 mm

THE JOINTS OF BLOCKWORK WALLS CAN BE REINFORCED WITH EXPANDED MESH STRIPS OR EXPANDED METAL LATH. JOINT REINFORCEMENT MUST BE ADEQUATELY PROTECTED WITH A GOOD GRADE OF MORTAR. GALVANIZED TWISTED STEEL TIES ARE USED AT CORNERS AND JUNCTIONS UP TO THREE STOREYS IN LOAD BEARING BLOCKWORK WALLS. IN HIGHER MASONRY STRUCTURES STAINLESS STEEL TIES ARE USED.

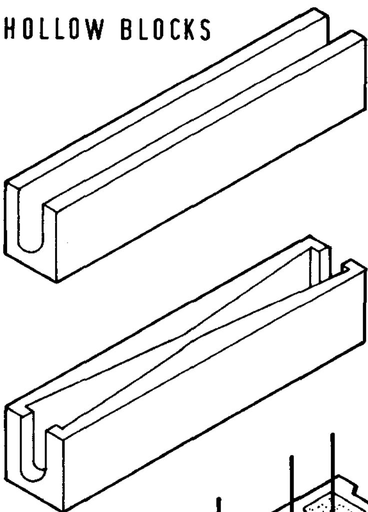


SOLID, KEYED BLOCK



THE VOLUME OF CAVITIES OF A HOLLOW BLOCK MUST NOT BE MORE THAN 50% OF THE GROSS BLOCK VOLUME. HOLLOW BLOCK DIMENSIONS ARE THE SAME AS THOSE FOR SOLID BLOCKS.

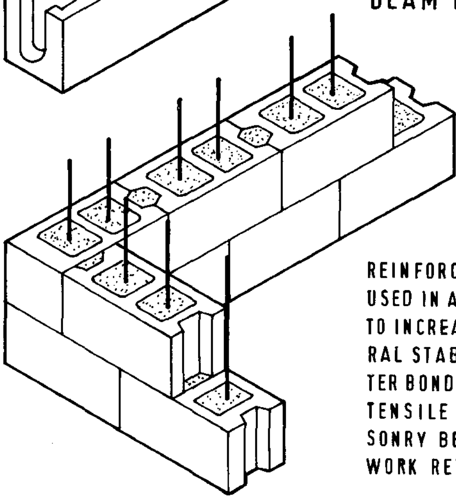
HOLLOW BLOCKS



LINTEL

UP TO 1250 mm IN LENGTH, THEY CAN BE USED FOR HORIZONTAL SERVICE RUNS OR FOR HORIZONTAL REINFORCEMENT IF USED AS LINTEL.

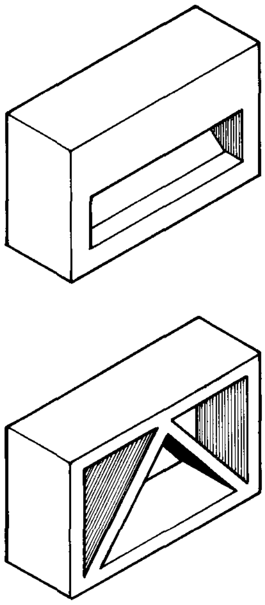
LINTEL OR BOND BEAM BLOCKS



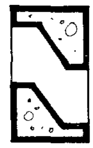
REINFORCEMENT MAY BE USED IN A BLOCKWORK WALL TO INCREASE ITS STRUCTURAL STABILITY, FOR A BETTER BOND AND TO IMPART TENSILE STRENGTH TO MASONRY BEAMS AND BLOCKWORK RETAINING WALLS.

REINFORCED BLOCKWORK

FIG. 284 : SAND-CEMENT BLOCKS



SIZES SIMILAR TO CEMENT-SAND BLOCKS.



MANY DIFFERENT VARIETIES OF VENTILATION BLOCKS, SCREEN WALL AND HONEYCOMB WALL BLOCKS CAN BE CAST IN MOULDS TO THE ARCHITECT'S OWN DESIGN MANUFACTURED BY CONTRACTORS.

CONCRETE VENTILATION BLOCKS AND SCREEN WALL AND HONEYCOMB WALL BLOCKS

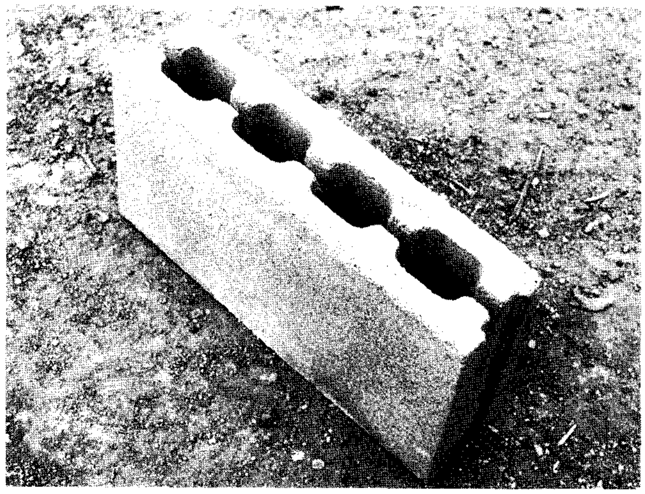
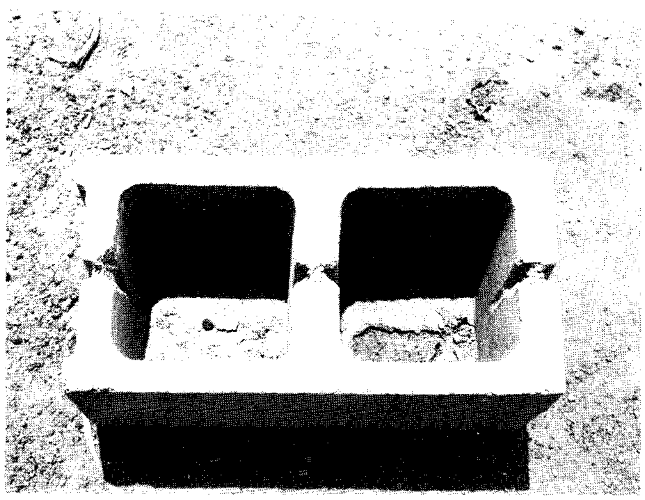


Fig. 285: 100 mm thick cement-sand hollow block (J. Monta Ltd., Kumasi).

Fig. 286: 230 mm thick cement-sand hollow block (J. Monta Ltd., Kumasi).



– **Block Walls:**

I. **TEK-Blocks:** These are blocks pressed from laterite, which has been stabilized with cement. The blocks are produced with the TEK-Block press (designed by the Department of Housing and Planning Research, Faculty of Architecture, U.S.T., Kumasi). Their sizes are normally 290 mm (in length) × 215 mm (in width) × 140 mm (in height). The block mould size can be adjusted to suit different requirements. The mix proportions with cement are from 4 to 8% which will result in the following block numbers from one bag of Portland cement:

4% – 65 blocks per bag
5% – 52 "
6% – 45 "
7% – 37 "
8% – 33 "

Blocks used for external walls should be mixed with 4 to 6% cement, blocks for foundation walls with 7 and 8%. TEK-Blocks have been successfully used for two-storey structures (Fig. 283) as students dormitories at U.S.T., Kumasi.

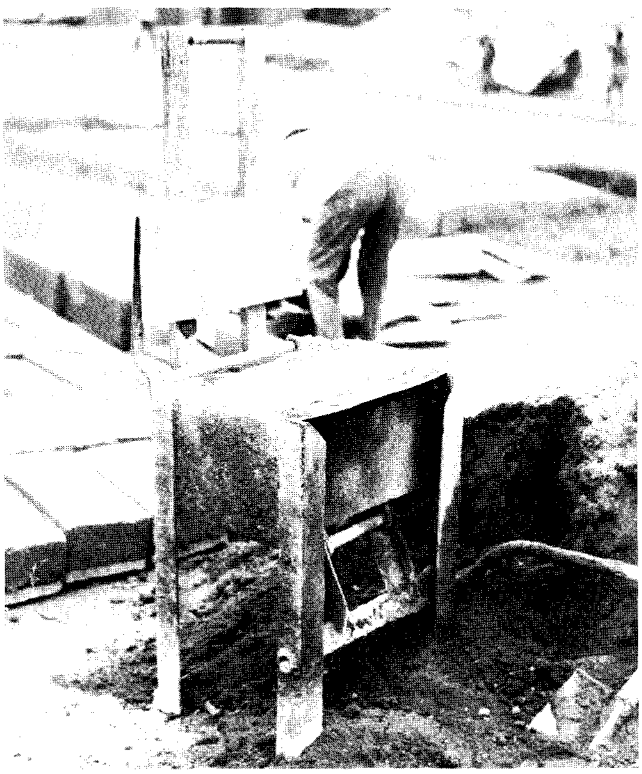


Fig. 288: A local block-making press in Kumasi, 1981.

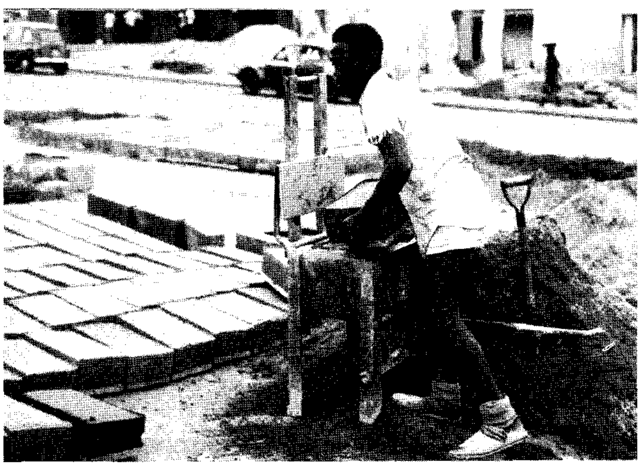


Fig. 289: A 350 × 230 × 150 mm block has been pressed. The block maker will turn the handle down to lift the block up.

II. **Sand-Cement Blocks:** These could also be described as dense aggregate concrete blocks and are produced as solid or hollow blocks (Fig. 284 *to* 287). They are made by local contracting firms or special concrete block-producing firms. These have each their own designs and, in the absence of standards, also their own dimensions. Sizes vary between 300 and 450 mm (length) × 100 to 230 mm (width) × 230 mm (height) per block.

A simple block-making press is used by the local builder. This press, with which solid sand-cement (sandcrete) blocks are made, is not producing the same compaction as the Cinva-ram or TEK-Block press. Such blocks are of inferior quality (Fig. 288 *to* 290).

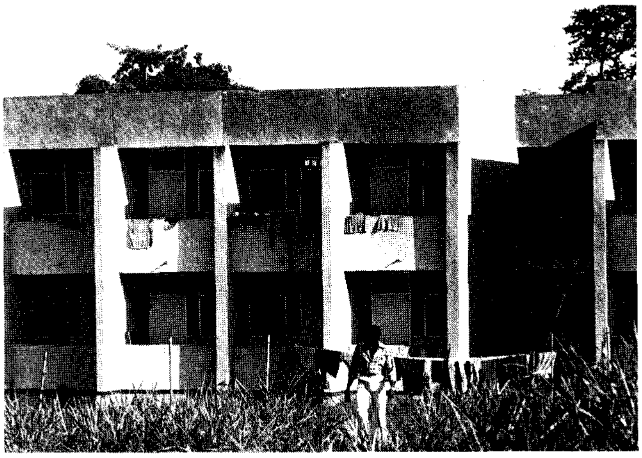


Fig. 283: Students' Hostel, U.S.T., Kumasi with TEK-block walls, 1982. Department of Housing and Planning Research, U.S.T.

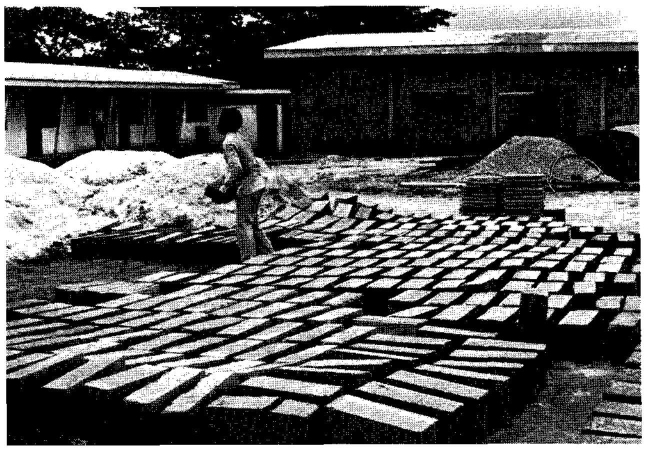


Fig. 287: 150 mm thick solid cement-sand blocks (U.S.T., Construction Unit).

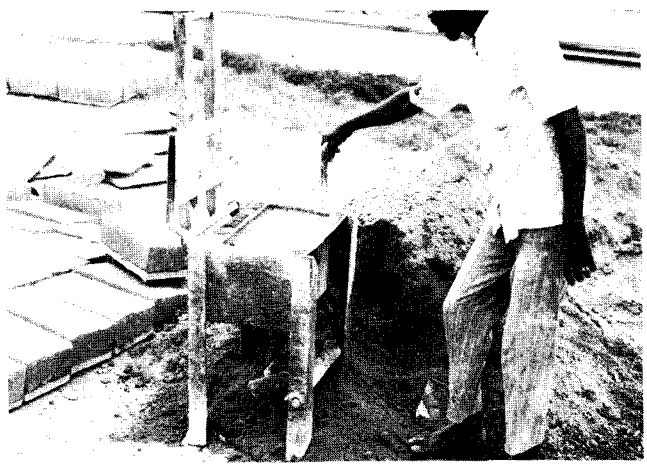


Fig. 290: The block is removed together with the moulding board.

– **Concrete Walls:**

The outstanding characteristic of concrete is that it can be cast in a mould to any desired shape. It is a material which has great plasticity when it is manufactured and great strength when it has set and is matured. As has been mentioned earlier, steel reinforcement and the application of more recent pre-stressing techniques add to its strength.

The most simple process of manufacturing concrete is casting it in situ in a prepared formwork from timber (or steelplates) after the reinforcement has been put into place.
A concrete wall is a homogeneous wall. Reinforced concrete walls should not be less than 100mm thick. When casting is not completed in one process, attention must be paid to the joints between one portion of concrete and the next. Joints in walls will be horizontal when casting, and they can normally be pre-determined, e.g. window or door sill level, head level. In ordinary concrete walls reinforcement with galvanized steel mesh at the front and back of the wall extending over its whole area is sufficient. Edges and corners can be stiffened in addition with extra bars (Fig. 291). Concrete walls have high thermal conductivity and they also transmit noise. If no other material can be specified they may require an internal insulative lining (in addition to the plaster) and a suitable vapour barrier. For larger structures (office buildings etc.) suitable expansion joints are necessary every 20 to 25 metres (Fig. 292).

In the industrialized countries system-building with precast concrete panels for external walls and floors is rapidly gaining increased acceptance, especially in the socialist countries of the East. These industrialized building techniques require "prerequisites" which cannot be met in most of the developing countries:

I. Fit relating to dimensional co-ordination;
II. Accuracy in manufacture;
III. Compatibility of edge profiles;
IV. Central location of assembly and easy transportation to site;
V. Availability of heavy lifting plant and machinery.

5.4.3.4 WALL FINISHES

The wall finish has specific functions to fulfil:

- To achieve a particular aesthetic effect;
- To increase the durability of the wall and to reduce the maintenance of the structure (external walls);
- To cover up an unsightly structure and to protect it against the weather (external walls).

The most common finish to walls is plastering. The primary function of plaster is to cover up an uneven background and at the same time provide a smooth, crack-free and hygienic surface which is suitable for the application of the final finish or the desired decorative finish which renders the wall resistant to damage.

– **Smooth Plaster Finish:** This finish can be achieved by mixing clean, fine (not dusty) sand with lime, gypsum or cement and the required amount of water, providing a mass which is consistent enough to be applied to the wall in different "throwing-on" methods. The plaster is then smoothened with steel trowels or plaster boards, which, when covered with felt, can achieve a satin finish. The finished surface can then, after setting of the plaster, be

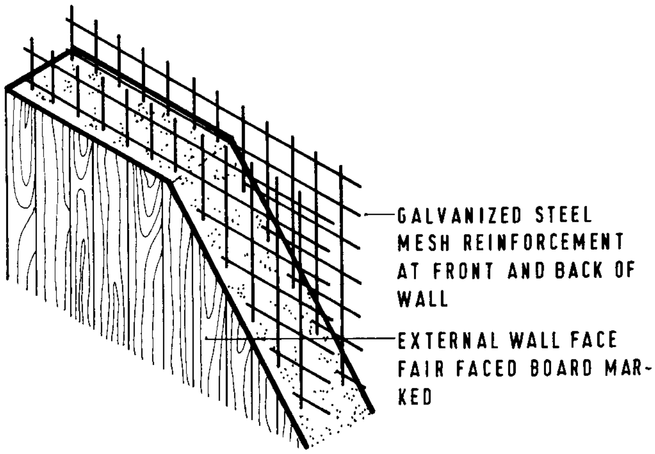


FIG. 291 : REINFORCED CONCRETE WALL

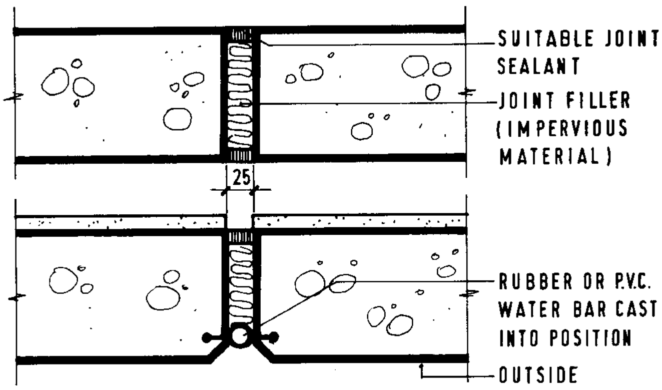


FIG. 292 : EXPANSION JOINTS IN CONCRETE WALLS

FIG. 293 : APPLICATION OF "TYROLEAN" FINISH.

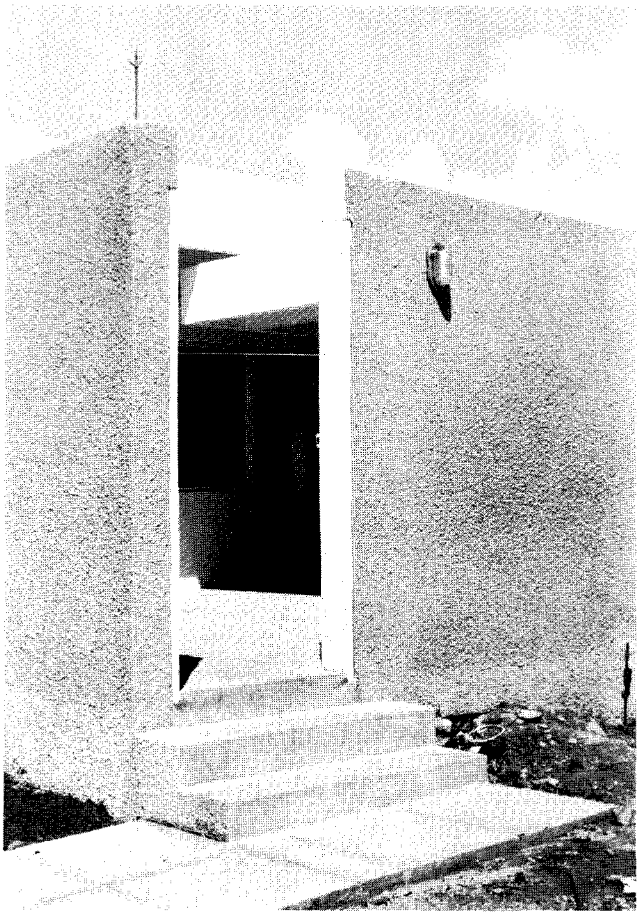


Fig. 294: Tyrolean finish on external walls, Principal's residence, Ghana Nautical College, Nungua, 1968. Architect: HANNAH SCHRECKENBACH.

painted with external quality emulsion paint or snowcem in two coats. Although this is a commonly used decorative finish, especially with white emulsion paint in tropical countries, it needs regular repainting because it dirties easily.

For mud walls, sand-cement plaster is not suitable since it has no cohesion on such walls. Good rendering for mud walls should be durable, sufficiently strong to withstand wear and tear, and should be waterproof. Materials required for the rendering should be readily available and its application so easy that a village house builder can do it himself without help. In any natural soil (other than humus), which is normally used for plaster by the indigenous builder, clay is present. Although it reduces the permeability of the soil mixture, it imparts to it its undesirable characteristic of shrinking on drying, which results in cracks. Mixing the soil together with sand to a careful mix ratio reduces the possible shrinkage to a minimum. This mixture can then be stabilized with 5% bitumen cutback, which is available in quite a number of developing countries with their own oil refineries, as a by-product from the petroleum refining process. A slow setting emulsion should be used when it is available, or medium curing cutback (MC2). Results in Ghana with plasters using a dark sandy soil with medium plasticity, mixed with sand in a ratio of 1:1 and a 5% MC2 addition on mud walls have been satisfactory. Only minute cracks appeared on drying which were removed by trowelling. The same results were achieved using reddish lateritic clayey soil with high plasticity, mixed with sand 1:1 and 5% MC2. The tests on compressive strength showed satisfactory results for the second soil-sand-bitumen

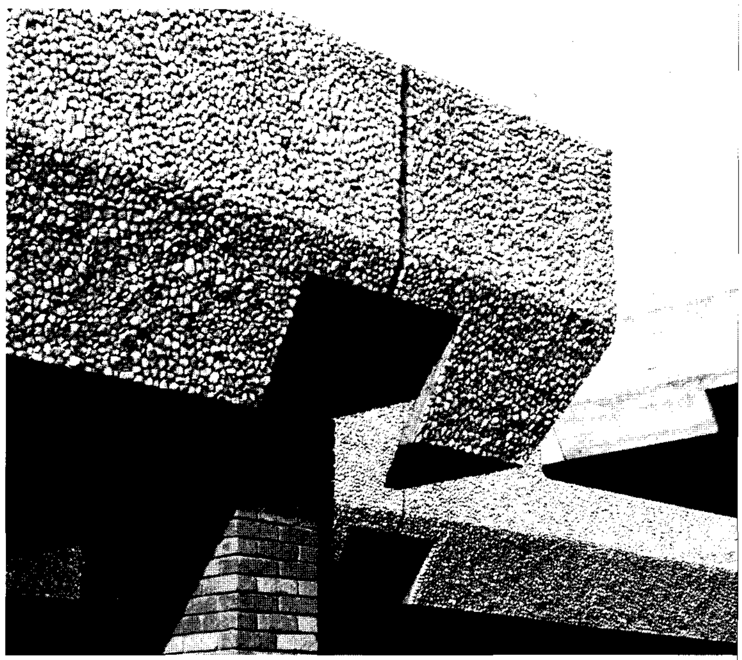


Fig. 295: Pebble dash finish on concrete roof fascia, C.S.I.R. Library building (under construction), Accra. Architect: V. MAHADEVAN.

mixture. Only that much soil and sand should be mixed with the bitumen cutback as can be finished as plaster on the wall in one day. The materials required for 10 square metres of wall are:

- Soil-sand mixture . . . . 9 headpans
- Bitumen cutback MC2 . . a bit more than half a headpan.

The finished wall can be painted with two coats of lime wash, cement paint or snowcem after the plaster is completely dry.

– **Textured Plaster Finish:** This is a finish which is applied by hand or machine-operated throwing-on technique on to an undercoat of plaster in the mix ratio or 1 part cement to 4 parts sand. It can also be applied directly to in situ concrete, masonry and suitable types of brickwork, but one should bear in mind that the degree of protection to the surface achieved with the throwing-on treatment without an undercoat is limited.
The commonly known textured finish is **Tyrolean** finish, which is applied with hand-operated small drums from which the thin plaster mix (which can be readily mixed with any colour) is thrown on to the wall surface by turning a handle (Fig. 293 and 294).

Another textured finish is pebble-dash, applied on to still wet plaster by the same method, using a plaster mixture with small pebbles. If the pebbles are larger, they can be fixed with plaster boards by hand (Fig. 295). Washed terrazzo is also a textured finish which is often used on concrete roof fascias, balcony walls or decorative walls. It consists of a terrazzo topping of about 7mm thickness which is applied to a still wet undercoat of cement-sand plaster and is then washed and broomed off before it has set in. Washed terrazzo is more often used on external non-slip floors or staircases. Its application on walls is a rather messy and dirty work.

Textured finishes will last a long time if correctly applied. They are very useful on walls around staircases and other walls which are in areas where people converge and the walls are used "for holding on to". Tyrolean wall finishes

Fig. 296: Patterned concrete finish on the walls of the Members' Lobbies, Parliament House extensions, Accra, 1970.

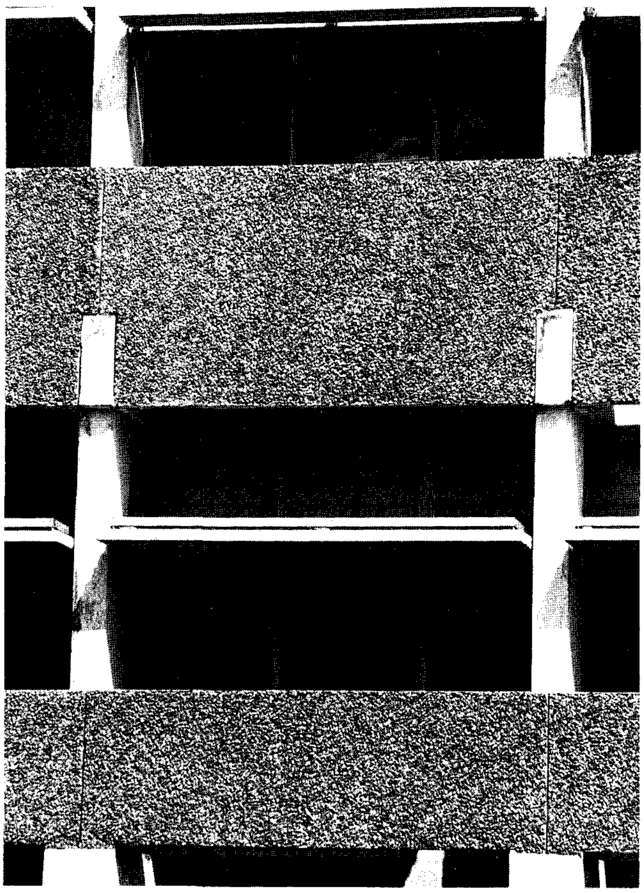


Fig. 297: Exposed aggregate finish on the second administration building, U.S.T., Kumasi. Architects: GERLACH & GILLIES REYBURN.

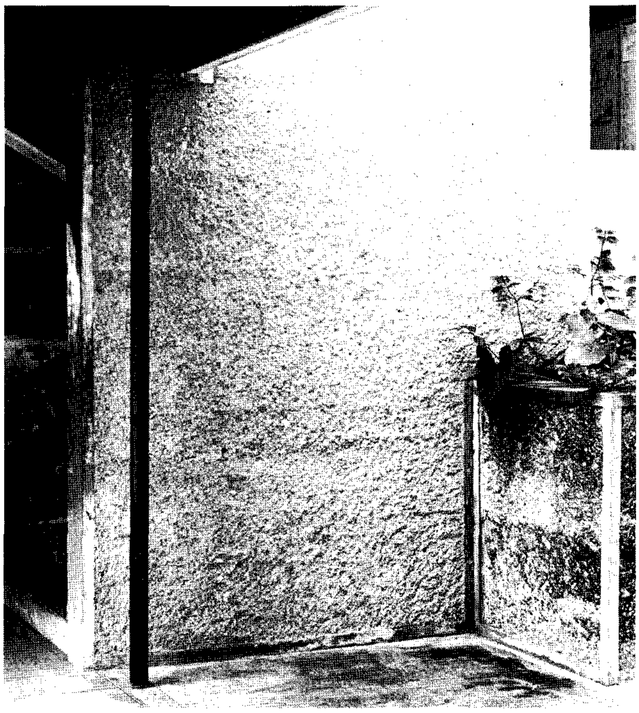


Fig. 298: Tooled concrete wall, Faculty of Architecture, U.S.T. Architect: L. CHRISTIANS.

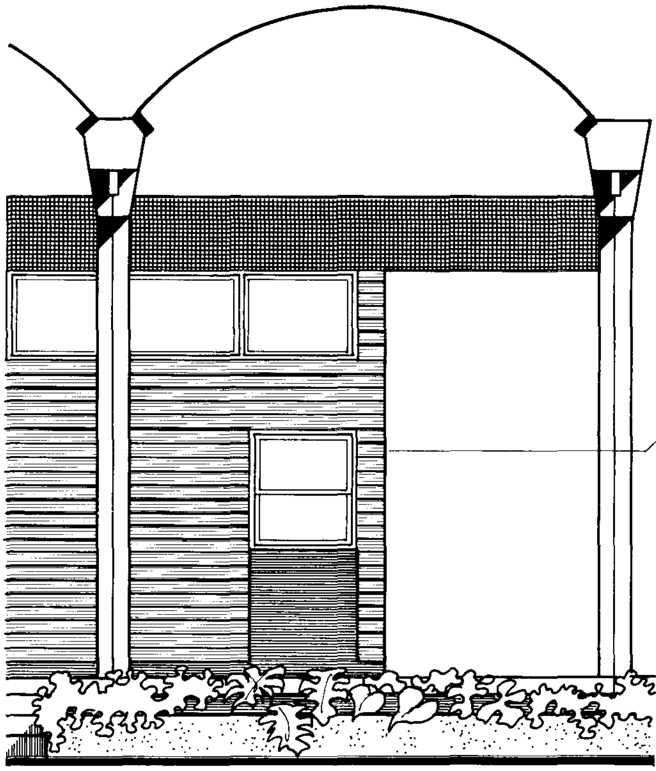
discourage touching because of their rather sharp texture. They do not, therefore, require regular re-painting. Even a light coloured textured wall will, with age, take on an even patina which does not appear as dirt.

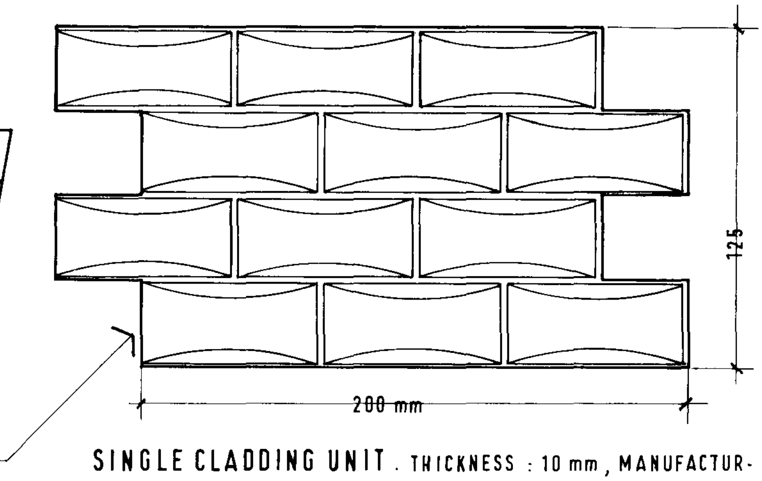
– **Concrete Wall Finishes:** There are large varieties of different finishes used for concrete walls (other than plaster finish). A concrete wall can be cast in specially prepared timber formwork, which shows the grain of the timber or board marks after striking the shuttering and remains fairfaced without other finishes. Different patterns can be incorporated in the form of battens in the formwork which appear on the finished surface as grooves (Fig. 296). Concrete cast in situ can have different types of aggregates exposed. The concrete surface is brushed and washed at an early stage in the setting process to expose the aggregate (Fig. 297). A textured surface can also be achieved on concrete walls after the formwork has been struck and the concrete set, with tools (tooled surface) or by abrasion blasting (Fig. 298).

– **Cladding:** There are different types of cladding suitable for walls:

I. **Small Unit Cladding**: Tiles, mosaics, stones, timber boards, shingles. These are not really claddings but wall facings which are fixed (in the case of tiles hung) to 50 × 20 mm timber battens (boards and shingles) or to a cement-sand bedding of 7 to 13 mm thickness (mosaics, glazed tiles, stones). A nearly impervious skin to the structure is provided which is capable of resisting driving rain and wind forces from all directions (Fig. 299 to 303).

II. **Sheet Cladding:** Panels from concrete, metal, plastics and plywood. Since concrete, metal and plastic claddings are mainly used in multi-storey structures they are not described here. The common sheet cladding for internal walls is plywood panelling, which is a beautiful finish for special rooms when decorative veneers are used with a matt polish finish, which brings out the beauty of the grain (Fig. (304).





SINGLE CLADDING UNIT. THICKNESS : 10 mm, MANUFACTURED BY MESSRS. A.LANG LTD.,TEMA.

FIG.299 : SMALL TERRAZZO CLADDING. EXTERNAL WALL OF THE POST OFFICE BUILDING, MAMPROBI, ACCRA, 1974. ARCHITECT : HANNAH SCHRECKENBACH.

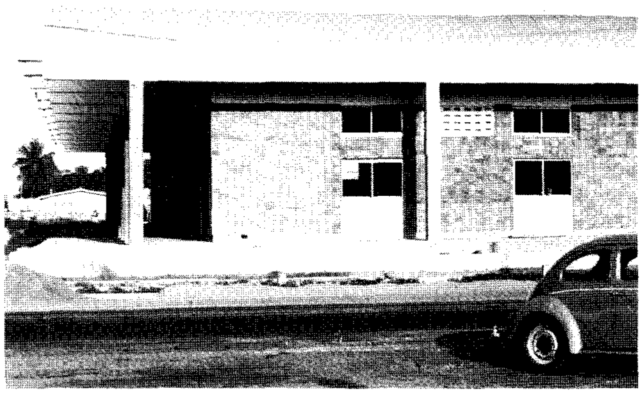
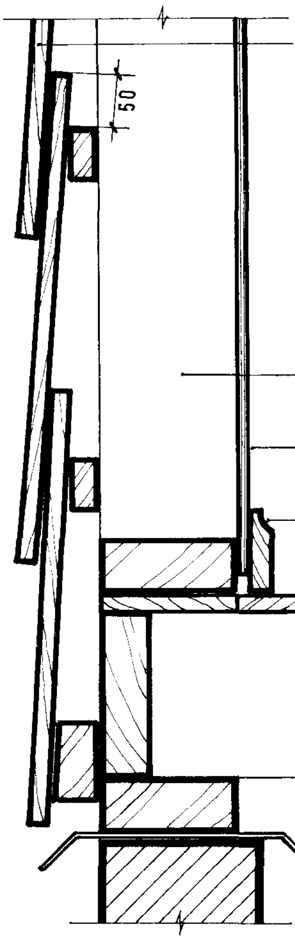


FIG.300 : PART OF THE EXTERNAL WALL OF THE MAMPROBI POST OFFICE SHOWING SMALL TERRAZZO CLADDING.

Fig. 301: Polished stone cladding (containing Jasper, Volta Region) on the Volta River Authority Building, Accra, 1982. Architect: KENNETH SCOTT.

Fig. 302: Fixing of glazed wall tiles, Kumawu, 1982.



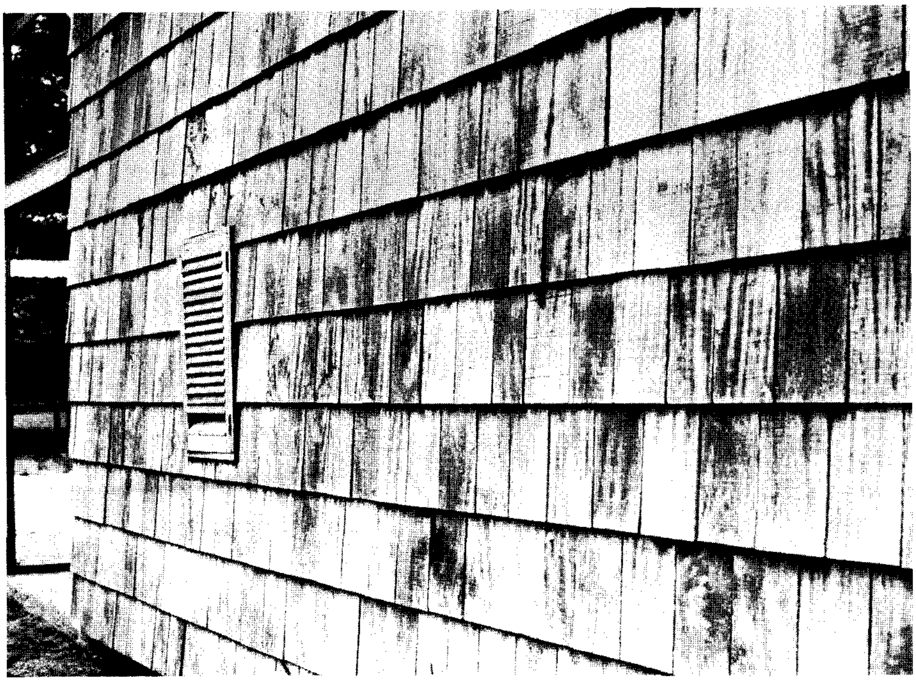


FIG.303 : **WOOD SHINGLES AS WALL CLADDING**

THE PHOTOGRAPH SHOWS THE GROUND FLOOR OF A STORE AND OFFICE BUILDING AT MESEWAM NURSERY OF THE FOREST PRODUCTS RESEARCH INSTITUTE NEAR KUMASI. THE WALLS AND ROOFS (ALSO OF THE PUMP HOUSE AND POTTING SHEDS) HAVE BEEN CLADDED AND COVERED WITH TERMINALIA IVORENSIS SHINGLES IN 1969. THE UNTREATED SHINGLES ARE STILL IN VERY GOOD SHAPE AFTER 12 YEARS. OTHER SUITABLE TIMBER SPECIES WILL BE DESCRIBED IN 5.4.7 ROOF STRUCTURES AND FINISHES.

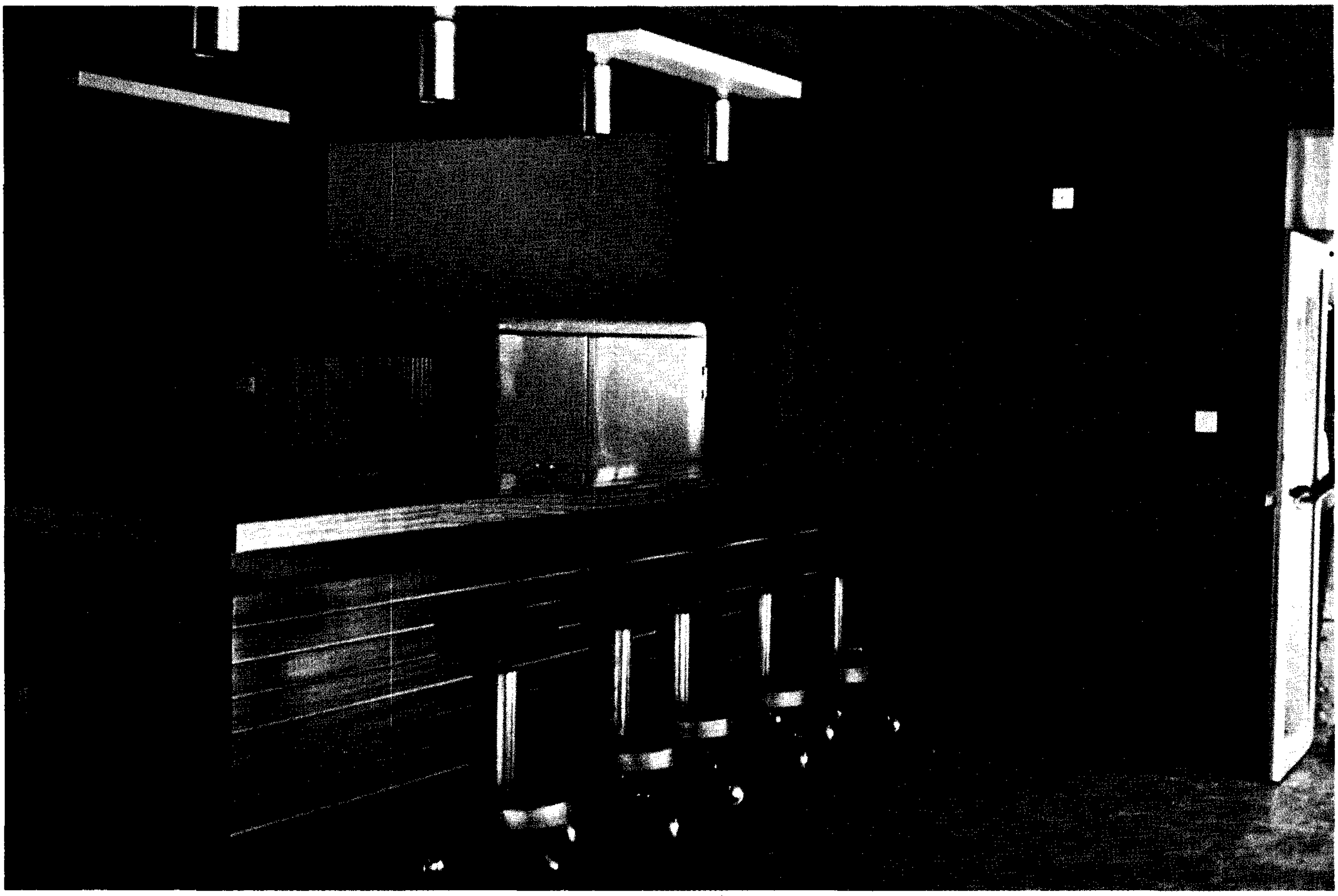
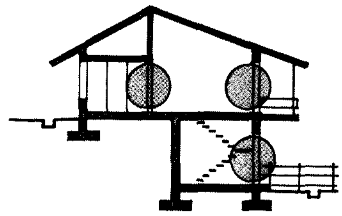


Fig. 304: Sapele veneered plywood panelling in the Members' Bar of Parliament House, Accra, 1972. Architect: HANNAH SCHRECKENBACH.

5.4.4 DOORS



There are two different groups of doors:

- **External Doors:** Entrance doors into a building, verandah doors, garage doors, gates.
- **Internal Doors:** Doors leading from room to room.

The external door is a movable barrier in the external envelope of the building. Normally this door occupies only a small area of the envelope, so that solar heat gain into the building is less critical than in the case of the window openings in the "building skin". The external door, however, faces the outside macroclimate with changes in temperature, humidity (in the hot arid climates) and is (if not located sheltered), exposed to rain and wind.
Doors face different stresses, depending on their uses (or abuses), e.g. constant closing and opening, banging, slamming, kicking etc.

There are different types of doors (Fig. 305). Doors may be hung to swing, to slide, to fold or to revolve. They will either be of unframed, framed or flush construction.

5.4.4.1 FUNCTION OF DOORS AND PERFORMANCE SPECIFICATION

Doors must be designed in such a way that they allow easy passage of people, goods and furniture. External doors should be slightly larger than internal doors.

- **Weather Resistance:** This applies to the external door which is exposed to sun, wind, rain, and has to exclude these from the interior. Fig. 306 shows some important design considerations and details of an external door. An entrance door should, if possible, not be positioned on the "weather side".
- **Security:** In order to deter forced entry, external doors should not be less than 45mm thick. In the case of glazed verandah doors, 6mm thick plate glass should be used with glazing beads on the inside. Strong room doors are specially designed security doors from steel in steel frames and special ironmongery.
- **Durability and Stability:** These are directly related to the materials with which a door is manufactured, to the quality of the worksmanship and to proper maintenance. The stability of a door and its strength in the face of all the different stresses to which it is exposed, depends on the method of construction (in the case of framed timber doors also on the joints used). Aluminium framed doors have inherent durability, but are expensive. Timber doors (plywood flush doors, board and panelled doors) are liable to distortion. Core material, boards and panels must be well seasoned before they are used. The durability of a door depends also on the ironmongery and door furniture used, e.g. hinges, locks, handles etc.
- **Fire Resistance:** A door is regarded as a weak point in respect of fire resistance. Local Building Regulations normally control the position and construction details of doors; they will also specify the hanging details (and direction of opening), so that a door can be a means of escape in a fire outbreak. As a general rule the designer should be guided to detail a door in such a way that it provides resistance to fire for the same period as is required for the wall in which the door is fitted and that it resists the spread of fire for a period of at least 30 minutes.
- **Privacy:** This involves requirements for visual and oral privacy. Visual privacy will in most cases be met by correct positioning of the door (important for bathrooms, toilets, bedrooms, etc.) and by using obscured glass if the door is glazed. Oral privacy is achieved by sound proofing a door. There may be special requirements for broadcasting rooms, sound studies etc. where, in addition to the door being solid with special seals at all edges, the passage of sound between the door and frame must be restricted or an intervening space may be provided between two sets of doors.

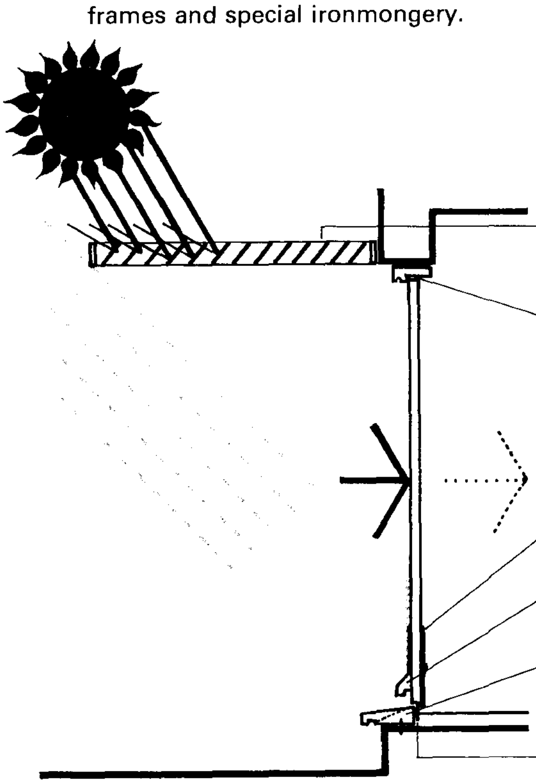
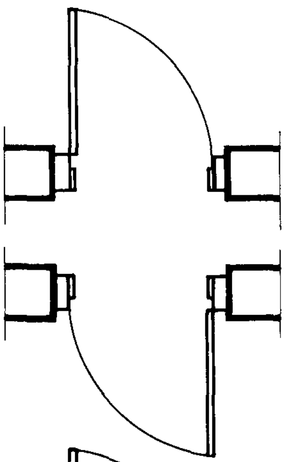


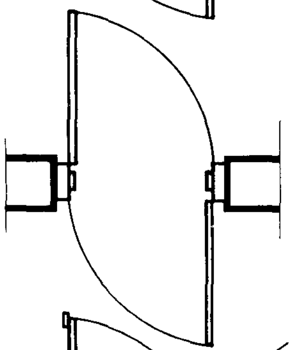
FIG. 306: **IMPORTANT DESIGN CONSIDERATIONS FOR EXTERNAL DOORS** - ADAPTED FROM "A.J.- HANDBOOK OF BUILDING ENCLOSURES" BY A.J. ELDER AND M. VANDENBERG, ARCHITECTURAL PRESS LTD., LONDON.

5.4.4 DOORS



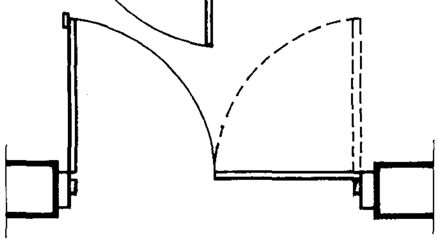
SIDE-HUNG, OUTWARD OR INWARD OPENING:

THE DIRECTION OF OPENING IS ALSO DESCRIBED AS CLOCKWISE OR ANTI-CLOCKWISE.



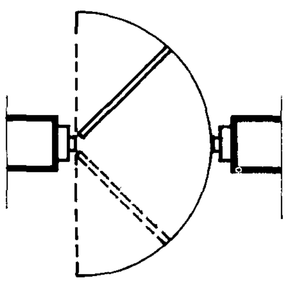
COMBINATION OF OUTWARD AND INWARD OPENING DOOR:

THIS IS USED WHERE AN INWARD OPENING MOSQUITO SCREEN IS REQUIRED.



SIDE-HUNG DOUBLE DOOR, OUTWARD OPENING:

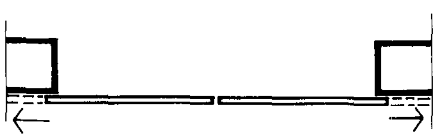
THIS TYPE OF DOOR IS OFTEN USED AS VERANDAH DOOR.



SIDE-HUNG SWING DOOR, SINGLE LEAF, DOUBLE SWING:

THE DOOR CAN ALSO BE A DOUBLE LEAF DOOR. IT IS USED IN HOSPITALS, CANTEENS, RESTAURANTS, ETC.

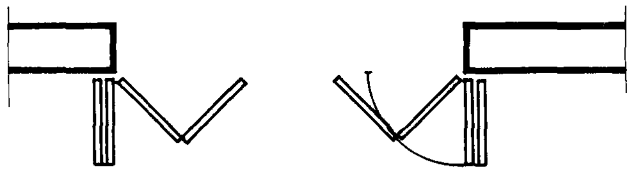
SINGLE TRACK, SINGLE LEAF, STRAIGHT RUN, TOP HUNG



SINGLE TRACK, DOUBLE LEAF

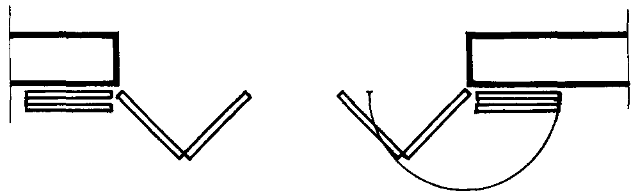
SLIDING DOORS:

MANY VARIATIONS ARE POSSIBLE WHICH ARE DETERMINED BY THE CHOICE OF TRACK. THE DOORS ARE NORMALLY TOP HUNG WITH BOTTOM GUIDE, WITH DOUBLE OR TRIPLE TRACK, OR SLIDING IN A CAVITY WALL. A SLIDING DOOR CAN BE ARRANGED TO HAVE FOLDING LEAVES. INTERNAL FOLDING PARTITIONS ARE SLIDING-FOLDING DOORS.



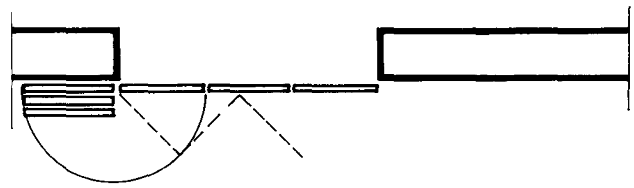
TWO LEAF DOUBLE SLIDING-FOLDING DOOR:

DOOR LEAVES FOLDING 90°



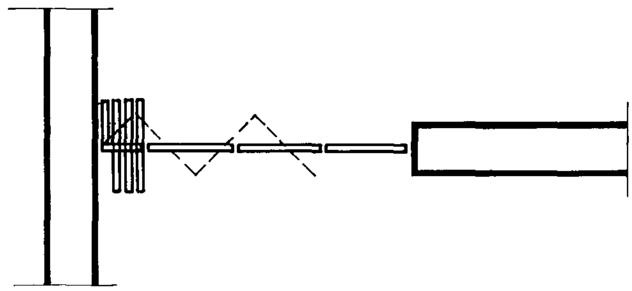
TWO LEAF DOUBLE SLIDING-FOLDING DOOR:

DOOR LEAVES FOLDING 180°



THREE LEAF SLIDING-FOLDING DOOR:

DOOR LEAVES FOLDING 180°



CENTRE HUNG SLIDING-FOLDING DOOR WITH HALF LEAF:

DOOR LEAVES FOLDING 90°

INDUSTRIAL DOORS: INDUSTRIAL DOORS ARE STRAIGHT SLIDING DOORS OR SLIDING-FOLDING DOORS, TOP HUNG WITH BOTTOM GUIDE OR TOP HUNG WITH BOTTOM ROLLER.

SPECIAL DOORS:

FLEXIBLE DOORS:

THESE ARE SPECIFIED FOR POSITIONS WHERE THE USER HAS HIS HANDS OTHERWISE OCCUPIED (PUSHING A TROLLEY, DRIVING A SERVICE VEHICLE IN A WAREHOUSE ETC.).

AUTOMATIC DOORS:

THESE ARE DOORS WITH INITIATING, SENSING AND TIMING DEVICES, ACTUATING A MOTOR GEAR WHICH PHYSICALLY MOVES THE DOOR (FOR SLIDING DOORS, FOLDING DOORS, SWING DOORS, UP AND DOWN DOORS AND GATES).

PEDESTRIAN OR PASS DOORS

FIG. 305: TYPES OF DOORS

5.4.4.2 SIZE OF DOORS

In the absence of standards, especially in developing countries which have only recently adopted the metric system, a designer is advised to choose for door sizes multiples of a 300mm module (which is more or less based on the inch-foot-system) or multiples of a 125mm module of the overall building components.
External door sizes are about 875mm (width) × 2000mm (height) × 45mm (finished thickness). Interior doors will have the same height, their widths vary from 750mm to 625mm × 40mm finished thickness.

5.4.4.3 DOOR FRAMES

Doors are hung on timber frames which are fixed inside the wall opening. The door frame should only support the door, it should not support any other construction. 2 to 3mm clearance should be allowed to the size of opening inside the frame for hanging and adjusting the door. Rebates in the frame to receive the door should be 12 or 13mm deep.
Frames are normally built in as the construction work of the wall proceeds. They are fixed to the wall (first temporary strutting is needed until the wall is built up) with galvanized steel cramps which are screwed to the back of the jamb (three each side) so as to coincide with the joints of brick-or blockwork. In order to achieve a tight fit a 12mm thick grounding can be fixed to the back of the frame. If frames are fixed into the wall opening after the walls have been built up, provision should be made in the form of wooden pads which are built into the wall (3 to each side of the opening). The frame can then be fixed in by screwing. The screw holes are later plugged with wood pellets (Fig. 307).

5.4.4.4 MATERIALS USED FOR DOORS

The most common material for doors is timber. This is also the main material for door frames.

– **Timber Doors**: There are different types of doors made from timber which will be shown further on.

I. **Unframed Doors** (Fig. 308): These are traditional and inexpensive doors made from vertical tongued and grooved (normally V-jointed) boards which are held in place by horizontal sections called ledges and strengthened by diagonal braces. These are:

- Ledged and Battened Doors;
- Ledged, Braced and Battened Doors.

II. **Framed Doors**: These have stiles which are framed to top, middle and bottom rails:

- Framed, Ledged, Braced and Boarded Doors;
- Framed and Panelled Door: This is also a traditional form of door construction (Fig. 309);
- Framed and Glazed Door (Fig. 310);
- Framed and Louvred Door (Fig. 311).

III. **Flush Doors** (Fig. 312): These are the most universally used pedestrian doors with many different types available:

– Solid Core Door: This has a solid core of laminated timber battens, with hardwood lipping all round.
– Semi Solid Core Door: Battens are fixed to hardwood stiles, top, centre and bottom rail with space between them.
– Cellular Core Door: These are very light doors using different proprietary methods of producing a cellular core such as hardboard lattice construction or extruded wood chipboard etc.

The plywood facings for all these doors are two continuous external surfaces and form a stressed skin panel. Flush doors do not sag, but may warp. It is therefore important that good quality plywood is used and that the core material is well seasoned. The plywood facings can be veneered for natural finish. Hardboard facings may be used if flush doors are to be painted.

– **Metal Doors**: There are a variety of metal framed doors from aluminium, steel, stainless steel and bronze (very expensive material, used for special decorative doors only). Many industrial doors, gates and shutters are from steel. Aluminium framed and glazed doors are assembled in some developing countries from imported sections and used as domestic doors and in offices etc. (Fig 313).

– **Other Materials**: Special toughened plate glass can be used for showroom and shop front doors. Flexible and rigid plastic or lightweight rubber doors are produced, all for special purposes, for industrial buildings, warehouses and hospitals where the users may be pushing trolleys through the doors or carrying bulky goods.

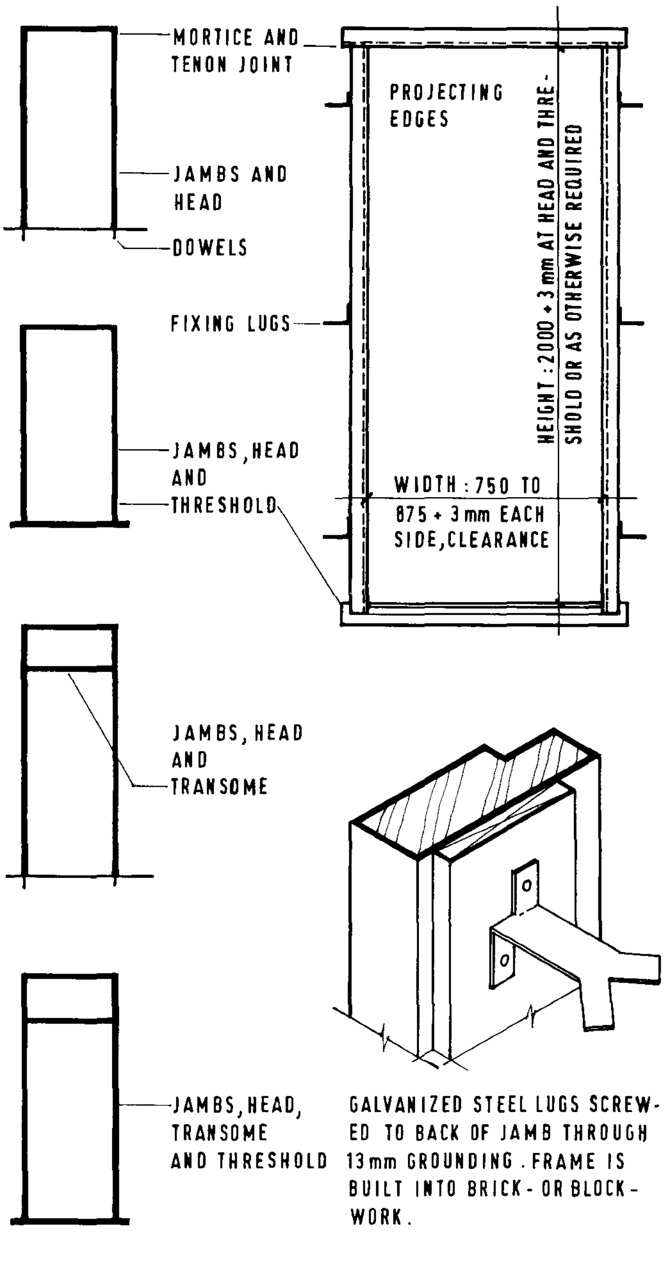
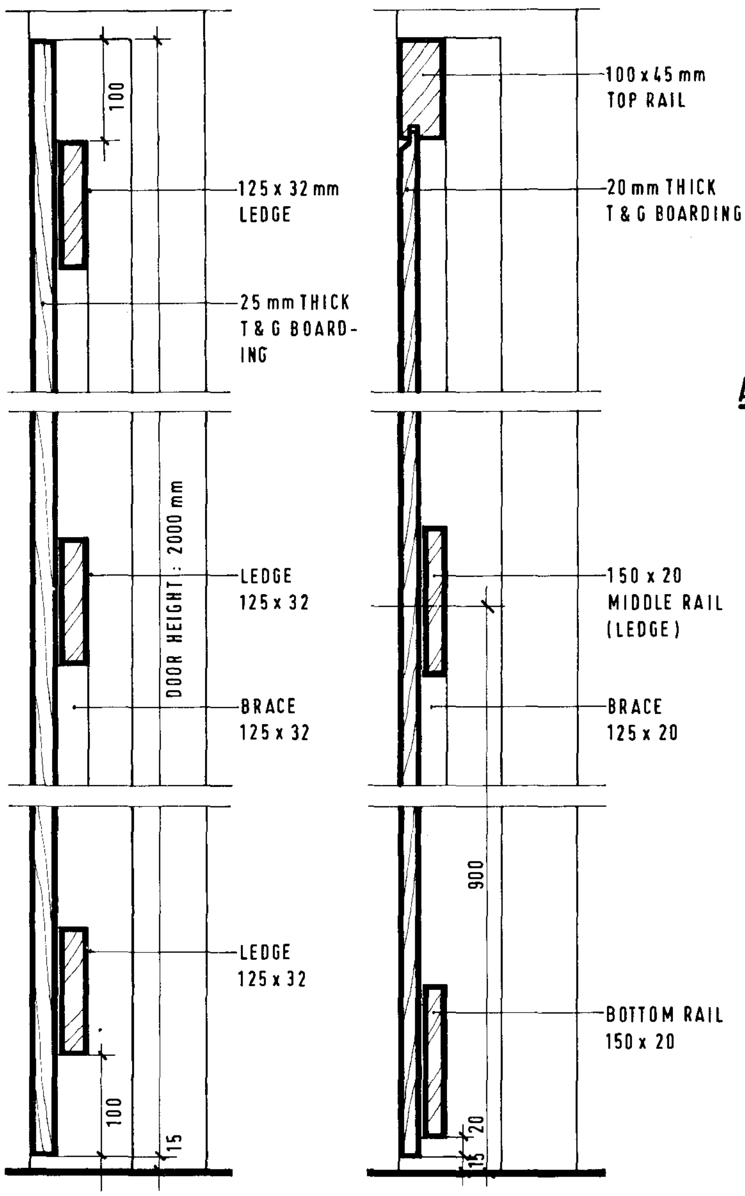
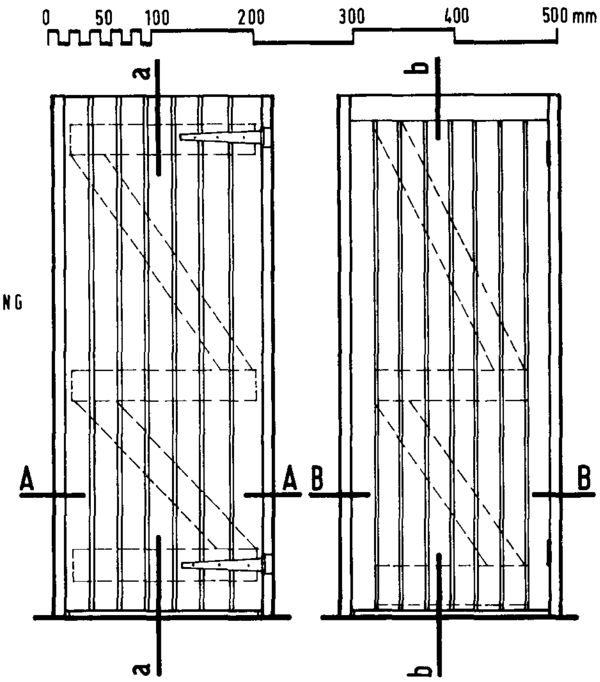


FIG. 307 : DOOR FRAMES AND FIXING

5.4.4 DOORS



1 SECTION a-a **2** SECTION b-b

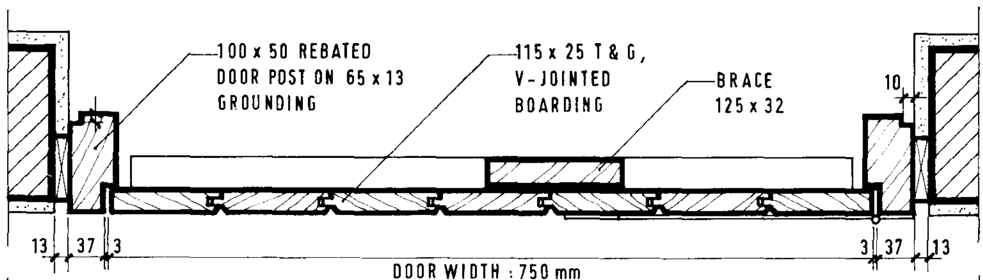


DOOR 1 : LEDGED, BRACED AND BATTENED DOOR

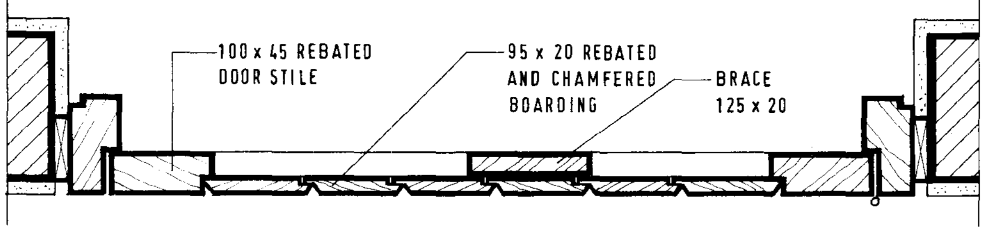
THE DOOR IS FIXED WITH T HINGES TO 100 x 50 REBATED DOOR POSTS.

DOOR 2 : FRAMED, LEDGED, BRACED AND BATTENED DOOR

THE DOOR IS FIXED WITH 1 PAIR OF BRASS BUTT HINGES TO 100 x 50 REBATED DOOR POSTS.



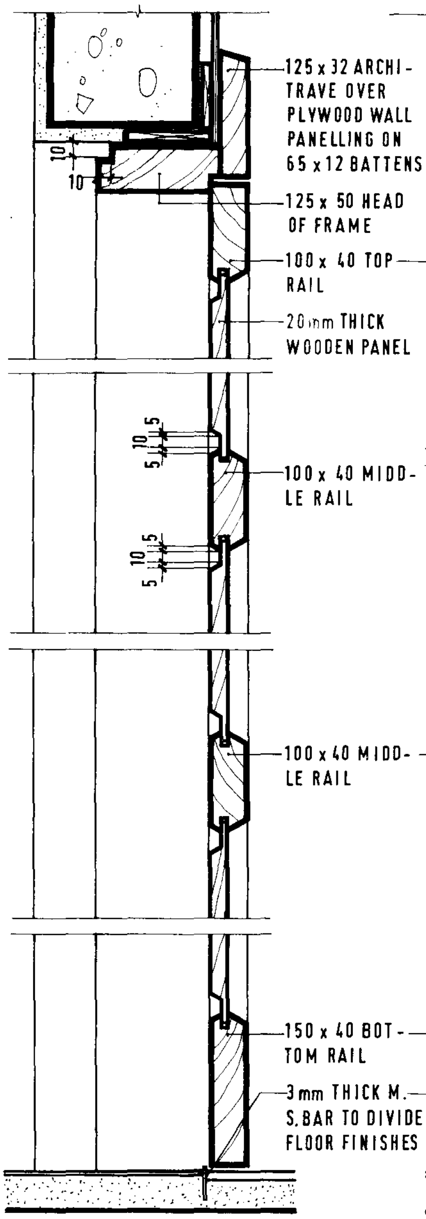
1 PLAN A-A



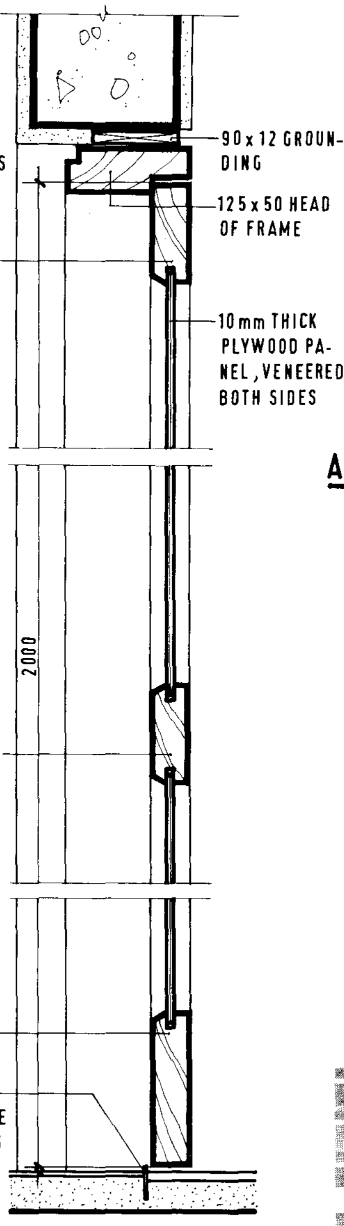
2 PLAN B-B

FIG. 308 : **UNFRAMED AND FRAMED, LEDGED, BRACED AND BOARDED DOORS**

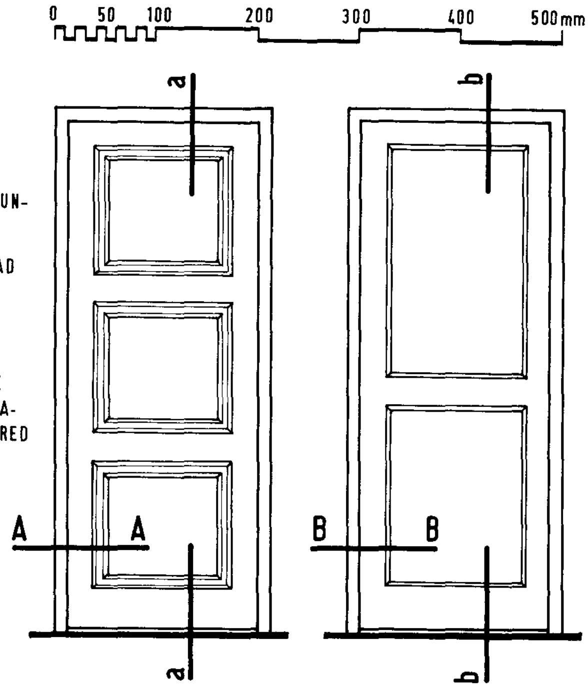
5.4.4 DOORS



4 SECTION a - a



5 SECTION b - b

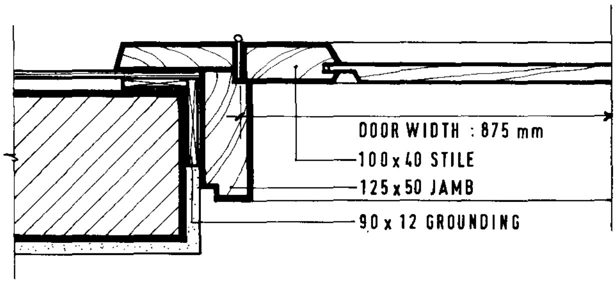


DOOR 4 : FRAMED AND PANELLED DOOR

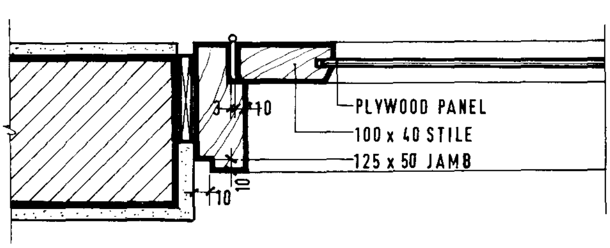
INTERIOR DECORATIVE DOOR, THE WOOD PANELS ARE RAISED AND FIXED TONGUED AND GROOVED INTO STILES AND RAILS. THE DOOR IS FIXED WITH TWO PAIRS OF BRASS BUTT HINGES TO 125 x 50 REBATED DOOR FRAME.

DOOR 5 : FRAMED AND PANELLED DOOR

INTERIOR DOOR. PANELS ARE FROM PLYWOOD, 10 mm THICK, FIXED INTO STILES AND RAILS. THE DOOR IS FIXED WITH TWO PAIRS OF BRASS BUTT HINGES TO 125 x 50 DOOR FRAME. DOOR FURNITURE FOR BOTH DOORS : LEVER HANDLE AND MORTICE LOCK.



4 A - A



5 B - B

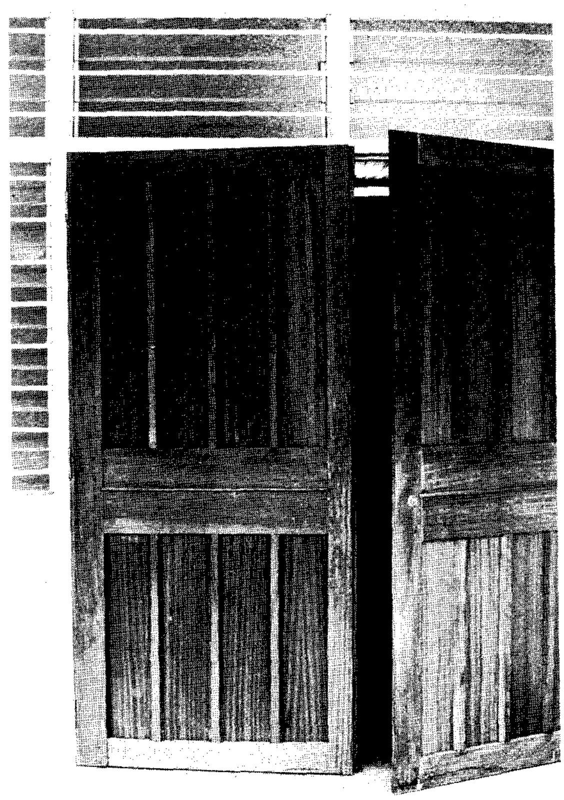
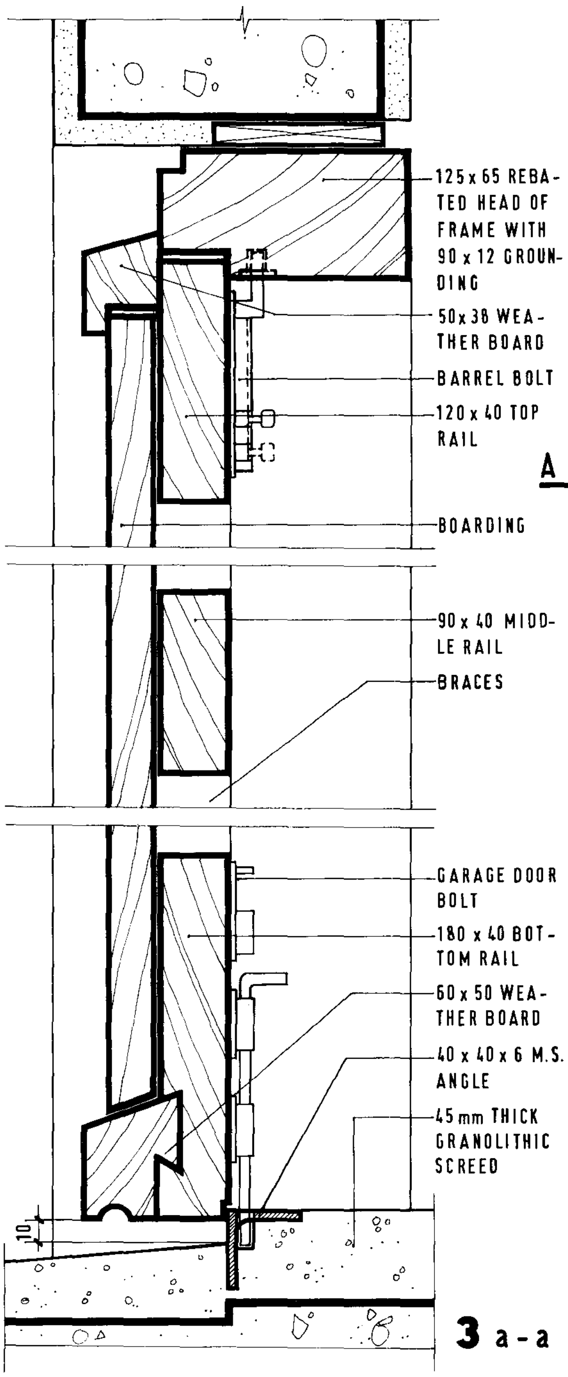
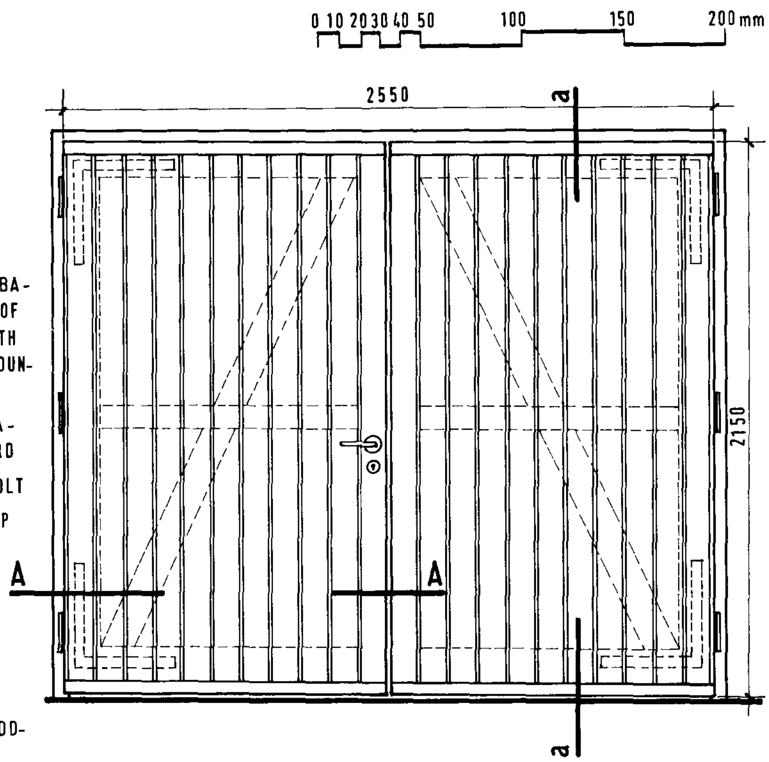


FIG. 309 : FRAMED AND PANELLED DOORS

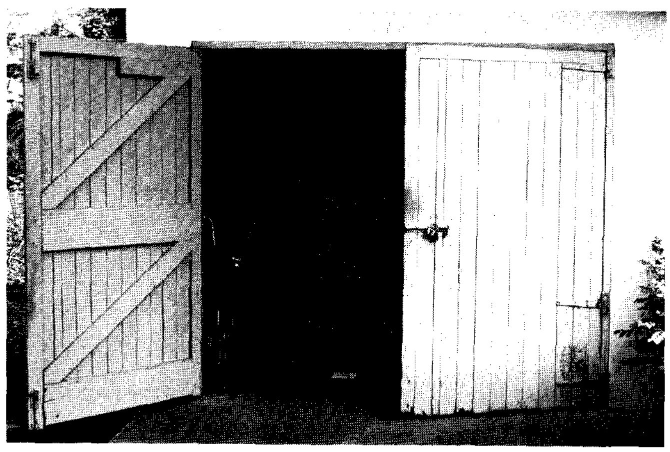


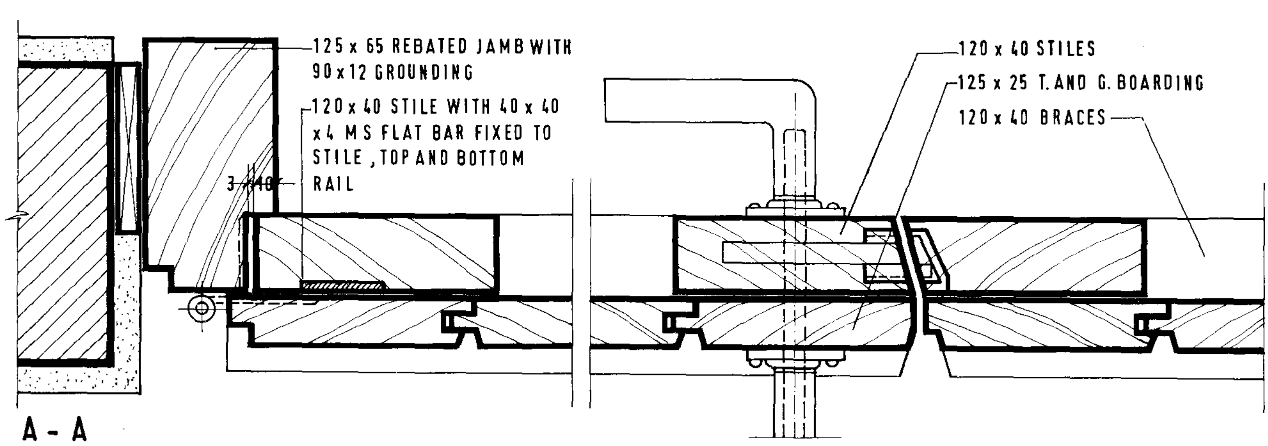
3 a - a



DOOR 3 : ELEVATION OF OUTWARD OPENING LEDGED, BRACED AND BOARDED GARAGE DOOR WITH TWO LEAVES.

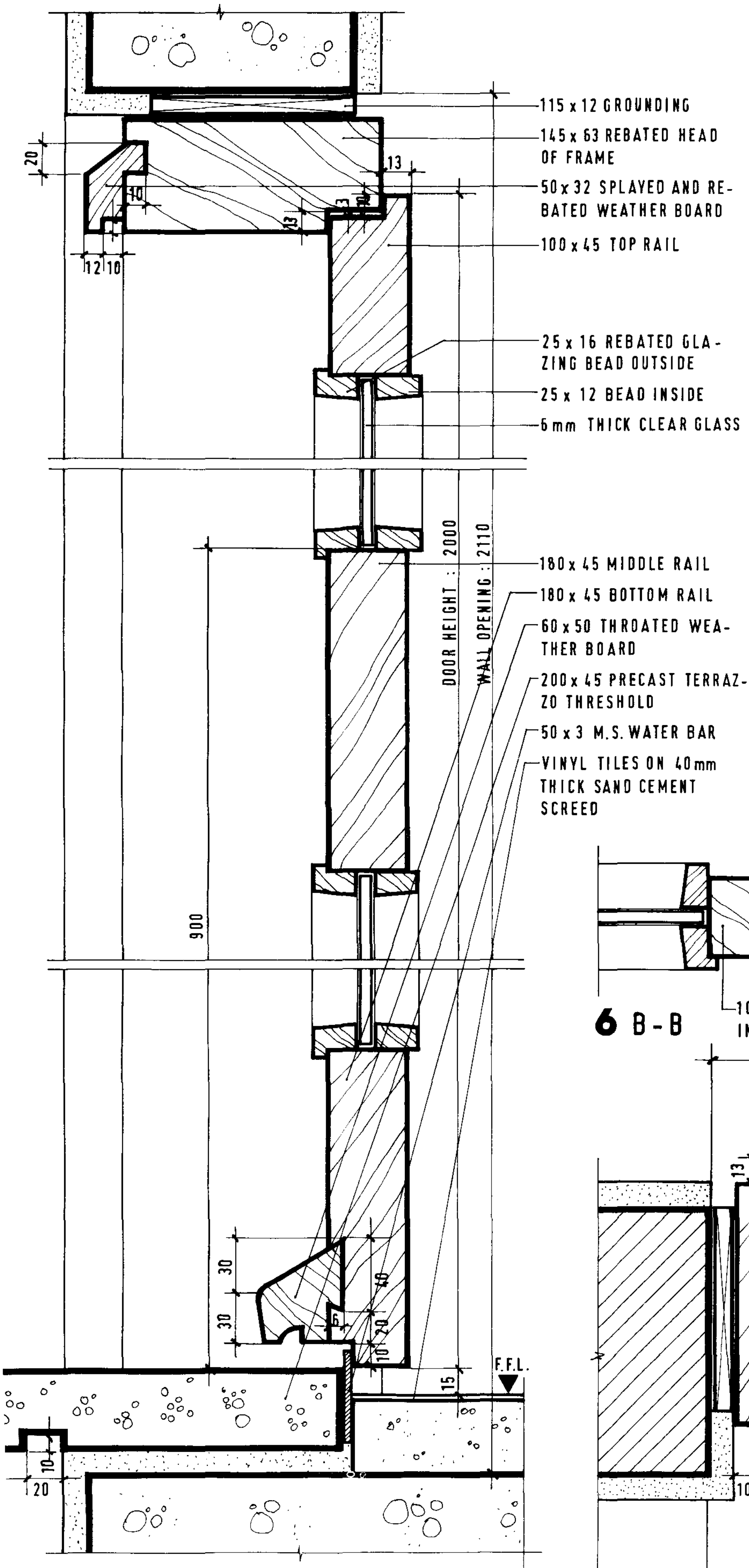
IRONMONGERY: 3 PAIRS OF 150mm LIFT-OFF BRASS HINGES (OR HALF-HINGES MORTICED INTO JAMBS AND STILES), BARREL BOLT UP AND GARAGE BOLT DOWN ON RIGHT DOOR LEAF FIXED ON THE INSIDE. DOOR FURNITURE: LEVER HANDLE AND MORTICE LOCK OR LATCH, HASP AND PADLOCK.





A - A

5.4.4 DOORS



6 SECTION a-a

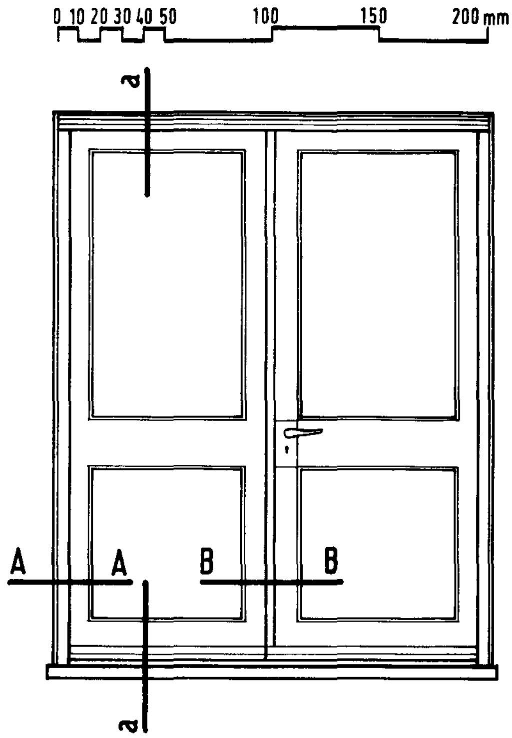
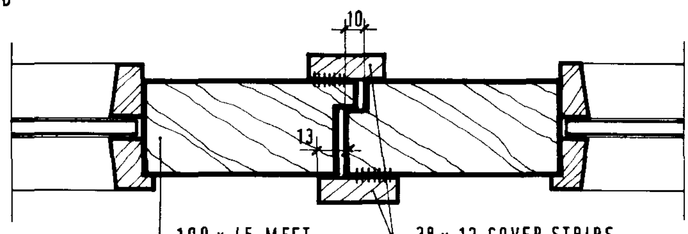


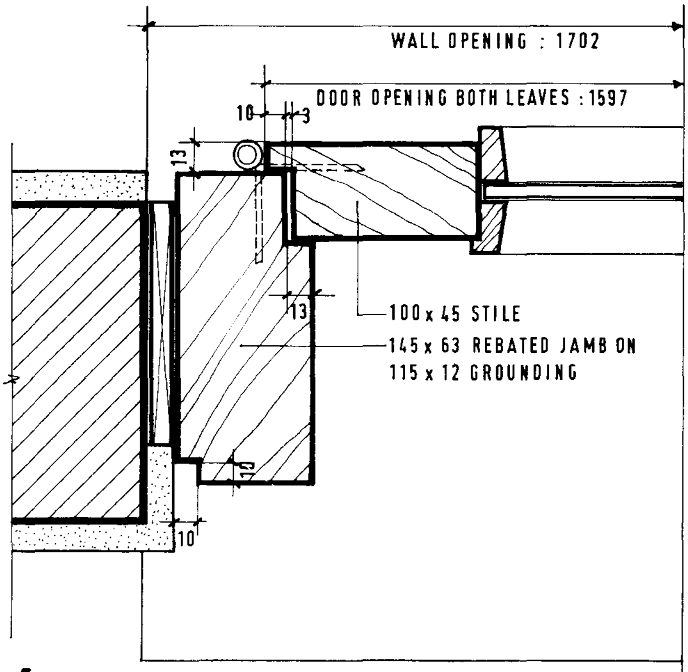
FIG. 310 : **FRAMED AND GLAZED VERANDAH DOOR**

DOOR 6 : ELEVATION

GLAZED VERANDAH DOOR WITH TWO LEAVES, 800 x 2000 mm EACH, FIXED TO 145 x 63 REBATED JAMB WITH $1^1/_2$ PAIRS OF LIFT-OFF BRASS HINGES WHICH ARE MORTICED INTO JAMB AND STILE. MORTICE LOCK AND LEVER HANDLE AND BOLTS UP AND DOWN ON INSIDE OF DOOR.



6 B-B



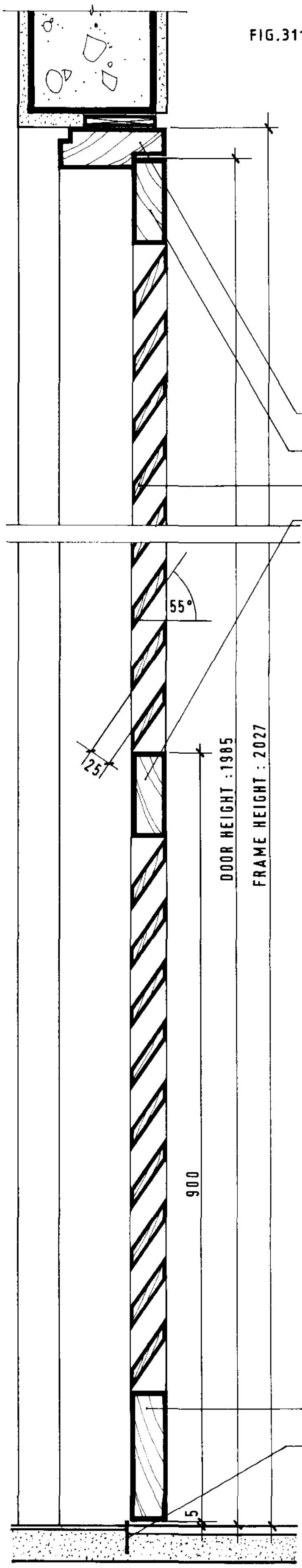
6 A-A

0 50 100 200 300 400 500

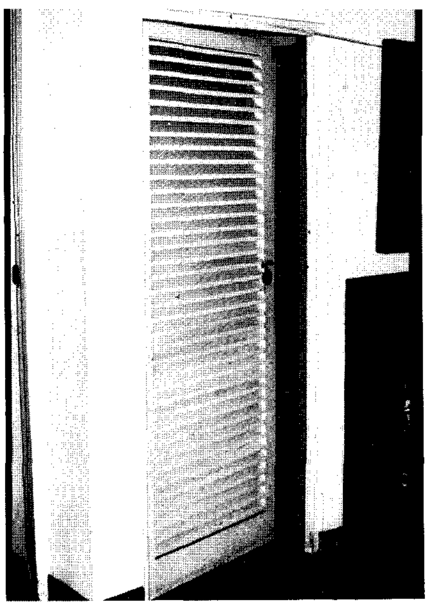
0 50 100 200 300 400 500mm

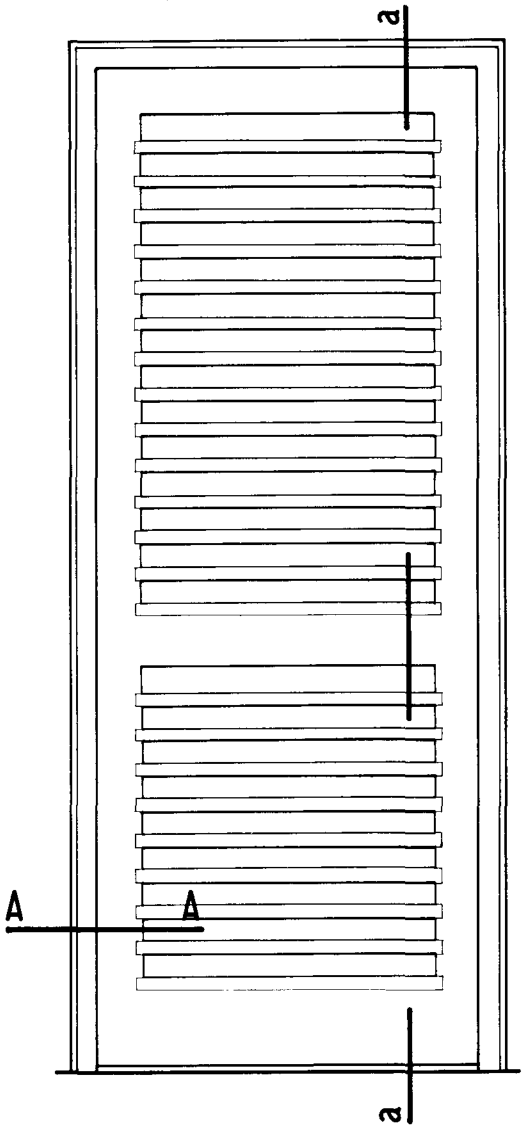
FIG.311: TIMBER LOUVRED DOOR

THIS TYPE OF DOOR IS USED AS INTERNAL DOOR IN AREAS WHERE PERMANENT VENTILATION IS REQUIRED. THE ARRANGEMENT OF THE TIMBER LOUVRES CAN BE DESIGNED IN DIFFERENT WAYS. THE LOUVRE SLATS ARE SET AT 45° TO 55° AND FIXED SO THAT THERE IS A MINIMUM OVERLAP OF 5mm. EDGES OF THE LOUVRES CAN BE CHAMFERED OFF TO BE FLUSH WITH THE DOOR FRAME AS SHOWN IN THIS DETAIL OR THEY CAN PROJECT IN FRONT OF BOTH DOOR FACES. THE LOUVRES ARE HOUSED INTO THE DOOR FRAME STILES OR CAN BE SET INTO LOUVRE STILES TO FORM A SEPARATE PANEL. THE DOOR IS HUNG ON $1\frac{1}{2}$ PAIRS OF BRASS BUTT HINGES.

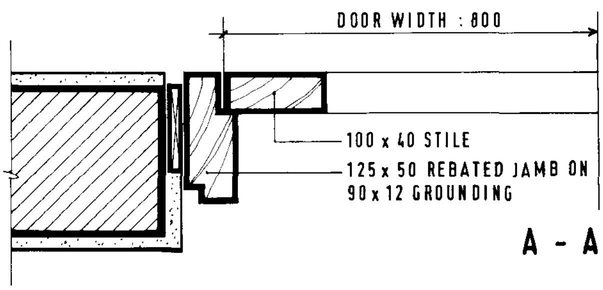


7 SECTION a-a





DOOR 7 : ELEVATION

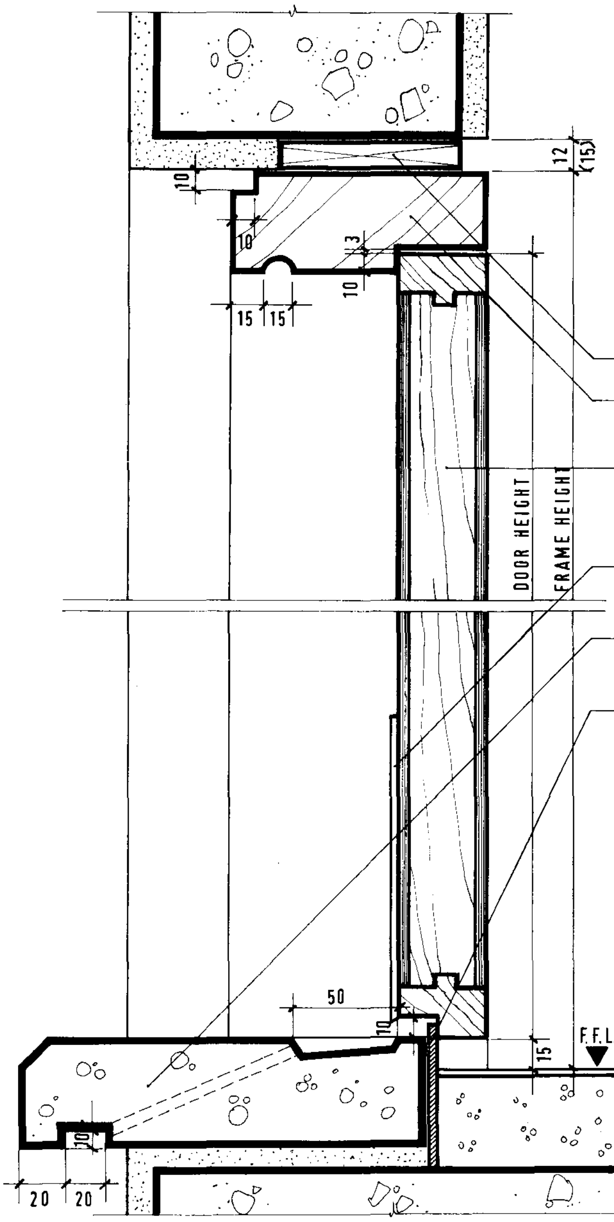


A - A

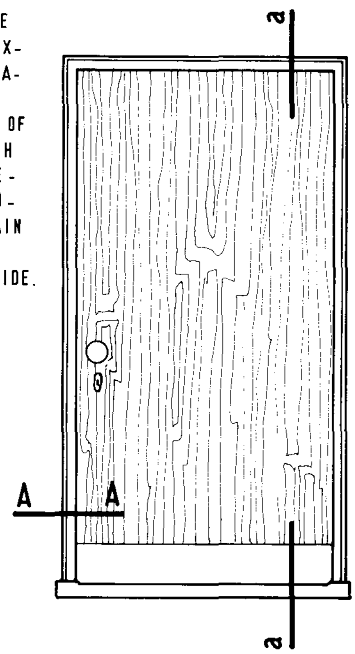
5.4.4 DOORS

0 10 20 30 40 50 100 150 200 mm

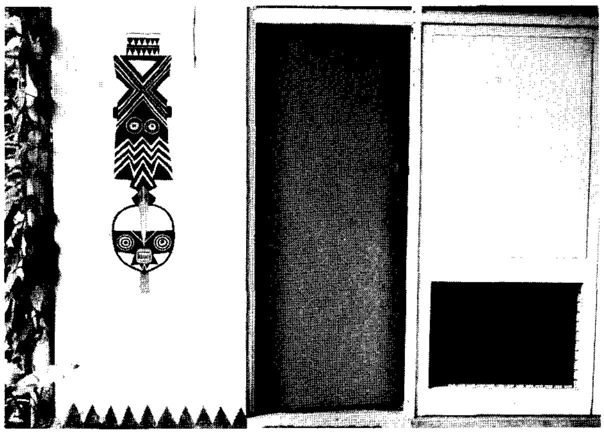
FLUSH SOLID CORE PLYWOOD ENTRANCE DOOR 875 x 2000 x 45 mm THICK, FIXED TO 125 x 50 REBATED TIMBER FRAME WITH 1½ PAIRS OF 100 mm FIXED PIN HINGES (BRASS). OUTSIDE SKIN OF DOOR TO BE PRIMED AND PAINTED WITH TWO COATS OF OIL PAINT OR TO BE VENEERED AND FINISHED WITH MATT POLISH. EXTERNALLY 150 mm WIDE PLAIN ALUMINIUM KICKING PLATE. YALE LOCK AND TURN KNOB OUT- AND INSIDE.

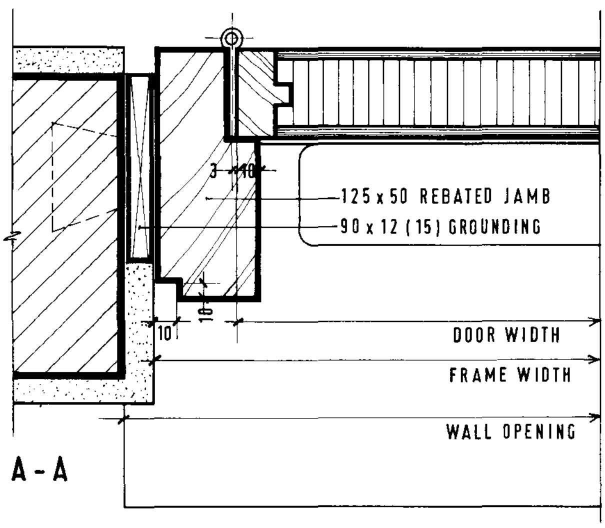


8 SECTION a-a

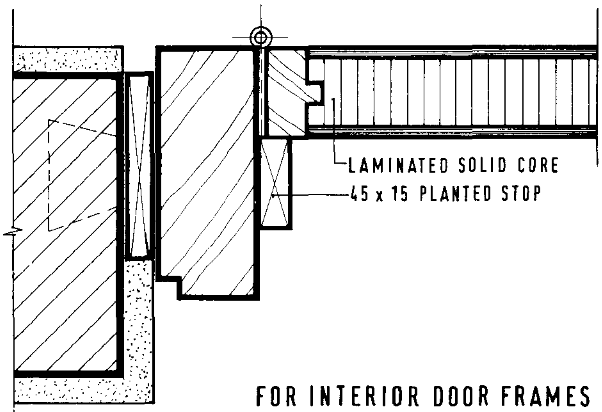


DOOR 8 : ELEVATION FROM THE OUTSIDE





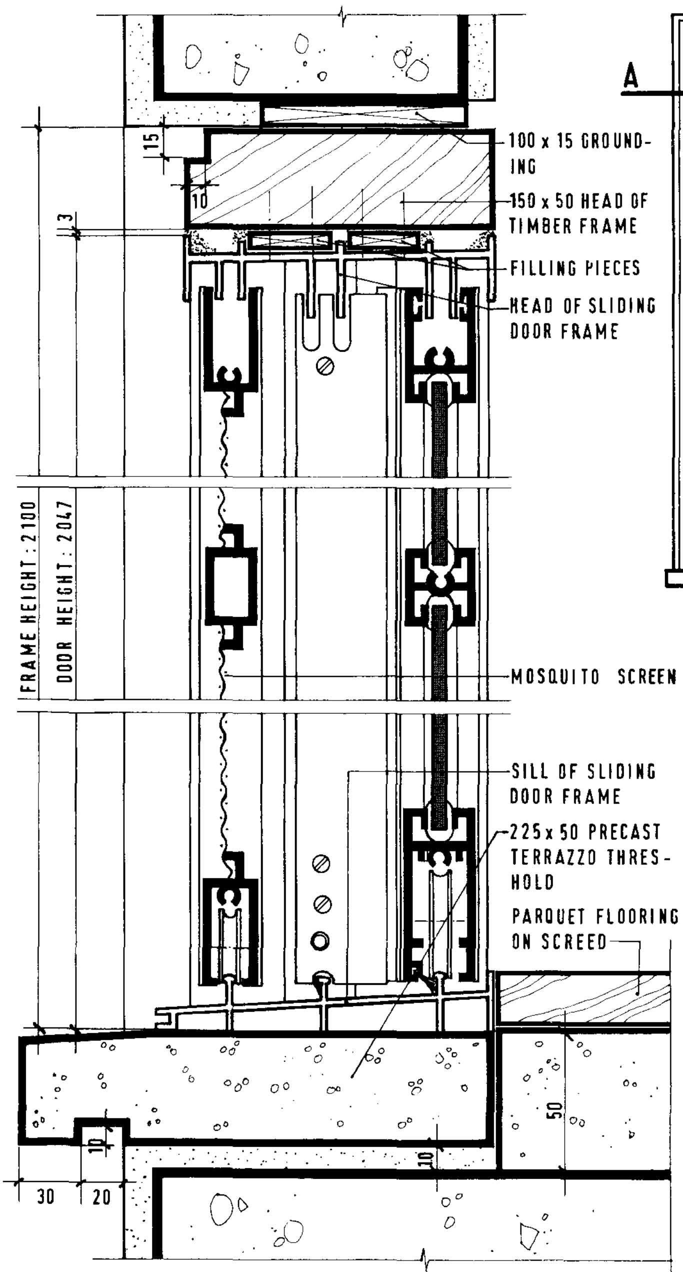
A-A



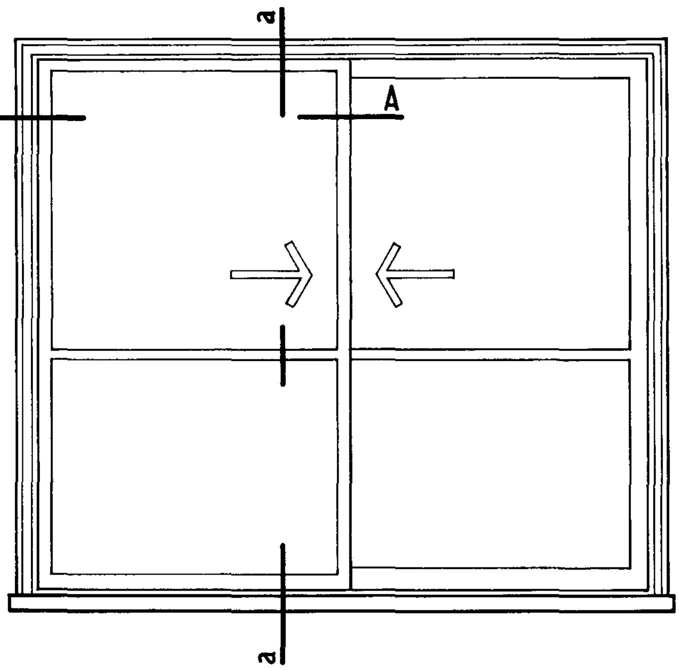
FOR INTERIOR DOOR FRAMES IT IS MORE ECONOMIC TO USE 45 x 15 PLANTED DOOR STOPS.

FIG. 312 : EXTERNAL SOLID CORE PLYWOOD FLUSH DOOR

SCALE AS FOR DOOR 8



9 SECTION a - a



DOOR 9 : ELEVATION FROM THE OUTSIDE IN CLOSED POSITION.

"ALUGAN" ALUMINIUM SLIDING DOOR, STRAIGHT RUN, DOUBLE LEAF, DOUBLE TRACK WITH A THIRD TRACK FOR A SINGLE LEAF MOSQUITO SCREEN, FIXED TO A TIMBER FRAME.

9 A - A

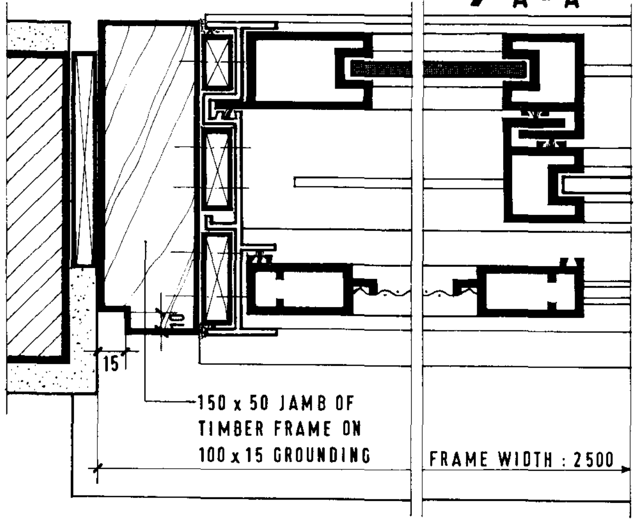


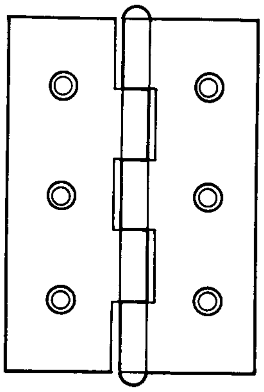
FIG. 313 : ALUMINIUM SLIDING DOOR

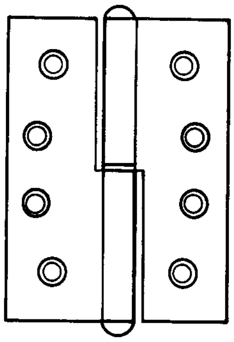
5.4.4.5 IRONMONGERY (Fig. 314)

Up to about 100 years ago architectural ironmongery was handmade. A lot of skill and ingenuity was and still is used by the local craftsman or village blacksmith to manufacture these mechanical products. Hinges and locking devices have been produced ever since man began to build, with surprisingly few changes in their basic working principles since early times. Some of the craftsmanship has been replaced by industrial production with machines which resulted in a wide range and variety of ironmongery offered. For the designer it is important to be familiar with ironmongery to enable him to select the right kind for the proposed doors and windows. The architect has to specify the ironmongery items and to inform the quantity surveyor also about the fixing sequence. Ironmongery should be treated in the same way as any other building component and selected with a complete understanding of its function and capabilities. There are two groups which should always be separated from one another:

- **Ironmongery**: Hinges, door stops, door closers, floor springs, door holders, door stays, locks and latches, bolts;
- **Door Furniture**: Knob and lever furniture, locking knobsets, door plates, pull handles or push pads, signs, letter plates, knockers.

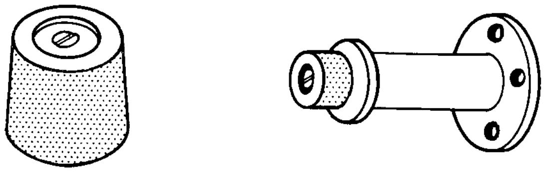
Most of these items (except hinges, bolts, stops, latches) are imported into developing countries and the architect will have to make a choice from catelogues available from local technical and hardware stores. In order to house all ironmongery securely and in addition to fixing the door furniture, doors should not be less than 40mm thick.



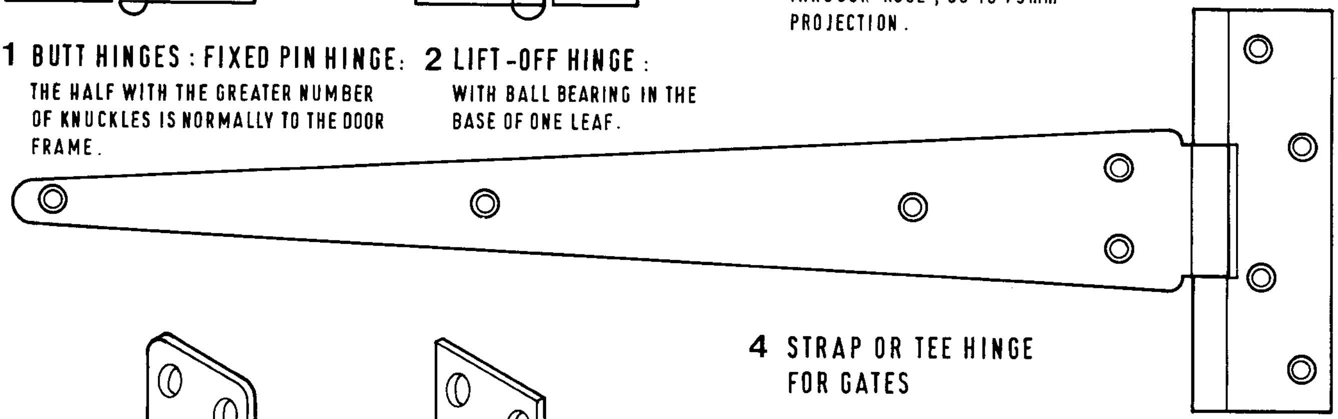


1 BUTT HINGES : FIXED PIN HINGE:
THE HALF WITH THE GREATER NUMBER OF KNUCKLES IS NORMALLY TO THE DOOR FRAME.

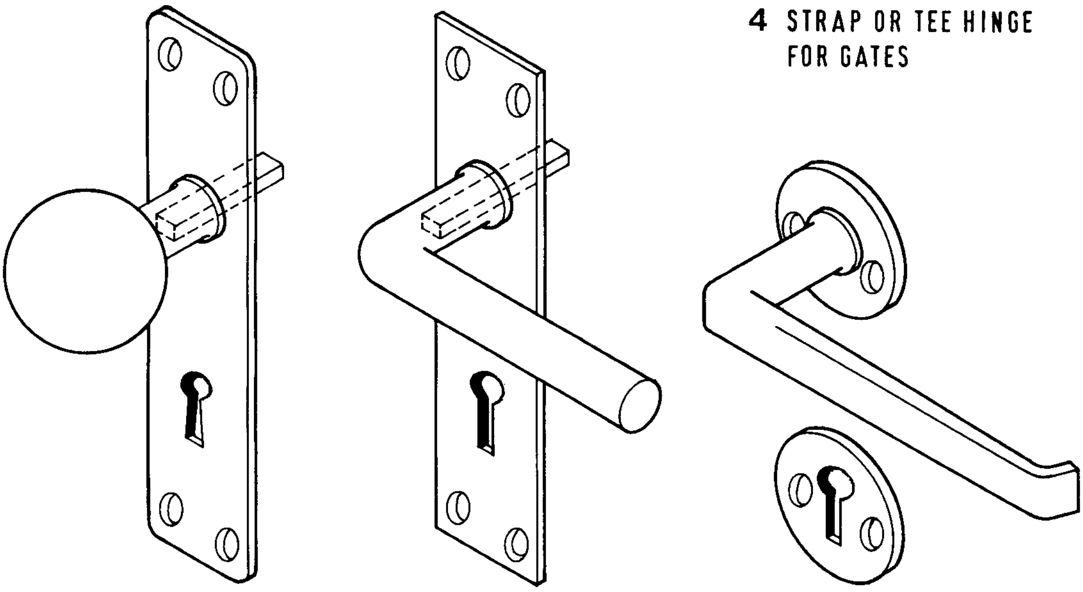
2 LIFT-OFF HINGE :
WITH BALL BEARING IN THE BASE OF ONE LEAF.



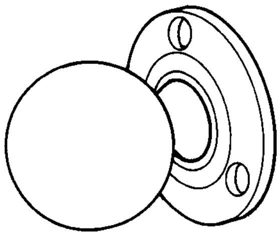
3 RUBBER DOOR STOPS :
ABOVE : FOR FIXING INTO FLOOR WITH CONCEALED SCREW.
ABOVE RIGHT FIXED PROJECTION STOP FOR WALL FIXING THROUGH ROSE, 50 TO 75mm PROJECTION.

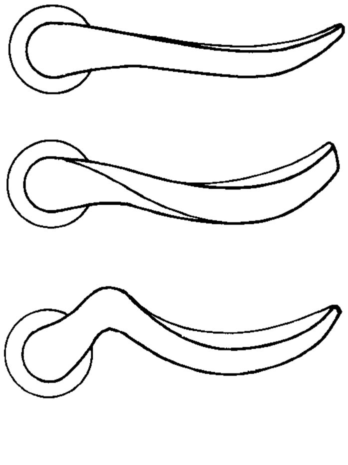


4 STRAP OR TEE HINGE FOR GATES

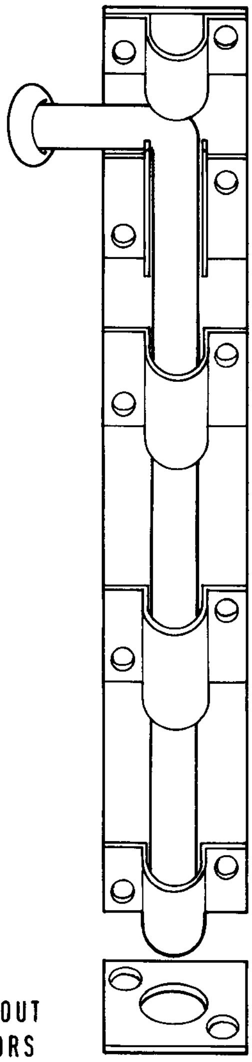


6 DOOR FURNITURE : KNOB OR LEVER HANDLES WITH LONG BACK PLATES OR ROSES
ASSEMBLY FIXED THROUGH HOLES IN NECK OF KNOB OR LEVER HANDLE OR IN ROSE WITH GRUBSCREW TO SPINDLE IN LOCK CASE. NORMALLY FOR USE WITH MORTICE LOCKS. BACK PLATES OF FURNITURE CAN BE SUPPLIED WITH EXPOSED OR CONCEALED SCREW FIXING.





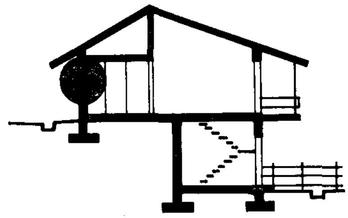
LEVER HANDLES :
LEVER HANDLES SHOULD BE WITHOUT SHARP EDGES AND SHAPED SO THAT A HAND DOES NOT EASILY SLIP OFF WHEN THE HANDLE IS DEPRESSED.



5 BARREL BOLT WITH OR WITHOUT BACK PLATE FOR GARAGE DOORS

FIG.314 : **SOME IRONMONGERY AND FURNITURE FOR DOORS**

5.4.5 WINDOWS



Traditionally the window was considered as an "opening" in the external wall. With the development of different building materials, the advent of metal and glass, windows in some cases now form the entire wall, that is, there is no longer a distrinction between the wall and windows (curtain walls, solar reflective walls of multi-storey and ultra-high structures). This book will concentrate on the conventional windows, their functions in a tropical setting and their detailing.

5.4.5.1 FUNCTIONS OF A WINDOW IN A TROPICAL CLIMATE

A window in a tropical country has to fulfil the following functions:

- To admit and direct ventilation;
- To admit daylight;
- To permit vision out (or in);
- To be an element of the architectural composition of the building;

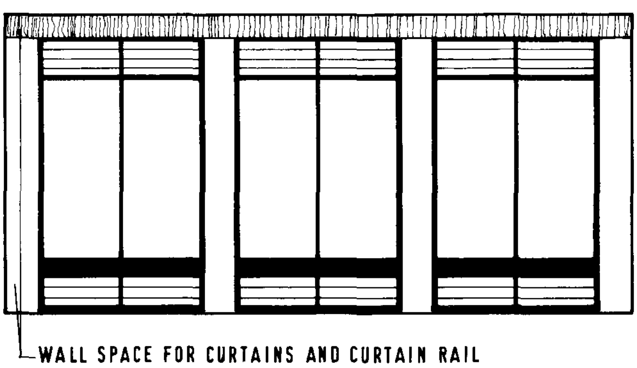
Ventilation: To arrange the windows in such a way that sufficient natural ventilation is provided, especially in the hot and humid climatic zones, is most important. Window openings should be arranged to suit the local climatic conditions.

– For the hot and humid zone: In this area the windows should be designed and placed so that cross ventilation is encouraged through the rooms, past the bodies of the occupants, to ensure rapid evaporation of sweat from the skin. In areas with prevailing winds the main rooms of a building, e.g. living room, bedrooms, study, offices etc. should be arranged so that window openings are set at an angle to the line of direction of the prevailing winds. Sizes of windows should be large, from ceiling to floor.

– For the hot and dry zone: In this area the day temperatures are very high, with a considerable dust content in the air. The night temperatures can drop very low (a change of temperature of 25°C and more from day to night is possible). Windows in this area should be arranged so that they fully admit the cool night air and help to store it during the day. Openings should be small or narrow and set in such a way that vertical ventilation (stack effect) is encouraged (Fig. 315).

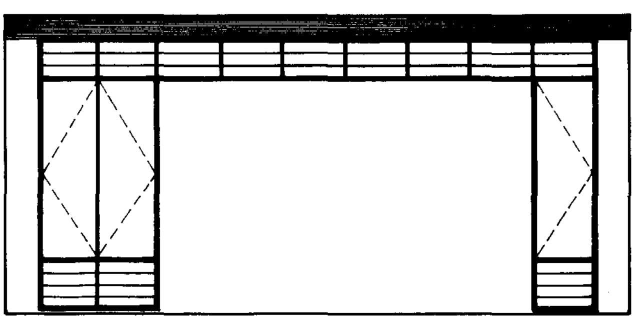
The rapid increase of mechanical air-conditioning in tropical countries in the urban centres and especially in offices, hotels, domestic buildings etc. has reduced the need for natural ventilation. But with the increasing costs of electricity the aim in a tropical developing country should be to fully utilize natural ventilation by designing and detailing for the climate. Electrical fans rather than airconditioners should be used in areas where there are little or no prevailing winds and high humidity. Available electricity sources should be used for more important services to the community rather than for mechanical air-conditioning. For specific purposes, however, mechanical air-conditioning must be provided (operation theatres, laboratories etc.). If windows are required for the admission of daylight, these must be specially insulated to ensure that conditioned air is not lost.

Admission of Daylight: Daylight in tropical countries can be very intense. Light sources which have to be considered here are the sun, the sky and reflected light from surfaces around a building. It is interesting to note the levels of "reflectances" (light reflected from building materials and outside surfaces):



FOR THE HOT AND HUMID ZONE :

WINDOW OPENINGS SHOULD BE ARRANGED FROM CEILING TO FLOOR TO FACILITATE CROSS VENTILATION THROUGHOUT THE WHOLE ROOM. WINDOWS CAN BE JALOUSIED OUTWARD OPENING CASEMENTS WITH INWARD OPENING MOSQUITO SCREENS OR LOUVRES . HIGH AND LOW LEVEL VENT OPENINGS SHOULD BE LOUVRES OR FIXED SHUTTERS .



FOR THE HOT AND DRY ZONE :

WINDOW OPENINGS SHOULD BE NARROW WITH HIGH LEVEL AND SOME LOW LEVEL VENT OPENINGS. WINDOWS CAN BE OUTWARD OPENING BOARDED CASEMENTS WITH INWARD OPENING MOSQUITO SCREENS. HIGH AND LOW LEVEL VENT OPENINGS SHOULD BE TIMBER LOUVRES. THIS WILL MAKE IT POSSIBLE TO RETAIN THE COOL NIGHT AIR WHEN THE WINDOWS ARE CLOSED DURING THE DAY IN THE PERIODS OF INTENSE HEAT.

FIG. 315 : ARRANGEMENTS OF WINDOWS IN DIFFERENT CLIMATIC ZONES.

Concrete	55%
Brick	48%
Sandstone	18%
White Paint Surface, fresh	25%
old	55%
Asphalt	7%
Soil	7%
Concrete Paving	18%
Gravel	13%
Grass	6%
Mean Vegetation	25%

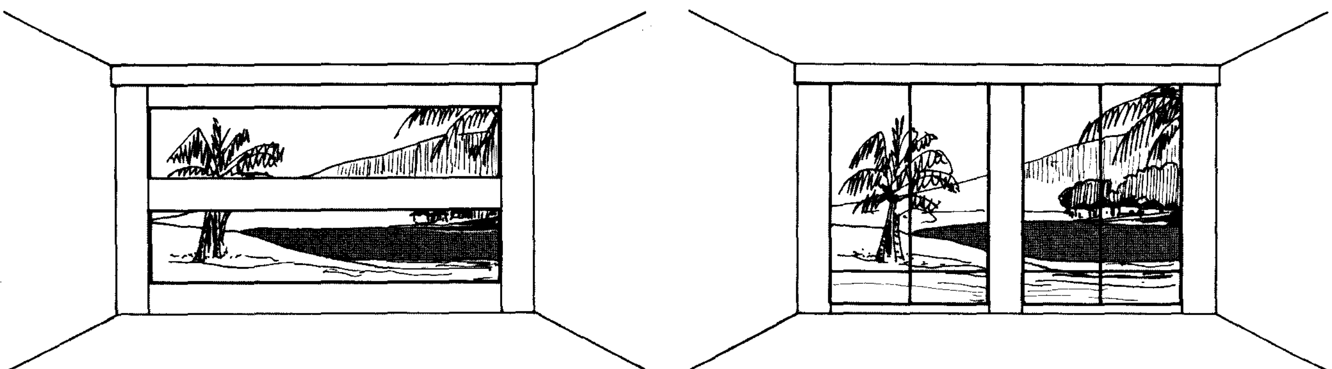
(Source: B.R.R.I. information)

A designer should take these figures into careful consideration when designing locations of window openings in relation to admission of daylight. In some of the tropical areas with very intense light and where vision to the outside is not considered important (e.g. internal courtyard arrangements) it is advisable to design the external wall together with the window openings so that diffuse, indirect light is admitted. Considering the environmental conditions, the roof structure should be designed to shade window openings of the east, south and west elevation of the building. Where this is not possible, suitable sun shading devices should be provided as part of the window or wall design. Sunlight should not enter a room through the windows. Besides heating up the room, sunlight can have adverse effects on curtains and furniture (bleaching, discolouring).

Vision out (or in): Vision out of a building into the surrounding landscape (or townscape) or into an internal landscaped courtyard must, if it is required, be unimpeded. It is desirable to include sky, vegetation, and sufficient foreground in the "picture one sees", so that windows should be arranged vertically rather than horizontally. Mullions, transomes or other window dividers should not be fixed at eye level of a standing or sitting person (Fig. 316).

Element of the Architectural Composition: Windows (and doors) are important elements of the overall architectural composition of a building. They contribute, more than any other part, to the aesthetic effect created by the building.

Security: In most of the urban areas of the world nowadays it has become necessary to provide burglar proofing to windows to safeguard a building against forced entry. The most effective burglar proofing is to incorporate mild steel bars into the frame design. Ordinary steel mesh gives only insufficient security and furthermore obstructs the vision out of a window. In most cases only the ground floor windows require burglar proofing. In some town houses this has been designed to be a decorative feature, welded to different designs by a metalworker (Fig. 318 *and* 319).



THE VISION OUT IS OBSTRUCTED IN A HORIZONTAL ARRANGEMENT OF THE WINDOWS.

VISION OUT INCLUDES THE COMPLETE LANDSCAPE, FORE- AND BACKGROUND AND THE SKY IN A VERTICAL ARRANGEMENT OF THE WINDOWS. THIS MAY RESULT IN LESS PRIVACY, BUT BETTER VISION.

FIG. 316: **VISION OUT OF WINDOWS** - ADAPTED FROM "A.J.-HANDBOOK OF BUILDING ENCLOSURE", BY A.J. ELDER AND M. VANDENBERG, THE ARCHITECTURAL PRESS LTD., LONDON.

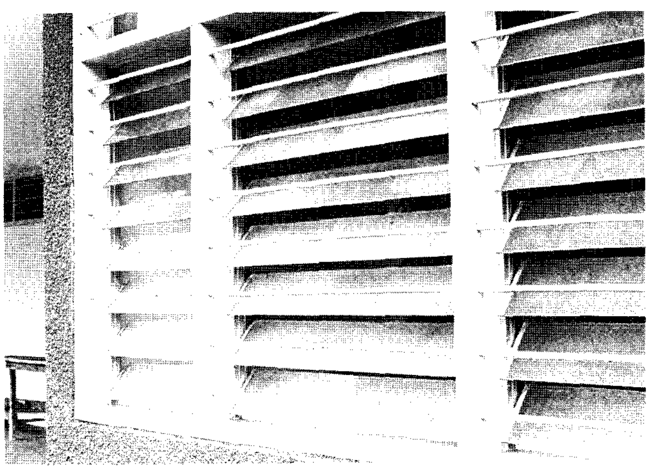
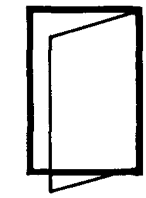


Fig. 318: Burglar proofing bars as part of a window frame. The louvres are fixed into the frame at a later stage, 1982.

Fig. 319: A metal worker welding together a burglar proofing screen at G.I.H.O.C. Steelworks, Tema, 1982.

5.4.5 WINDOWS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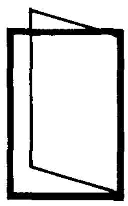
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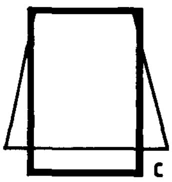
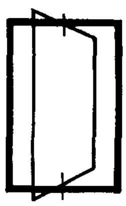

c

1 CASEMENT WINDOWS :

a SIDE-HUNG OPEN IN
b SIDE-HUNG OPEN OUT
c TOP-HUNG OPEN OUT

CASEMENT WINDOWS CAN BE USED AS INWARD OPENING MOSQUITO SCREEN TOGETHER WITH AN OUTWARD OPENING JALOUSIED SHUTTER, WHICH, WHEN CLOSED AND BOLTED FROM THE INSIDE, SAVES BURGLAR-PROOFING. THEY CAN BE MADE ENTIRELY FROM WELL SEASONED TIMBER WITHOUT GLASS. TOP-HUNG OPEN OUT CASEMENTS, BOARDED OR SHUTTERED, CAN BE USED TOGETHER WITH AN INWARD OPENING MOSQUITO SCREEN.

CASEMENTS ARE FIXED WITH CASEMENT STAYS. THESE WINDOWS ACHIEVE TOTAL WINDOW OPENING. THEY CAN, IF SO REQUIRED, BE ARRANGED WITH FIXED PICTURE WINDOWS (PLAIN GLAZED). CARE MUST BE TAKEN FOR EASY CLEANING.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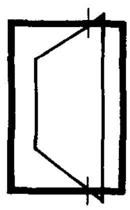
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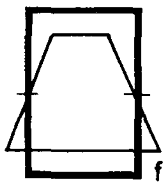
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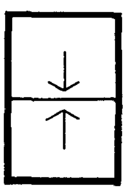
2 PIVOTS :

d VERTICAL PIVOT
e OFF-CENTRE VERTICAL PIVOT
f HORIZONTAL PIVOT

ALL PIVOT WINDOWS SHOULD HAVE SAFETY CATCHES TO PREVENT UNCONTROLLED MOVEMENTS.

HORIZONTAL PIVOTS CAN BE FIXED TO REVERSE FOR CLEANING. PIVOT WINDOWS ACHIEVE ABOUT 90% OF WINDOW OPENING. THEY ARE NORMALLY METAL FRAMED AND SUITABLE ONLY FOR BUILDINGS WHICH REQUIRE NO MOSQUITO AND BURGLAR PROOFING.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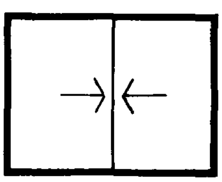
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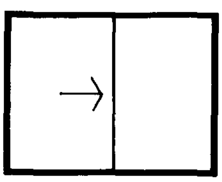
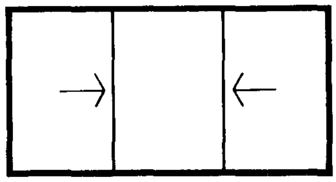

i

3 SLIDING WINDOWS :

g VERTICAL SLIDING (DEVELOPED IN THE 18th CENTURY IN EUROPE AS "DOUBLE HUNG SASH")
h HORIZONTAL SLIDING-TWO MOVING SASHES
i HORIZONTAL SLIDING-ONE MOVING SASH, ONE FIXED SASH
j HORIZONTAL SLIDING-TWO MOVING SASHES, ONE FIXED SASH
k HORIZONTAL SLIDING-THREE MOVING SASHES

SLIDING WINDOWS ACHIEVE UP TO 50% OF THE TOTAL WINDOW OPENING. HORIZONTAL SLIDING WINDOWS MUST BE DRAINED THROUGH THE SLIDING CHANNEL AT THE BOTTOM OF THE WINDOW, IF NO SUITABLE PROTECTION IS PROVIDED OUTSIDE AGAINST RAINWATER RUNNING DOWN THE FACE OF THE WINDOW.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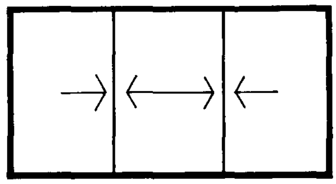
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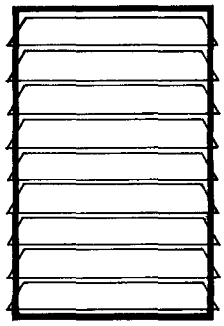
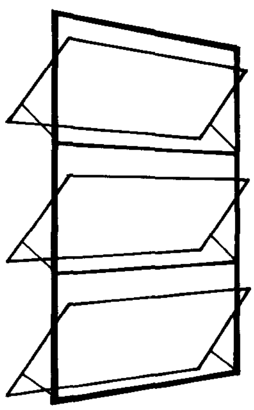
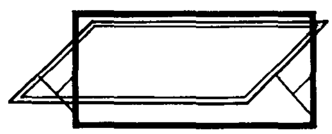
SLIDING WINDOWS ARE NORMALLY METAL FRAMED WINDOWS FROM STEEL AND ALUMINIUM WITH MANY DIFFERENT DESIGNS AVAILABLE. THEY CAN BE PRODUCED WITH MOSQUITO SCREENS WHICH CAN BE CLIPPED ON TO THE FRAME FROM THE INSIDE AND REMOVED FOR CLEANING. BURGLAR PROOFING HAS TO BE PROVIDED SEPARATELY.



4 LOUVRE WINDOWS :

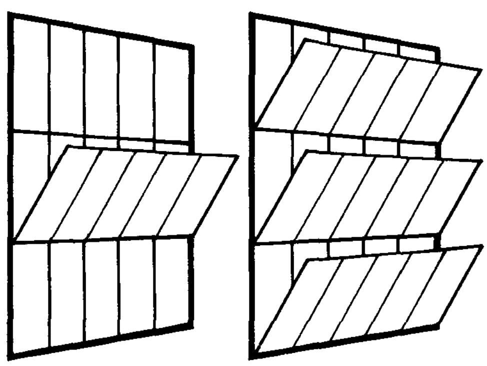
THESE ARE, IN PRINCIPLE, A SERIES OF HORIZONTAL PIVOTS. LOUVRES CAN BE MADE FROM TIMBER, METAL OR GLASS, E.G. "NACO" LOUVRES WHICH ARE FIXED IN NACO-LOUVRE CARRIERS FROM ALUMINIUM. CARRIERS ARE USUALLY FIXED ON A TIMBER SUBFRAME IN WHICH MOSQUITO AND BURGLAR PROOFING CAN BE INCORPOTED. WINDOW ACHIEVES 90% OF TOTAL OPENING.





5 AWNING AND PROJECTED WINDOWS :

THESE ARE TYPICAL METAL FRAMED WINDOWS WITH DIFFERENT NUMBERS OF VENTILATORS WHICH OPEN TOGETHER BY MANUAL OR MECHANICAL CONTROL. FRAMES CAN TAKE CLIPPED-ON MOSQUITO SCREENS. WINDOW FRAMES SHOULD BE FIXED ON TIMBER SUBFRAMES.



6 SECURITY OR GUARD WINDOWS:

THESE WINDOWS ARE NORMALLY USED IN PRISONS. THEY ARE BOTTOM HUNG, INWARDS OPENING METAL FRAMED WINDOWS WITH VERTICAL BARS AS PART OF THE FRAME.

FIG.317 : WINDOW TYPES SUITABLE FOR TROPICAL CLIMATES

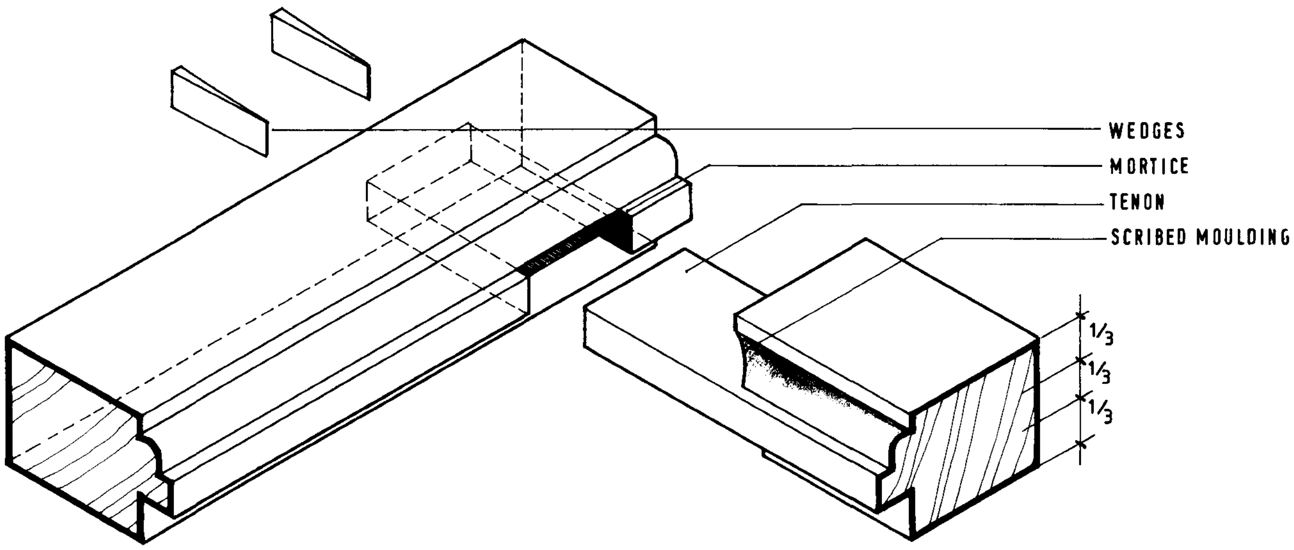
5.4.5.2 MATERIALS USED FOR WINDOWS

Windows are commonly made of wood, metal (steel and aluminium) and nowadays also of plastics. Where timber is available, it should be used in preference to metal framing, which has to be imported in the case of most tropical developing countries. In some of these countries workshops have been set up which assemble imported steel or aluminium sections to specified window sizes.

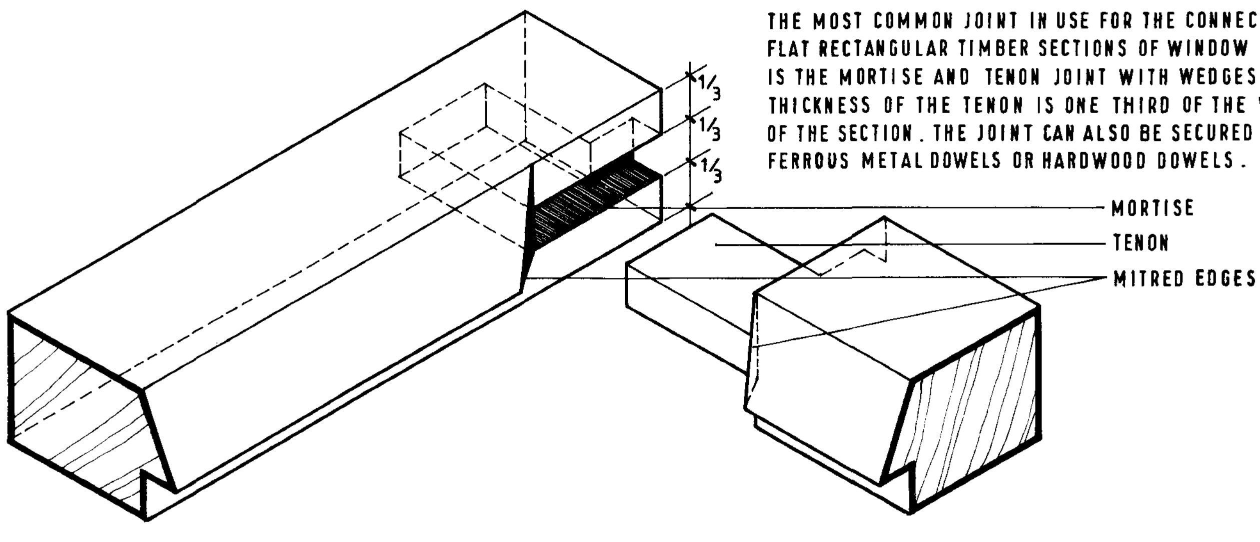
– **Timber**: Tropical hardwood is a very suitable material for all framing sections of a window, including louvres. The timber must be well seasoned and treated with preservatives. As mentioned before **(4 Timber and Timber Frame Construction)** there are some timber species which weather very well and do not require paint or varnish for protection after fixing (e.g. Odum – *Chlorophora Excelsa*). Otherwise timber windows should be protected with paint (primer and oil paint) or varnish.

– **Metal**: Steel and aluminium together dominate the market for metal windows and a desire for permanence. Although steel windows are strong and have dimensional stability, they require protection against corrosion in humid areas and along the coast, in the form of anti-corrosive painting and cover painting after galvanizing the steel. Aluminium windows are lighter and do not normally required protection, except in seriously polluted atmospheric conditions. They only need regular cleaning. All metal windows provide poor insulation. It is advisable to fix a metal window in a timber sub-frame or on to timber grounding (Table 19).

– **Plastics**: Limited use is already being made in the U.S.A. and Europe of glass-reinforced polyester for complete windows frames using tubular box sections which incorporate steel stiffening bars. Whereas a decade ago the development of plastic window frames was encouraged, the oil crisis since 1973 has slowed down this trend



WINDOW FRAME WITH SCRIBED MOULDING AND MORTICE AND TENON JOINT :



THE MOST COMMON JOINT IN USE FOR THE CONNECTION OF FLAT RECTANGULAR TIMBER SECTIONS OF WINDOW FRAMES IS THE MORTISE AND TENON JOINT WITH WEDGES. THE THICKNESS OF THE TENON IS ONE THIRD OF THE WIDTH OF THE SECTION. THE JOINT CAN ALSO BE SECURED BY NON-FERROUS METAL DOWELS OR HARDWOOD DOWELS.

WINDOW FRAME WITH MITRED SPLAY AND MORTISE AND TENON JOINT :

FIG. 320 : TYPICAL WINDOW FRAME JOINTS

in favour of the utilization of materials which do not require oil for their production. Timber framed windows with better insulative properties are preferred in most of the industrialized countries, where energy-saving is now influencing design decisions (in the case of windows heat-loss from the centrally heated buildings in such countries).

5.4.5.3 FRAMING JOINTS

Except for large projects with a repetitive number of window sizes and similar frame components, window frame parts (jamb, sill or transome) are manufactured and assembled on the site. This work involves two stages:

- The frame of the window;
- The opening portions (sashes or casements, louvres).

The designer should have basic knowledge of the different means of preparation of the timber and types of suitable joints so that he (or she) can make a choice with due regard to strength, appearance and costs of the window (Fig. 320). Frames can be fixed into the opening together with galvanized steel lugs as the brick- or blockwork proceeds, or inserted later and screw-fixed through a grounding into timber pads which have been incorporated into the wall earlier. It is important to provide a clear detail where the plaster meets the frame. Plaster will not be finished true to the timber frame and will crack should the frame shrink (Fig. 321).

5.4.5.4 IRONMONGERY

The basic items of ironmongery used for the windows which are detailed on the following pages are shown in Fig. 322. For pivot windows a number of patent pivots have been developed which transfer the point of balance during the opening movement of the window. They include friction mechanisms which prevent the window from slamming when the 180° point is approached (in the case of reversible horizontal pivots).

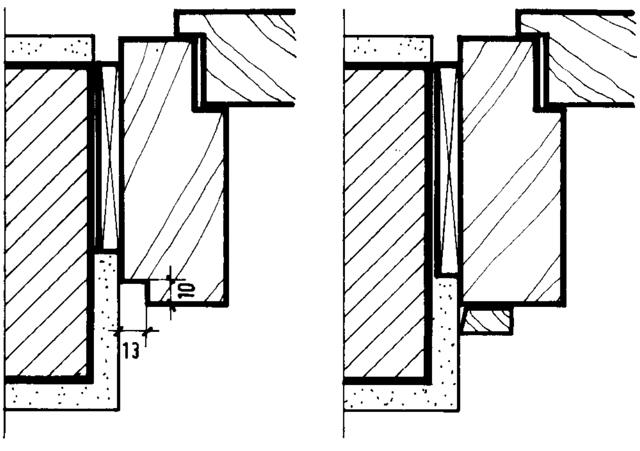
5.4.5.5 GLAZING

It is necessary to provide clearance between the edge of the glass and surrounding frame to allow for fitting, fixing and thermal movement. In timber frames glass should be fixed with hardwood beads which can be secured by panel pins or countersunk brass screws and cups. The beads should be internal where possible. Glass and beads can be bedded in a glazing compound (normally linseed oil putty or mastic). In metal frames metal beads are fixed either by means of screws into threaded holes or by clipping over protruding studs in the frame. The glass is bedded in a glazing compound before the metal clips are screwed or clipped on.

5.4.5.6 SEALING

A large variety of weatherstrips and seals are available to seal the opening portions of the windows against the frame. They are:

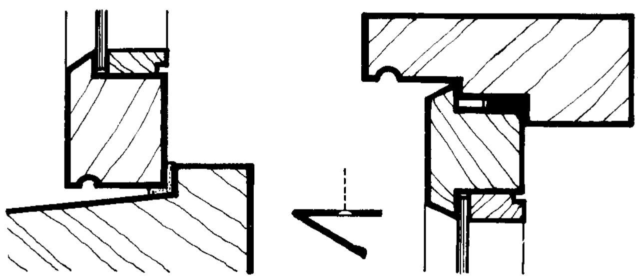
– **Compressive Strips:** From foam plastics and rubbers. Some of these strips can become waterlogged after a time in exposed conditions and will have to be renewed. They are suitable for casement windows.
– **Metal Strips:** These are designed for casements, sliding windows and glass louvre windows (Fig. 323).



JAMB AND HEAD OF FRAME GROOVED TO SEPARATE FRAME FROM PLASTER SURFACE.

25 x 12 mm COVER BATTEN FIXED ALL ROUND.

FIG. 321 : PLASTER FINISH TO FRAME

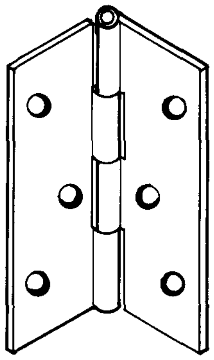


COMPRESSIVE FOAM STRIP

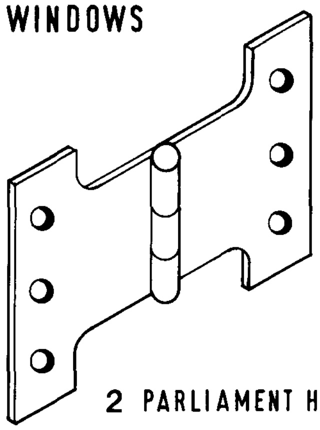
METALLIC SEALING STRIP

FIG. 323 : SEALS AND WEATHER STRIPS

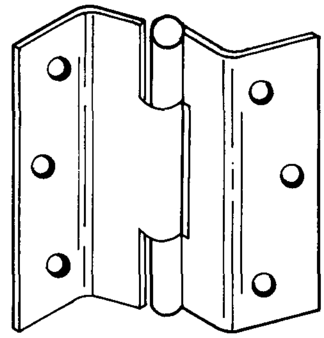
FIG.322 : SOME IRONMONGERY FOR WINDOWS



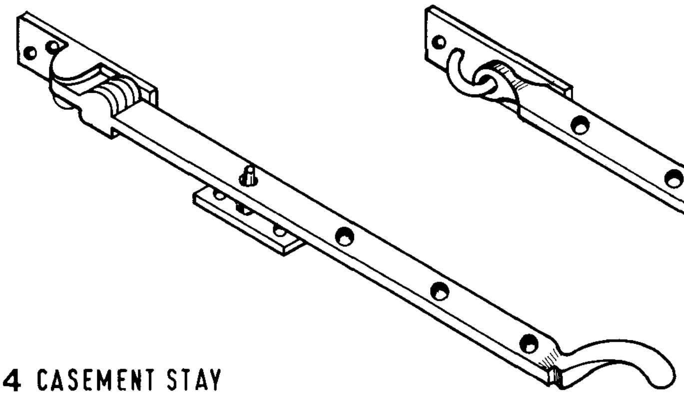
1 BRASS BUTT HINGE



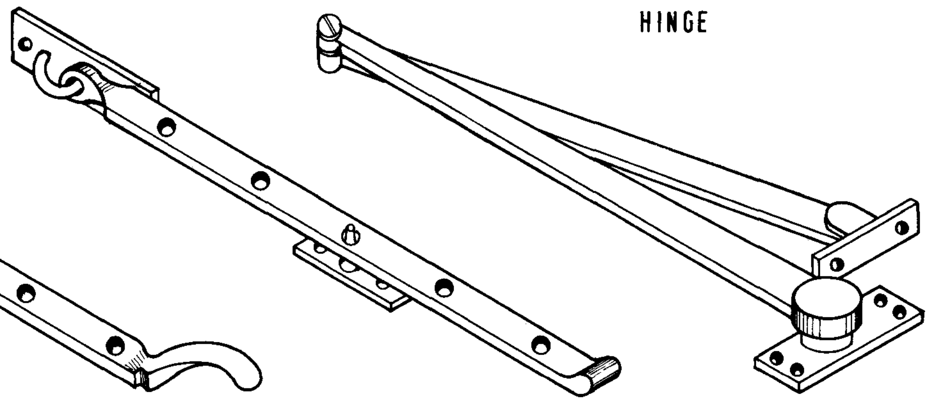
2 PARLIAMENT HINGE



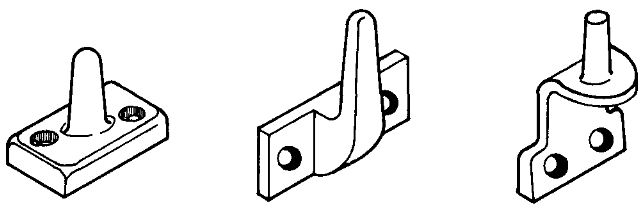
3 STORMPROOF BUTT HINGE



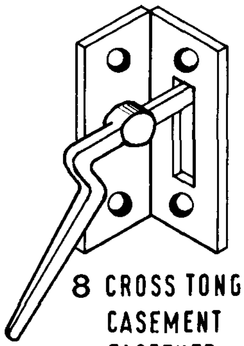
4 CASEMENT STAY



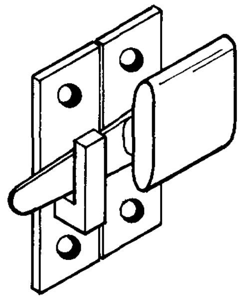
5 FANLIGHT STAY — 6 FRICTION STAY



7 STAY PINS : STANDARD, FLUSH AND CRANKED

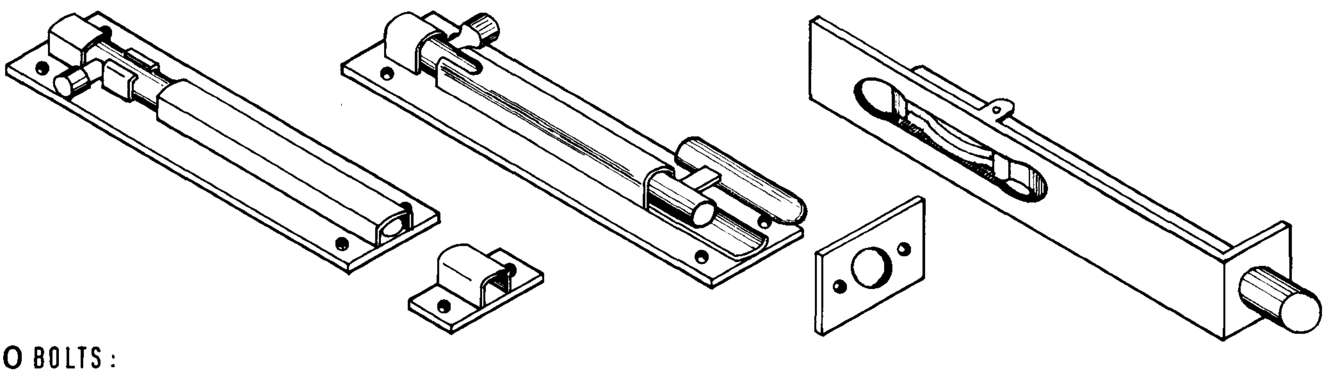


8 CROSS TONGUE CASEMENT FASTENER

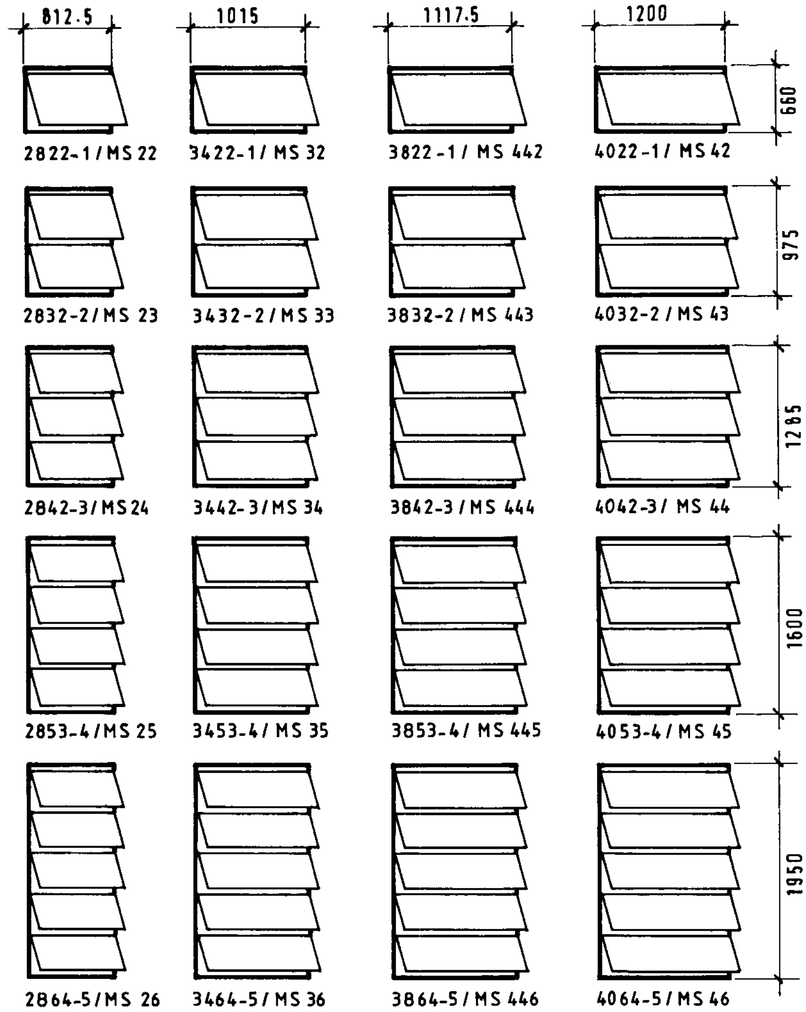


9 WEDGE TYPE FASTENER

1 BRASS BUTT HINGE WITH STEEL OR BRASS PIN, 65 mm
2 PARLIAMENT HINGE, A VARIATION OF THE FIXED PIN HINGE. FOR THICK FRAMES AND WHERE THESE ARE REQUESTED TO OPEN 180°.
3 STORMPROOF BUTT HINGE, CRANKED 8 mm, USED FOR CASEMENT WINDOWS, 65 mm (100 mm FOR DOORS).
4 CASEMENT STAY : FOR SECURING AN OPEN CASEMENT WINDOW INTO POSITION WITH STAY BAR AND FIXED PIN (FIXED TO FRAME). NORMALLY FLAT OR CHANNEL SECTIONS OF BRASS OR ALUMINIUM EXTRUSIONS, FROM 200 TO 300 mm.
5 FANLIGHT STAY : FOR RETAINING TOP HUNG VENTS IN THE OPEN POSITION.
6 FRICTION STAY : FOR CASEMENT WINDOWS, TOP AND BOTTOM HUNG VENTS.
7 STAY PINS : DEPENDING ON THE JOINERY APPLICATION, DIFFERENT STAY PINS MAY BE SPECIFIED.
8 CROSS TONGUE FASTENER WITH HOOK AND MORTICE PLATE.
9 WEDGE TYPE FASTENER WITH HOOK PLATE AND FASTENER.



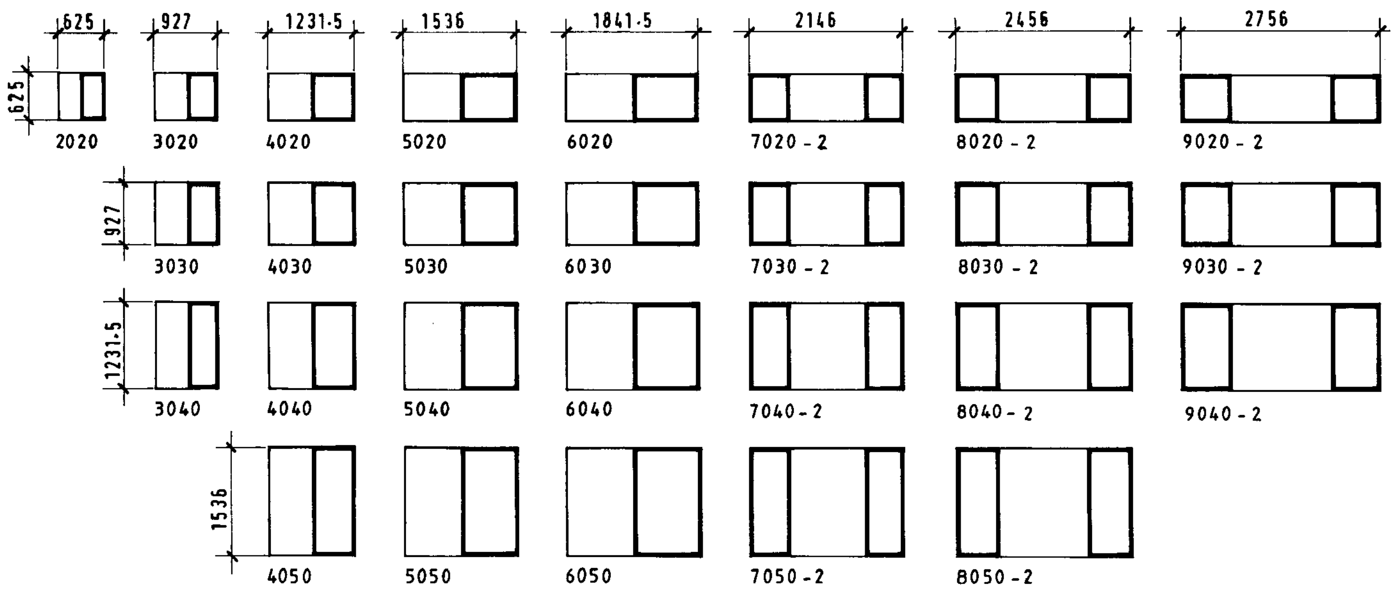
10 BOLTS :
WITH STRAIGHT, ROUND BRASS SHOOT — WITH NECKED BRASS SHOOT — FLUSH LEVER BOLT



MODEL 450, 460, MODULAR STANDARD SIZES, ALUMINIUM VENT-LOCK AWNING WINDOW :

STANLEY ALUMINIUM WINDOWS ARE ASSEMBLED IN GHANA. THE AWNING WINDOWS HAVE EXCLUSIVE SELF-LOCKING VENTS. THIS IS AN AUTOMATIC LOCKING SYSTEM WHICH PULLS THE WINDOW IN AND SECURES ALL FOUR CORNERS OF EACH VENTILATOR. THE WINDOWS ARE PROVIDED WITH WEATHERSTRIP AND CLIP-ON ALUMINIUM MESH FLY SCREEN.

0 500 1000 4000 mm



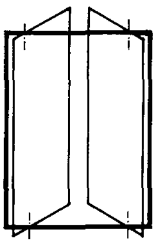
MODEL 360, 361, 362 ALUMINIUM SLIDING WINDOWS :

STANLEY SLIDING WINDOWS ARE GLAZED WITH VINYL CHANNELS. PANELS, BOTH OPERATING AND FIXED, ARE REMOVABLE FOR RE-GLAZING (IF NECESSARY) AND FOR EASE OF CLEANING. WINDOWS ARE COMPLETELY WEATHERSTRIPPED. PANELS MOVE ON NYLON ROLLERS.

0 500 1000 5000 mm

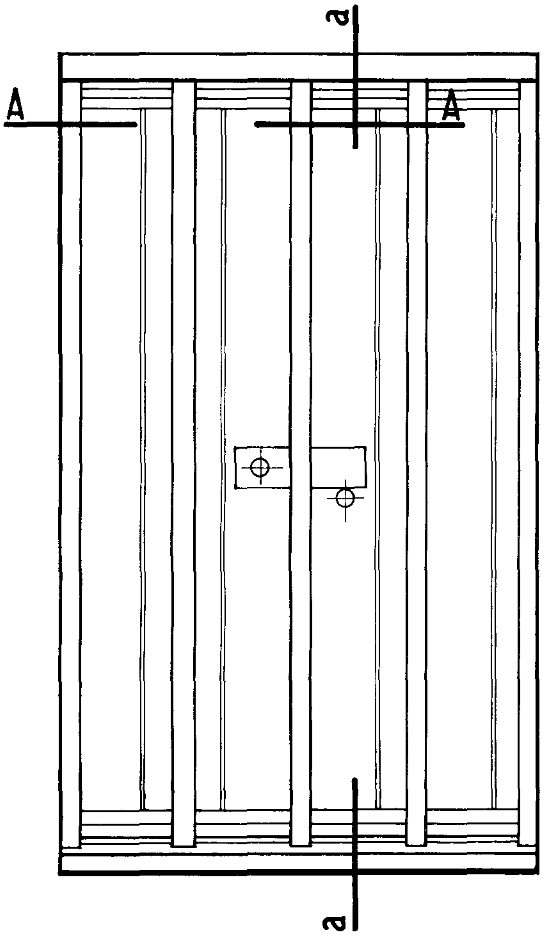
TABLE 19 : STANLEY ALUMINIUM AWNING AND HORIZONTAL SLIDING WINDOWS

5.4.5 WINDOWS

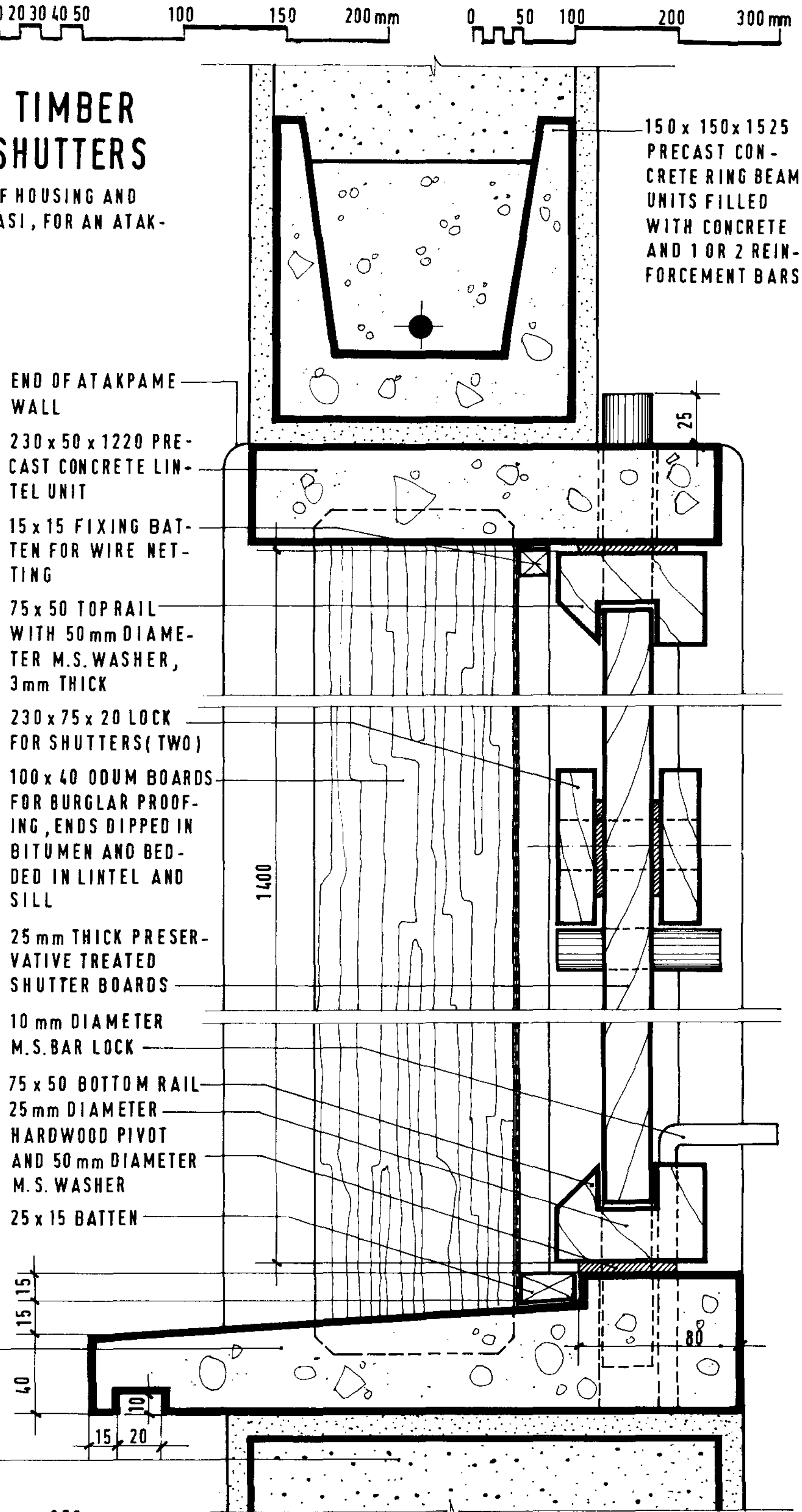


VERTICAL PIVOTED TIMBER WINDOW WITH 2 SHUTTERS

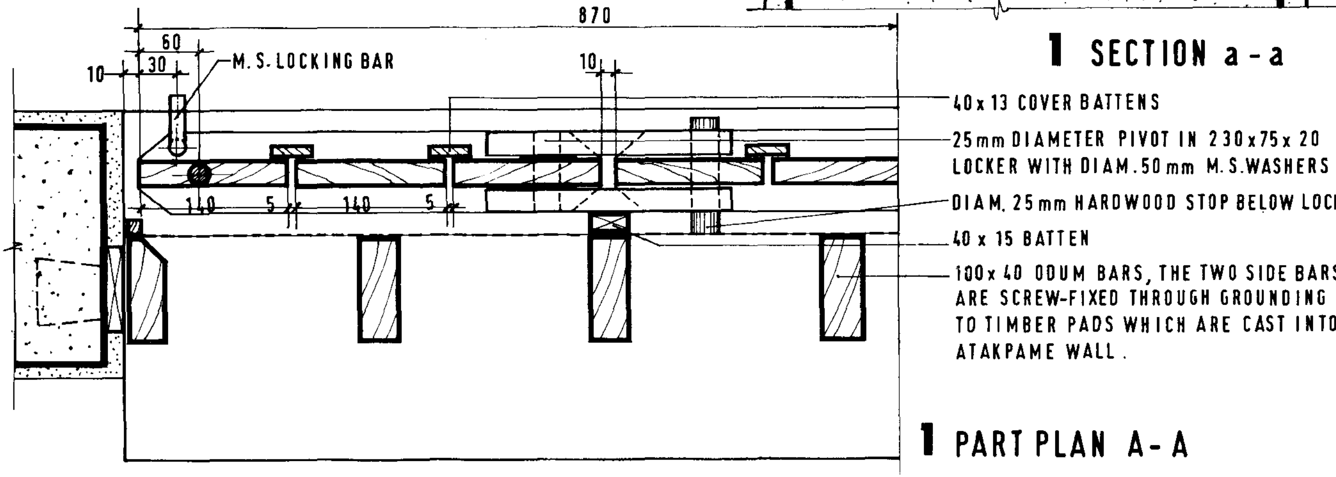
DESIGNED BY THE DEPARTMENT OF HOUSING AND PLANNING RESEARCH, U.S.T. KUMASI, FOR AN ATAKPAME HOUSE.



WINDOW 1 : ELEVATION IN CLOSED POSITION FROM THE OUTSIDE



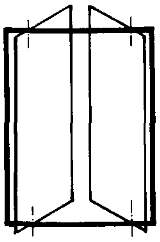
1 SECTION a - a



1 PART PLAN A - A

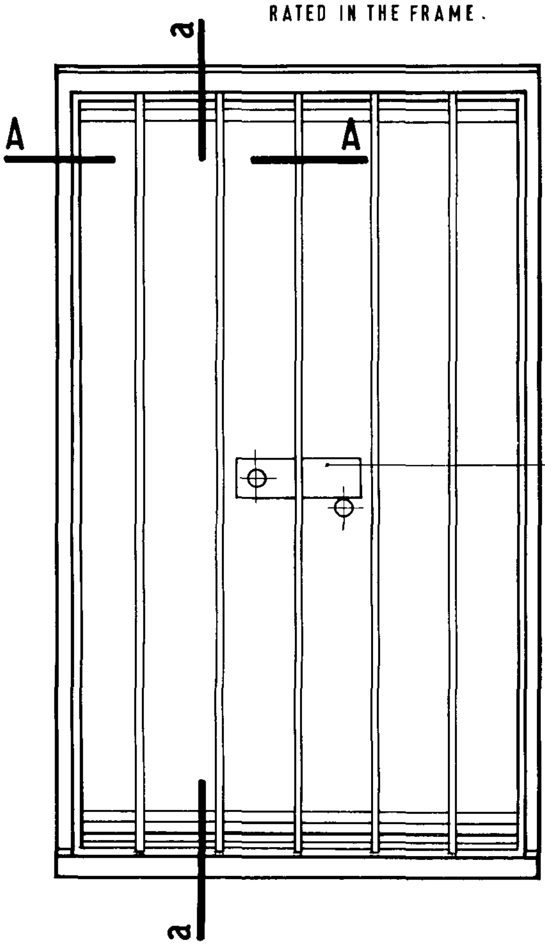
5.4.5 WINDOWS

SCALES AS WINDOW 2



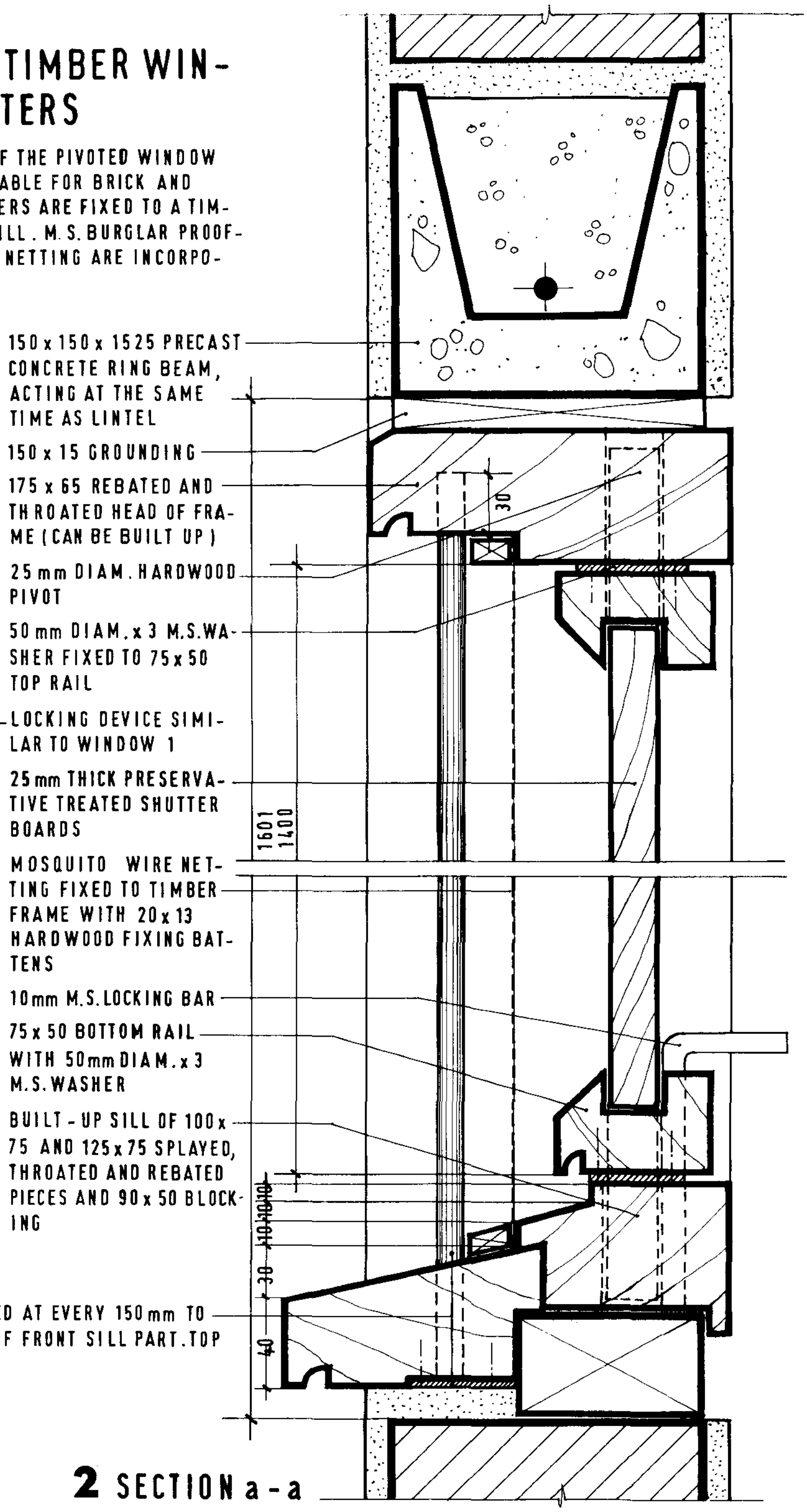
VERTICAL PIVOTED TIMBER WINDOW WITH 2 SHUTTERS

THIS IS A MODIFIED VERSION OF THE PIVOTED WINDOW SHOWN IN DETAIL 1. IT IS SUITABLE FOR BRICK AND BLOCKWORK WALLS. THE SHUTTERS ARE FIXED TO A TIMBER FRAME WITH A BUILT-UP SILL. M.S. BURGLAR PROOFING BARS AND MOSQUITO WIRE NETTING ARE INCORPORATED IN THE FRAME.

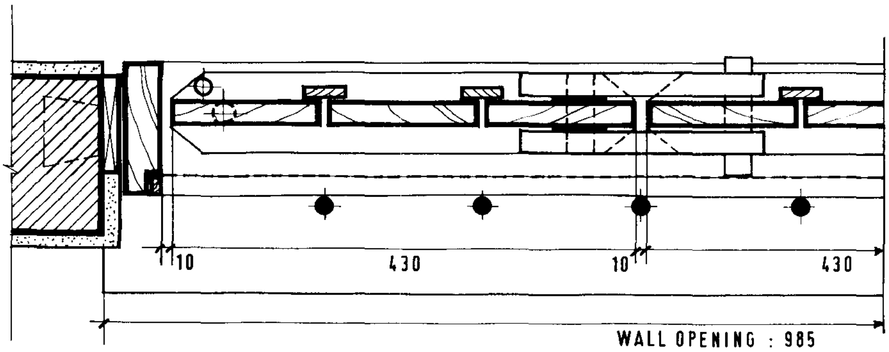


WINDOW 2 : ELEVATION IN CLOSED POSITION FROM THE OUTSIDE

12 mm DIAMETER M.S. BURGLAR PROOFING BARS WELDED AT EVERY 150 mm TO 50 x 3 M.S. FLAT BAR WHICH IS FIXED TO UNDERSIDE OF FRONT SILL PART. TOP END OF BARS LET INTO HEAD OF FRAME.



2 SECTION a-a



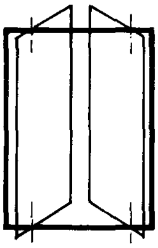
SHUTTER DETAILS SIMILAR TO WINDOW 1: 125 x 40 JAMBS OF FRAME FIXED THROUGH 90 x 12 (15) GROUNDING TO TIMBER PADS WHICH ARE SET INTO THE WALL DURING CONSTRUCTION.

140 x 25 SHUTTER BOARDS

2 PART PLAN A-A

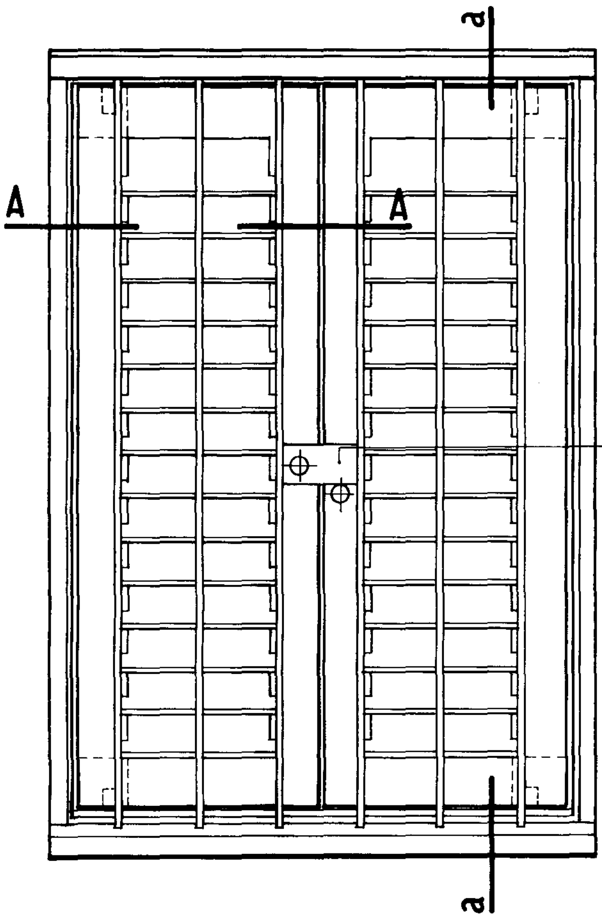
5.4.5 WINDOWS

SCALES AS FOR WINDOW 2



VERTICAL PIVOTED TIMBER WINDOW WITH 2 LOUVRED SHUTTERS

THIS IS ANOTHER MODIFIED VERSION OF THE PIVOTED WINDOW SHOWN IN DETAIL 1. IT HAS 2 SHUTTERS WITH FIXED TIMBER LOUVRES AND A FRAME DETAIL SIMILAR TO WINDOW 2.



WINDOW 3 : ELEVATION IN CLOSED POSITION FROM THE OUTSIDE

175 (OR BUILT UP) x 65 REBATED AND THROATED HEAD OF FRAME WITH 130 x 12 (15) GROUNDING

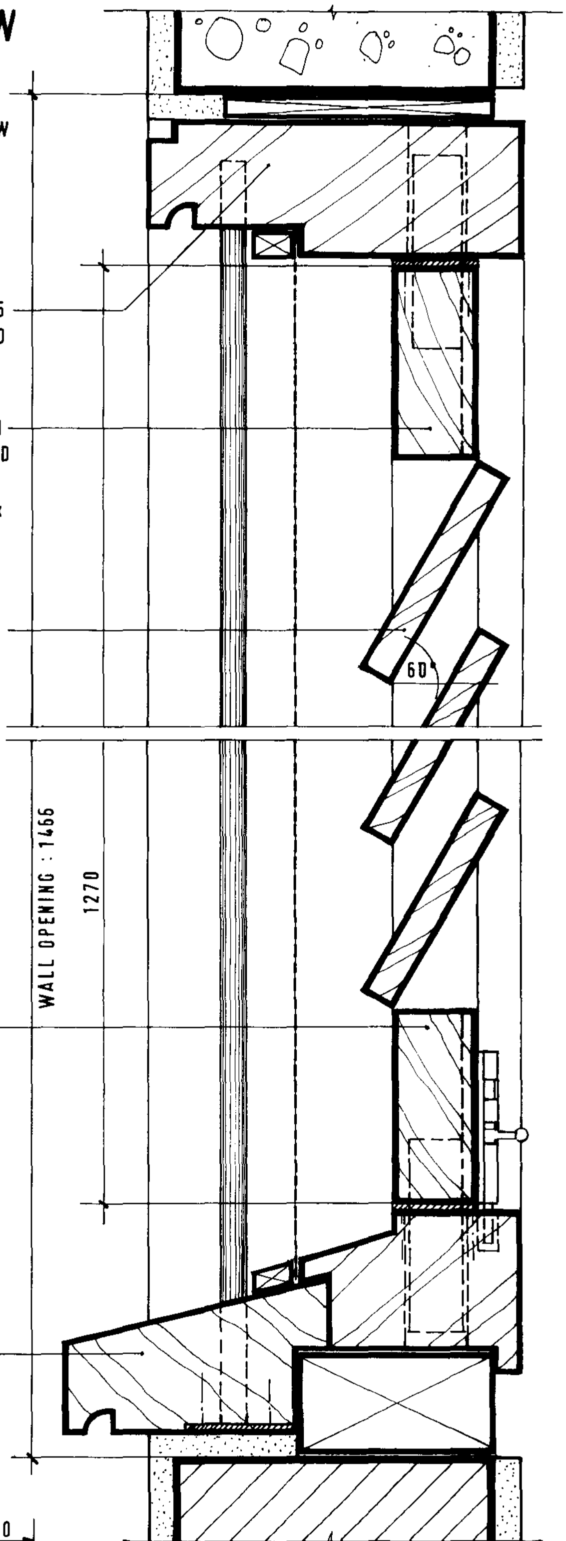
90 x 40 TOP RAIL WITH 25 mm DIAM. HARDWOOD PIVOT, 60 x 40 x 3 M.S. WASHER PLATE AND 90 x 90 x 6 PLYWOOD PLATE SET INTO TOP RAIL TO HOLD PIVOT IN PLACE

115 x 16 ODUM LOUVRES HOUSED INTO STILES

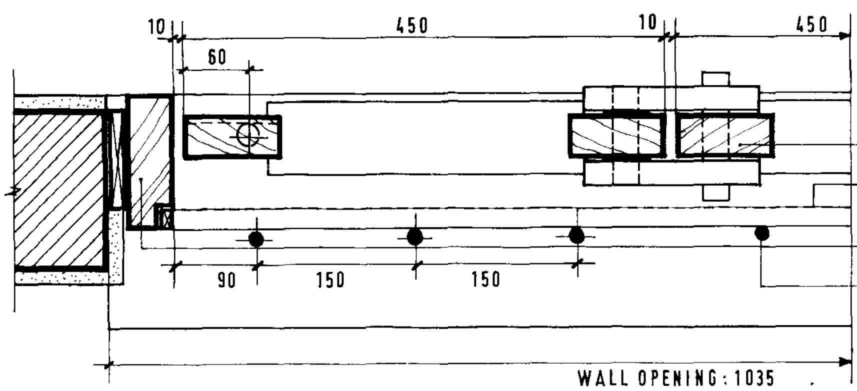
TWO 160 x 25 LOCKING BOARDS WITH 25 mm DIAM. PIVOT AND FIXED STOP

90 x 40 BOTTOM RAIL WITH PIVOT FIXED AS IN TOP RAIL. BARREL BOLT FIXED DOWN AT MEETING POINT ON RIGHT HAND SHUTTER

BUILT-UP SILL SIMILAR TO WINDOW 2



3 SECTION a-a



90 x 40 STILES

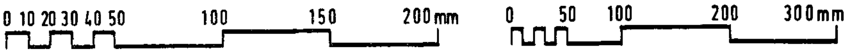
MOSQUITO WIRE NETTING FIXED TO FRAME WITH 20 x 13 BATTENS

125 x 40 REBATED JAMB

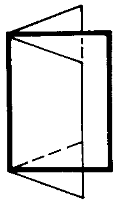
12 mm DIAMETER M.S. BURGLAR PROOFING BARS AT 150 mm CENTRES

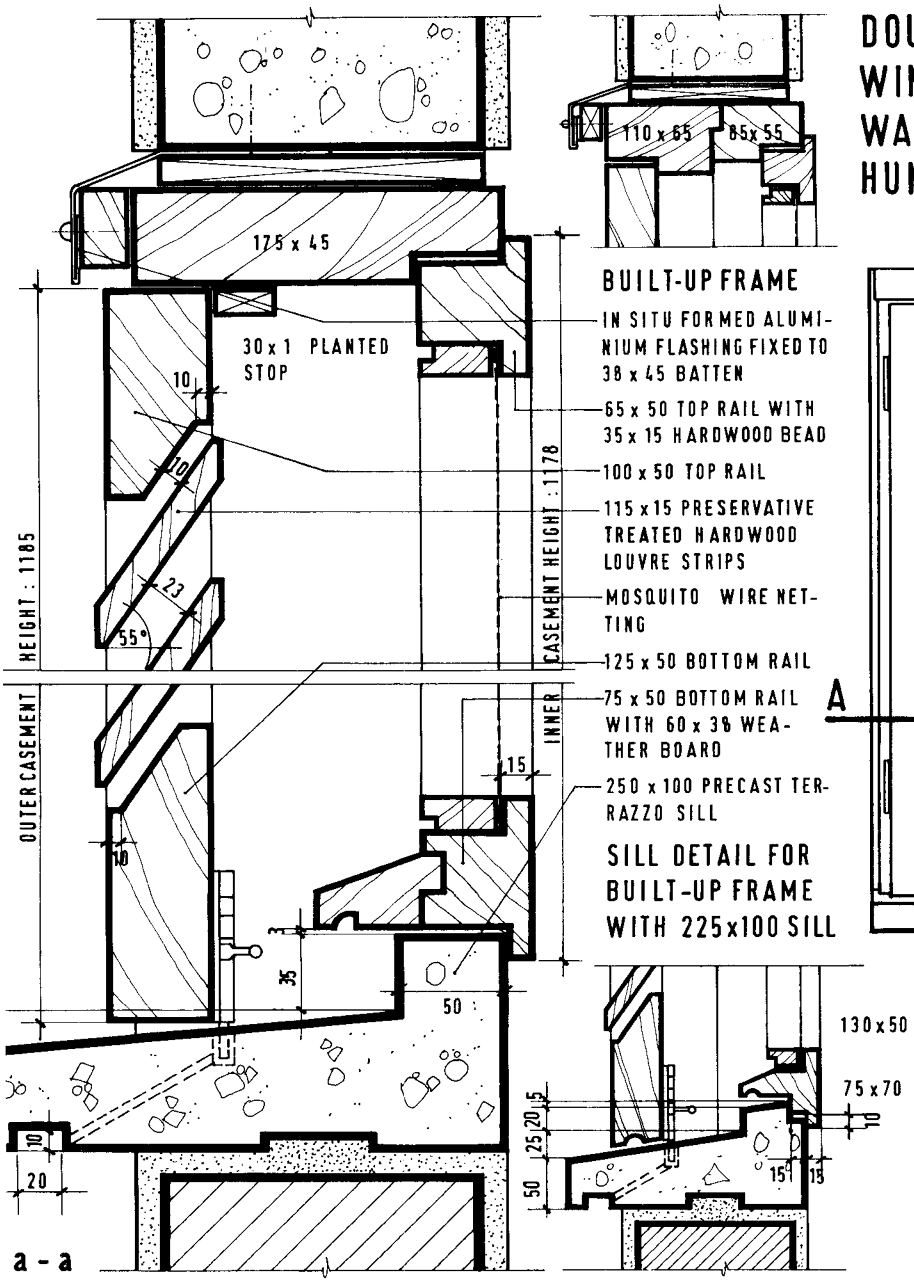
3 PART PLAN A-A

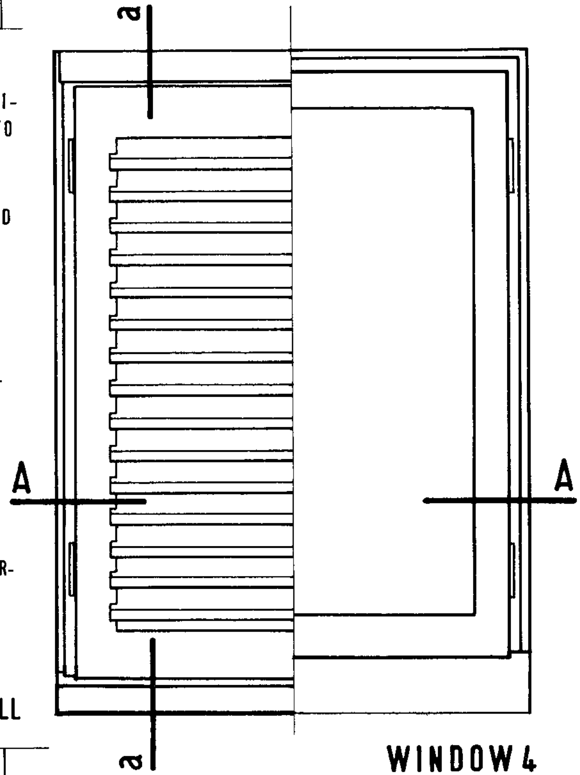
5.4.5 WINDOWS



DOUBLE CASEMENT WINDOW, IN AND OUTWARD OPENING, SIDE-HUNG



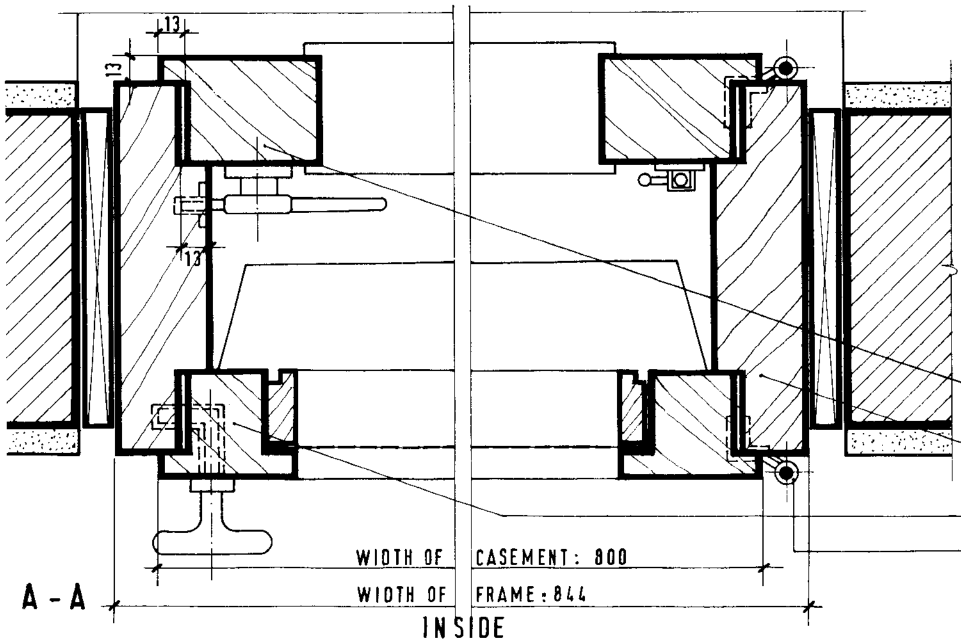


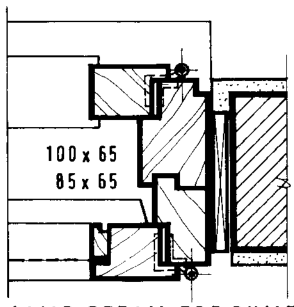


WINDOW 4

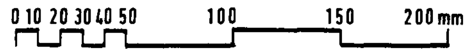
ELEVATION FROM OUT AND INSIDE IN CLOSED POSITION

DOUBLE CASEMENT WINDOW WITH EXTERNAL LOUVRED SHUTTER AND INWARD OPENING MOSQUITO SCREEN. IRONMONGERY : CROSS TONGUE FASTENER, CABIN HOOK FIXED TO JAMB, BARREL BOLT DOWN ON BOTTOM RAIL FOR OUTER CASEMENT, CASEMENT FASTENER FOR INNER CASEMENT.

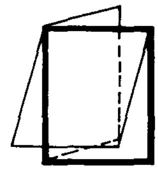


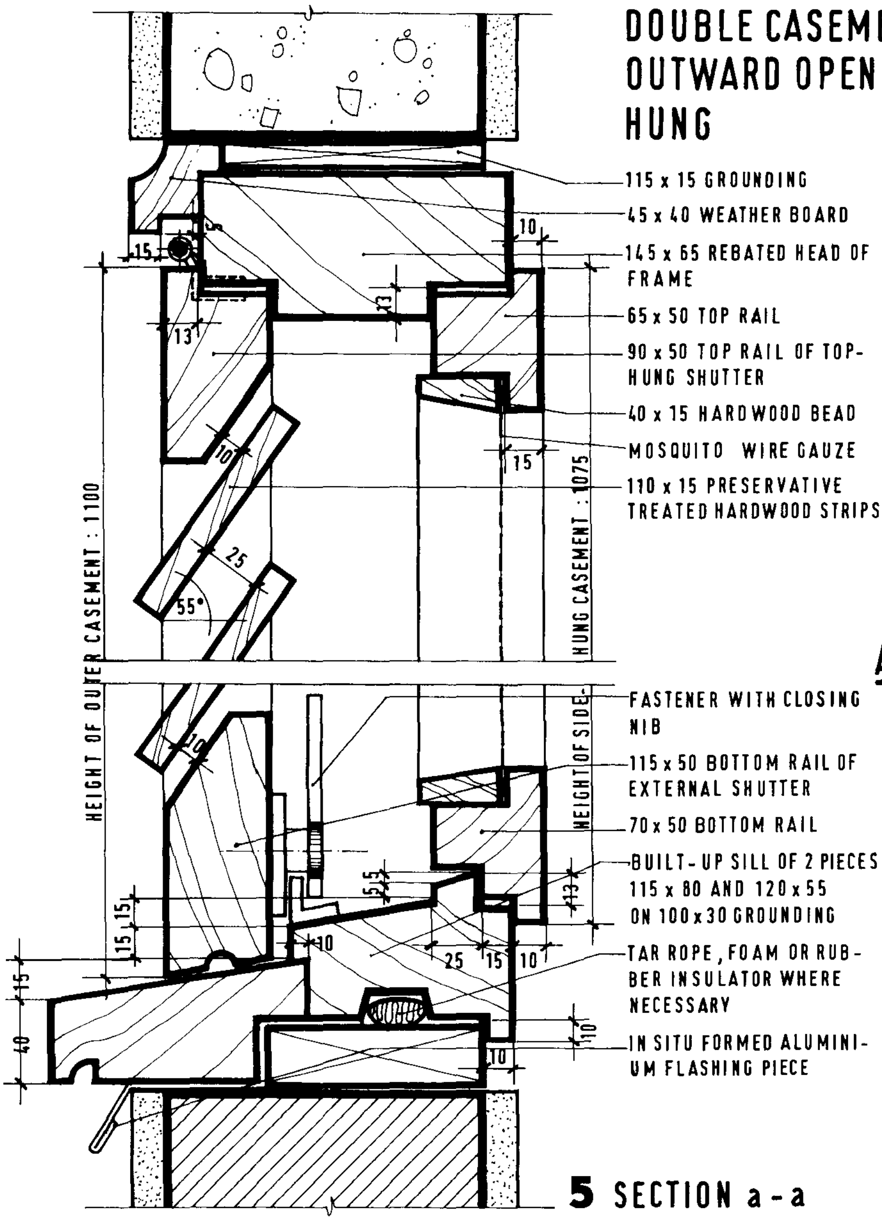


JAMB DETAIL FOR BUILT-UP FRAME

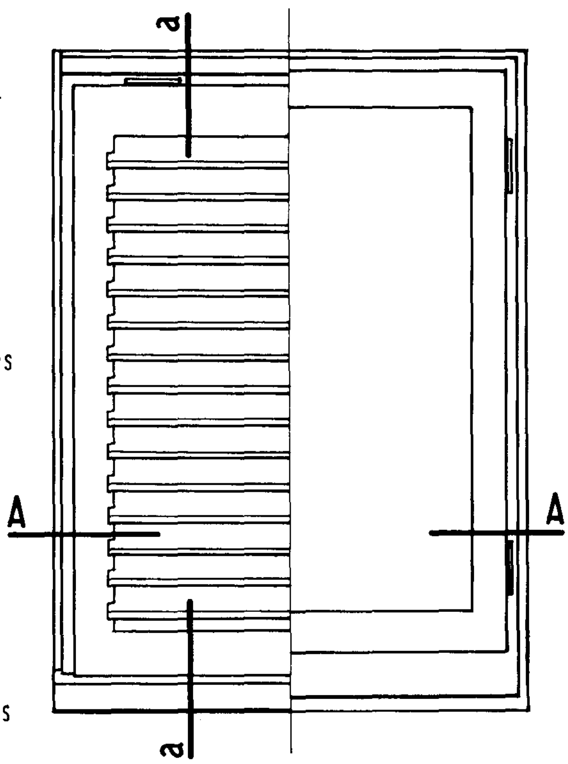


DOUBLE CASEMENT WINDOW IN AND OUTWARD OPENING, TOP-AND SIDE-HUNG



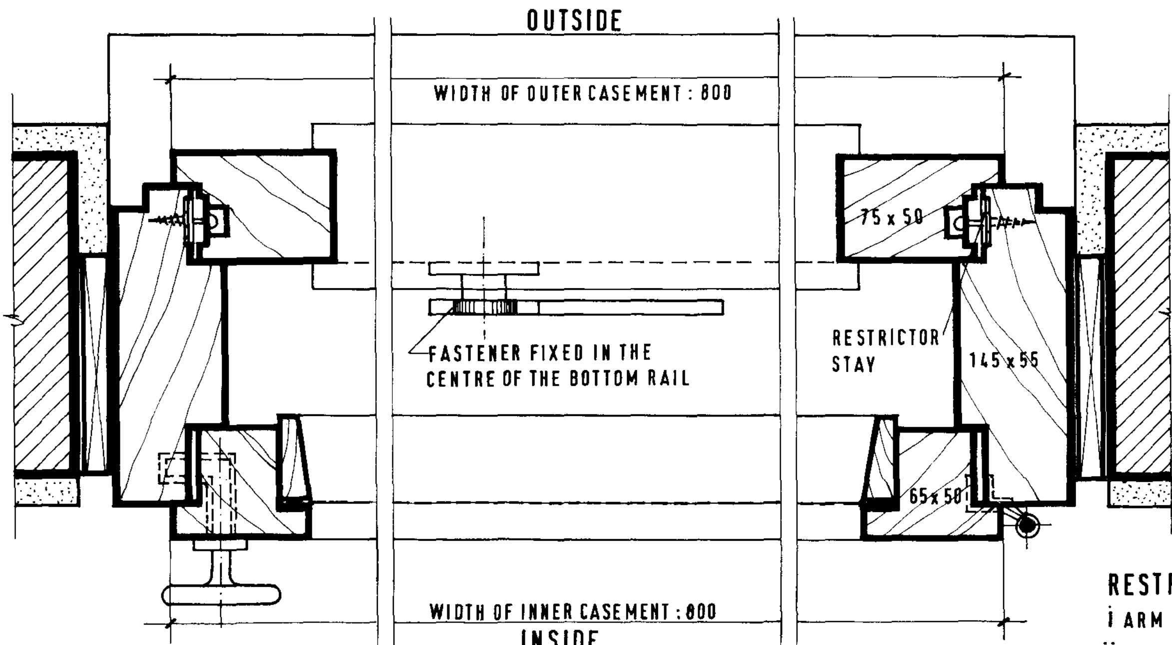


5 SECTION a - a

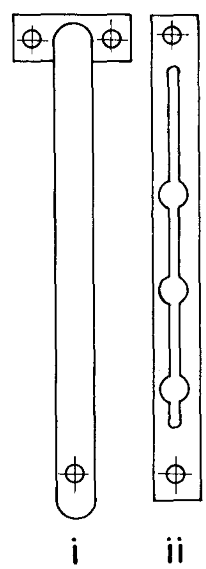


WINDOW 5 : ELEVATION FROM OUT- AND INSIDE IN CLOSED POSITION

EXTERNAL TOP-HUNG, OPENING OUT LOUVRED SHUTTER WITH STRAIGHT HANDLE WITH TONGUE WHICH GOES OVER A CLOSING NIB, FIXED TO BOTTOM RAIL AND SILL, AND RESTRICTOR STAYS FIXED TO STILE AND JAMB. INWARD OPENING, SIDE-HUNG MOSQUITO SCREEN WITH CASEMENT FASTENER.



5 PLAN A - A

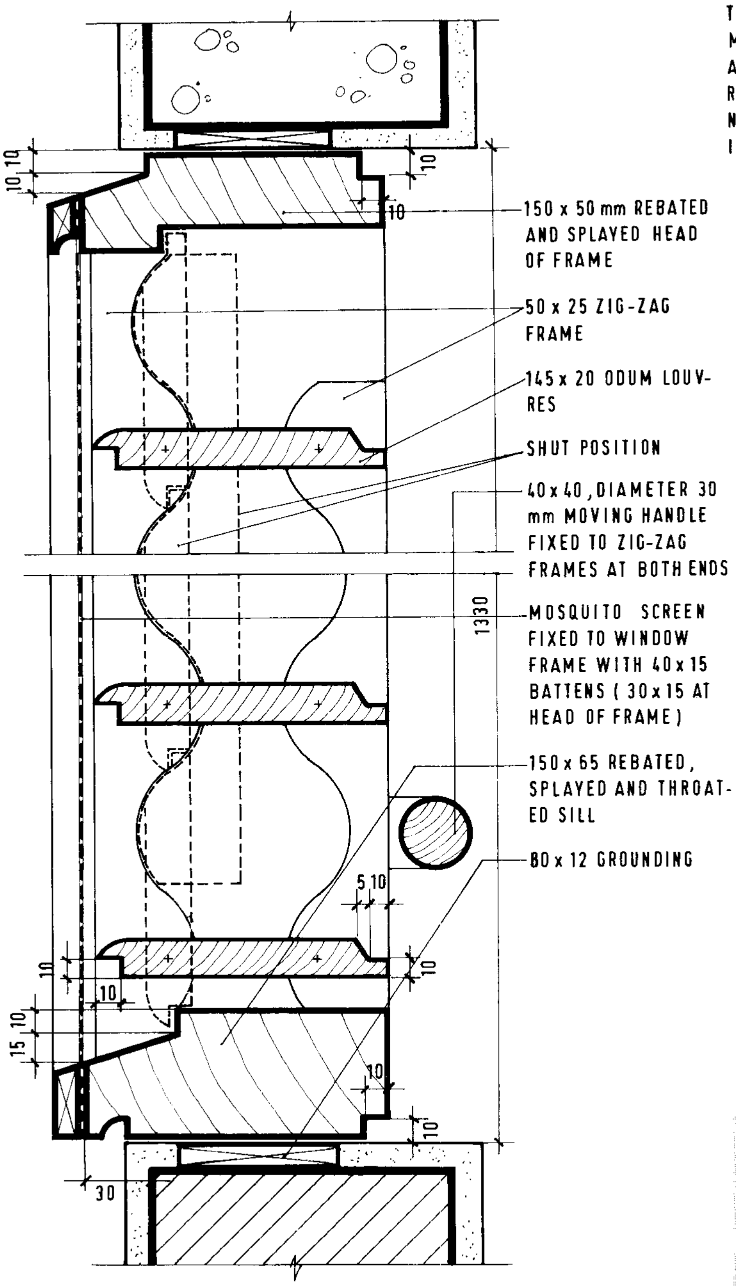


RESTRICTOR STAY i & ii

i ARM WITH STUD ON JAMB

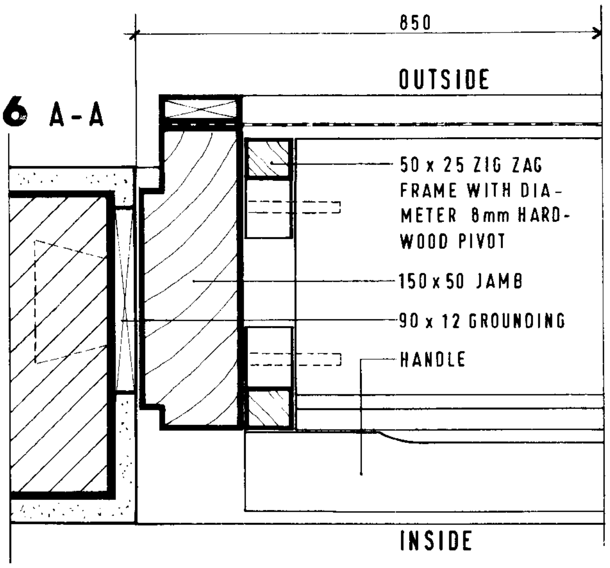
ii GUIDE TRACK WITH 3 POSITIONS ON STILES

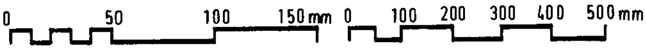
5.4.5 WINDOWS



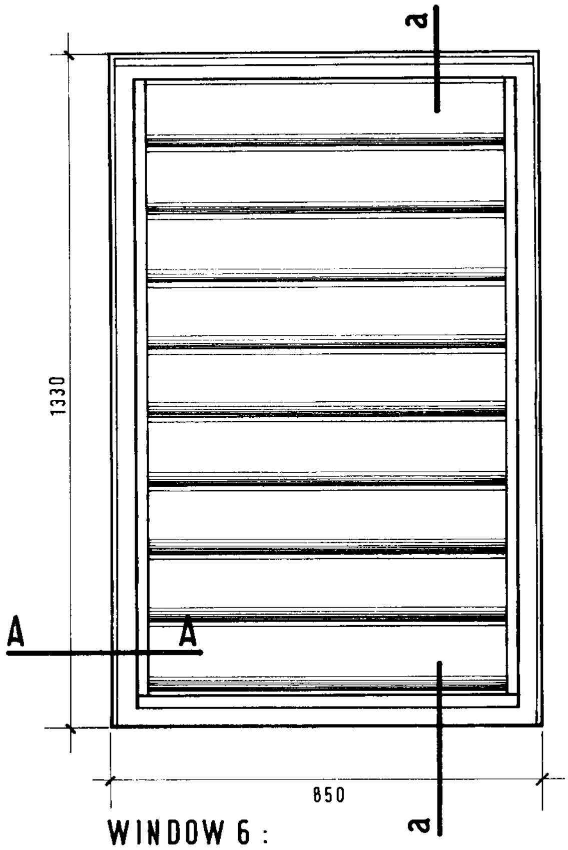
6 SECTION a-a

6 A-A

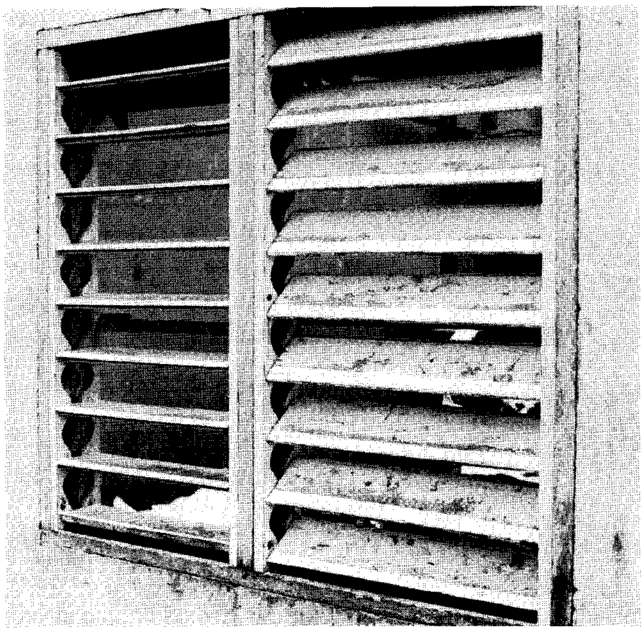




THIS LOUVRE WINDOW, TOGETHER WITH THE ZIG-ZAG SIDE FRAME, IS MANUFACTURED TO ANY GIVEN SIZE BY EWE-CARPENTERS AT ANLOGA, KUMASI, FROM WELL SEASONED ODUM (CHLOROPHORA EXCELSA). THIS WINDOW TYPE IS ALSO KNOWN IN THE PHILIPPINES AND PAPUA-NEW GUINEA (INFORMATION CONFIRMED BY F.P.R.C. IN BOROKO, PAPUA-NEW GUINEA).

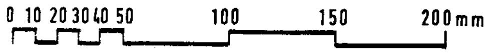


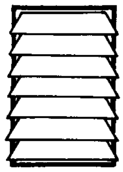
WINDOW 6:
ELEVATION OF WINDOW IN CLOSED POSITION FROM THE OUTSIDE



TIMBER LOUVRE WINDOW WITH ZIG-ZAG SIDE FRAME

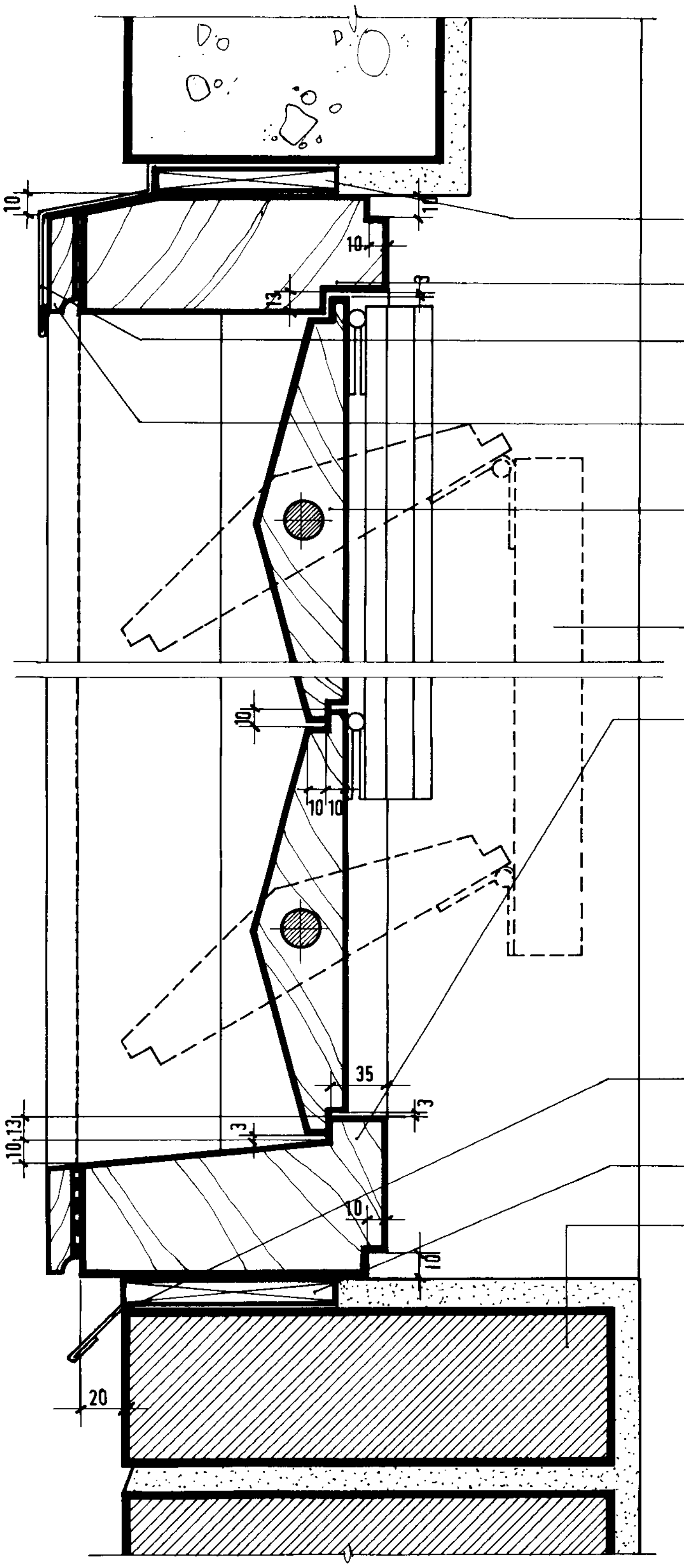
5.4.5 WINDOWS



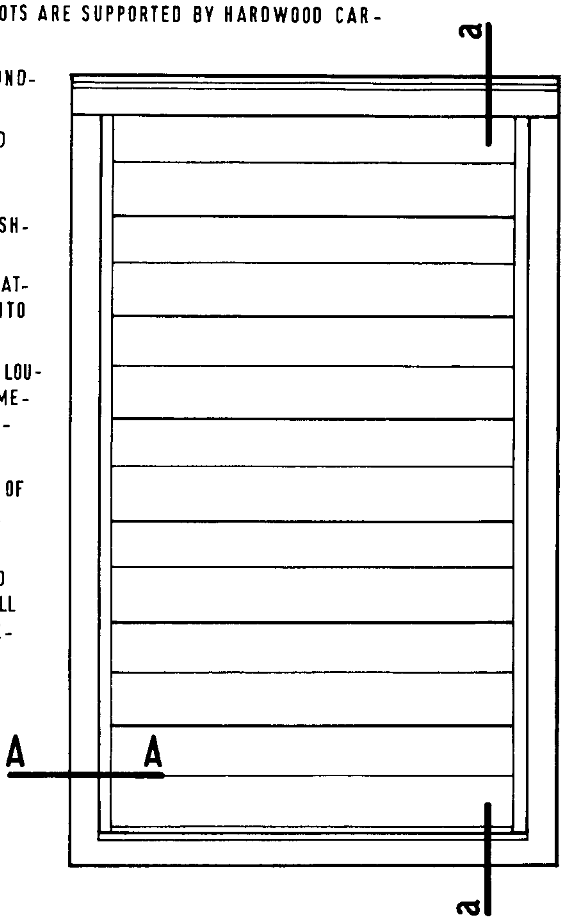


TIMBER LOUVRE WINDOW WITH HARDWOOD PIVOTS

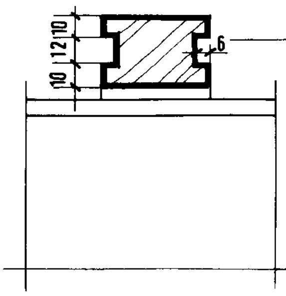
LOUVRES AND FRAME ARE FROM ODUM (CHLOROPHORA EXCELSA). THE PIVOTS ARE SUPPORTED BY HARDWOOD CARRIERS.



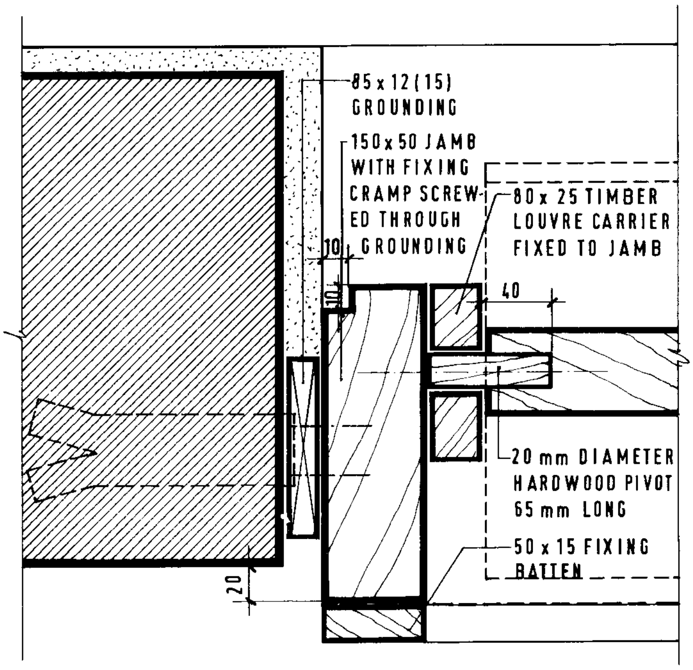
7 SECTION a - a



WINDOW 7 : ELEVATION IN CLOSED POSITION FROM THE OUTSIDE



50 x 32 GROOVED HANDLE FIXED TO TIMBER LOUVRES WITH HINGES IN CENTRE OF WINDOW

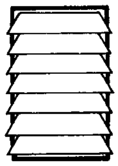


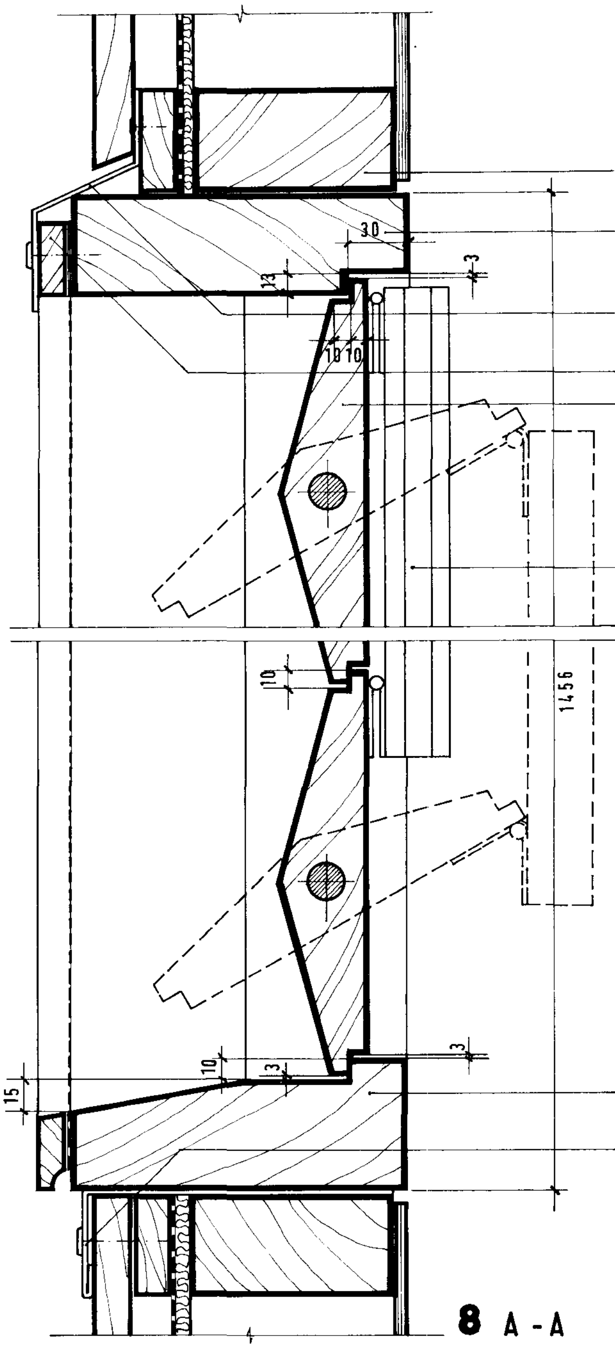
7 PART PLAN A - A

5.4.5 WINDOWS

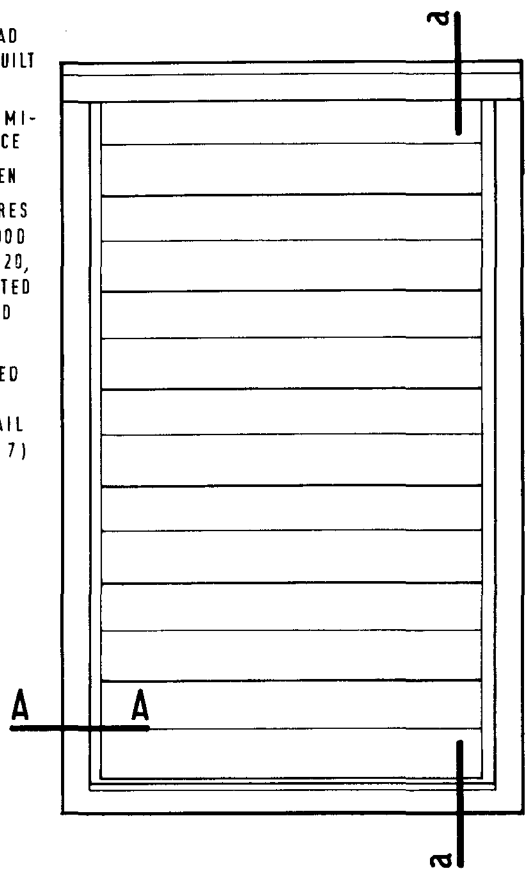
0 10 20 30 40 50 100 150 200 mm

TIMBER LOUVRE WINDOW WITH HARDWOOD PIVOTS IN TIMBER FRAMEWORK

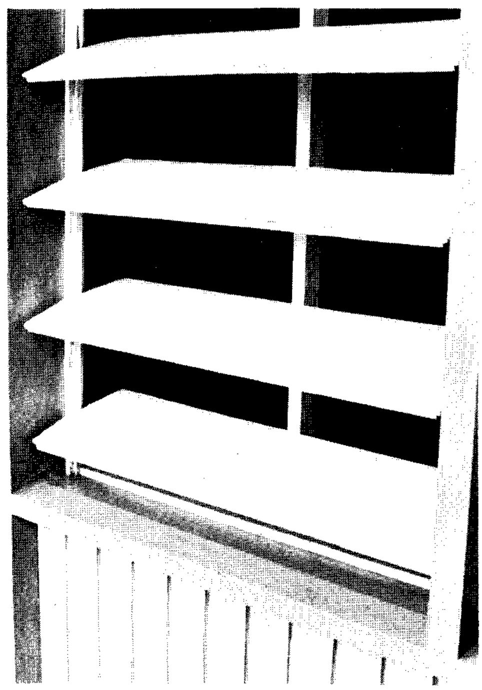


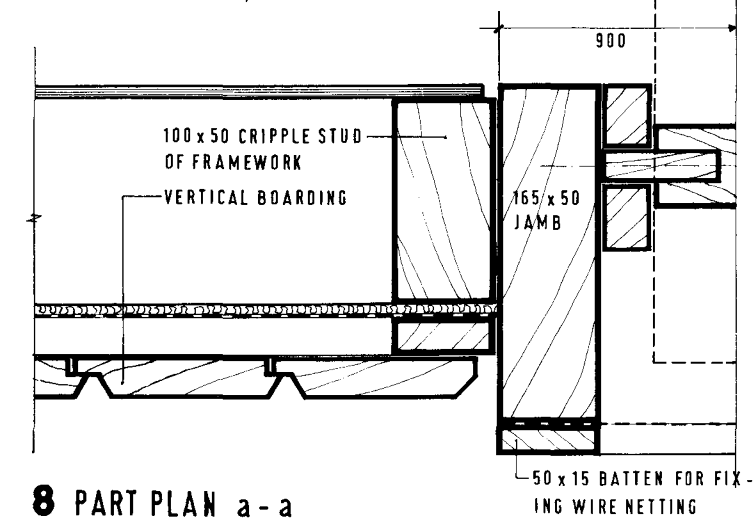


8 A - A



WINDOW 8 : ELEVATION IN CLOSED POSITION FROM THE OUTSIDE

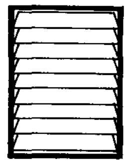


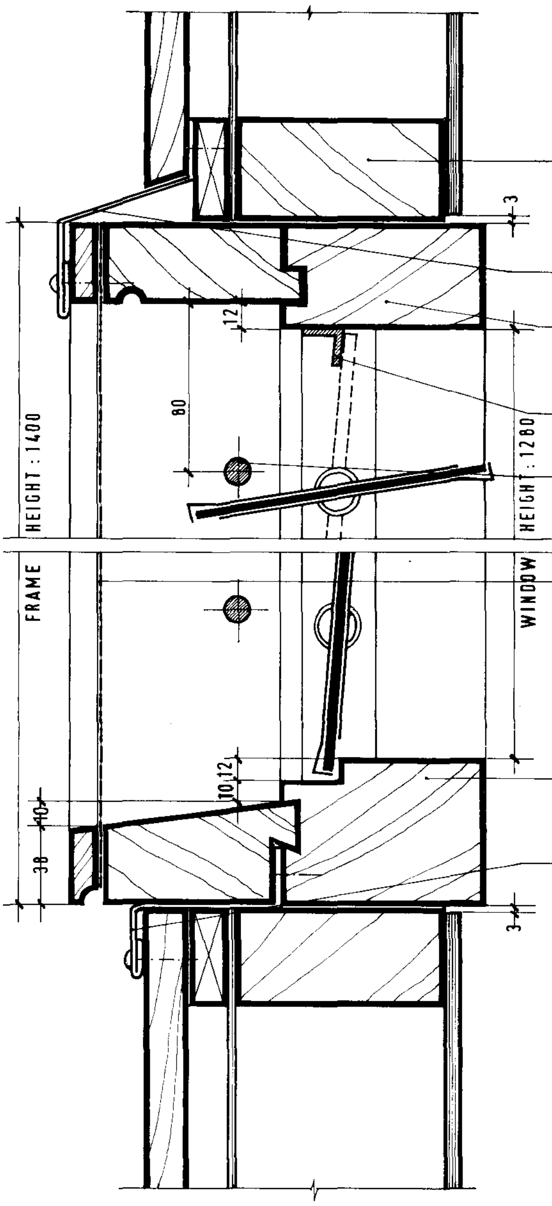


8 PART PLAN a - a

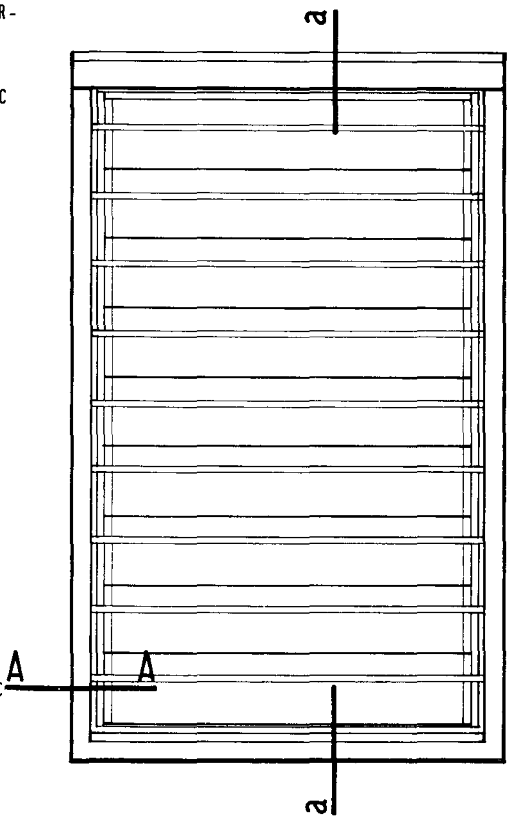
5.4.5 WINDOWS

NACO LOUVRE WINDOW SET IN TIMBER FRAMEWORK



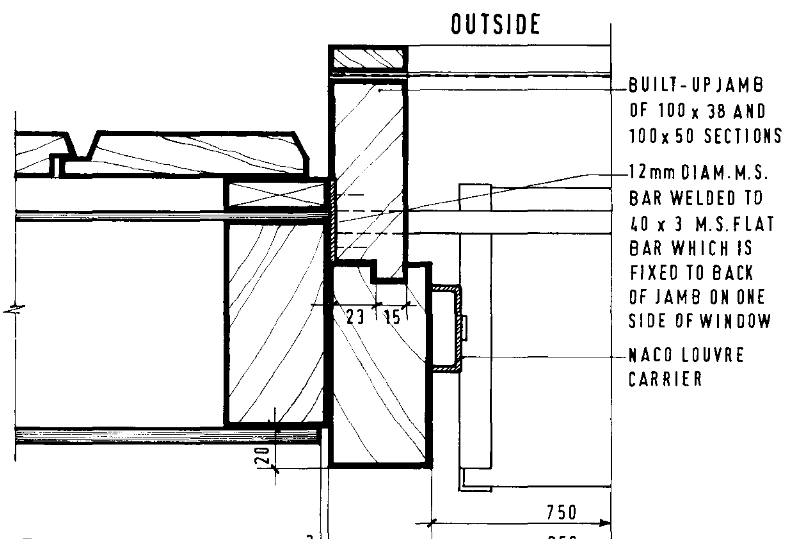


9 SECTION a - a



WINDOW 9 : ELEVATION FROM THE OUTSIDE IN CLOSED POSITION

NACO LOUVRE WINDOW WITH 9 BLADES, 150 mm WIDE, CLEAR GLASS, WITH MOSQUITO GAUZE AND BURGLAR PROOFING AS PART OF THE FRAME, WITH NACO LOUVRE CARRIERS AND ALUMINIUM WEATHER STRIP.

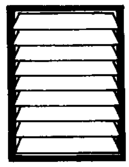


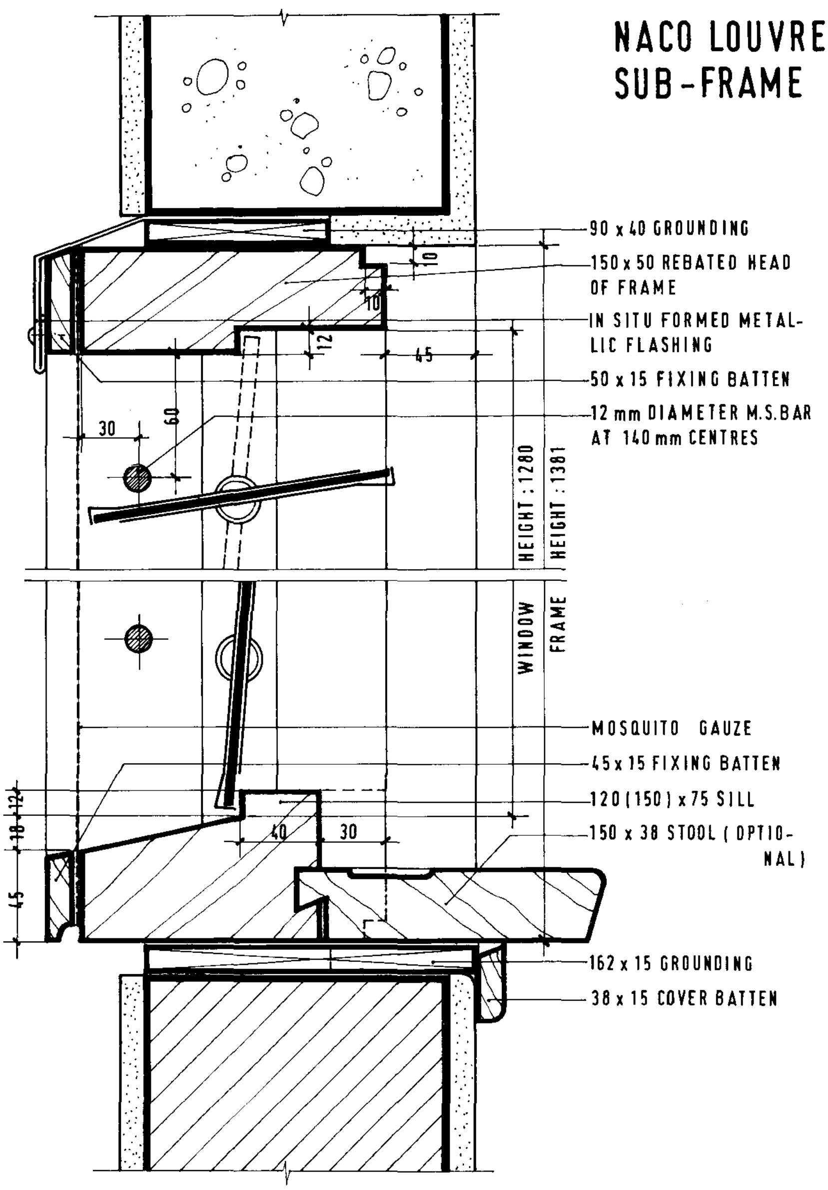
9 PART PLAN A - A

5.4.5 WINDOWS

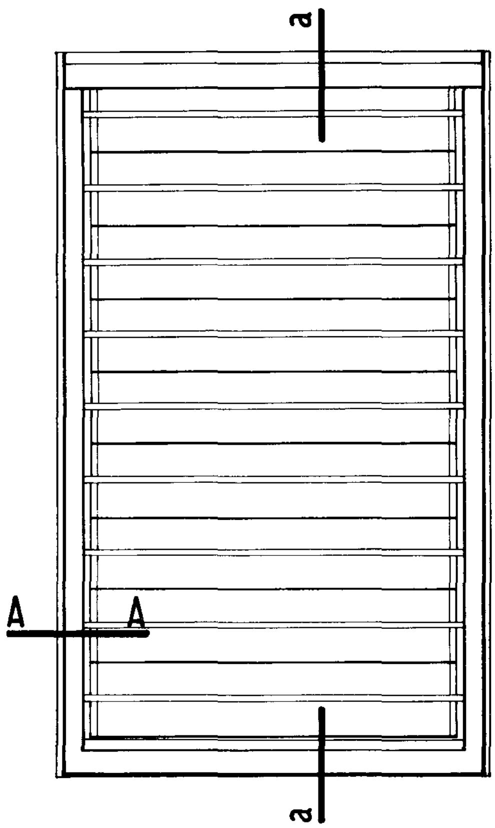
SCALE AS FOR WINDOW 9

NACO LOUVRE WINDOW IN TIMBER SUB-FRAME



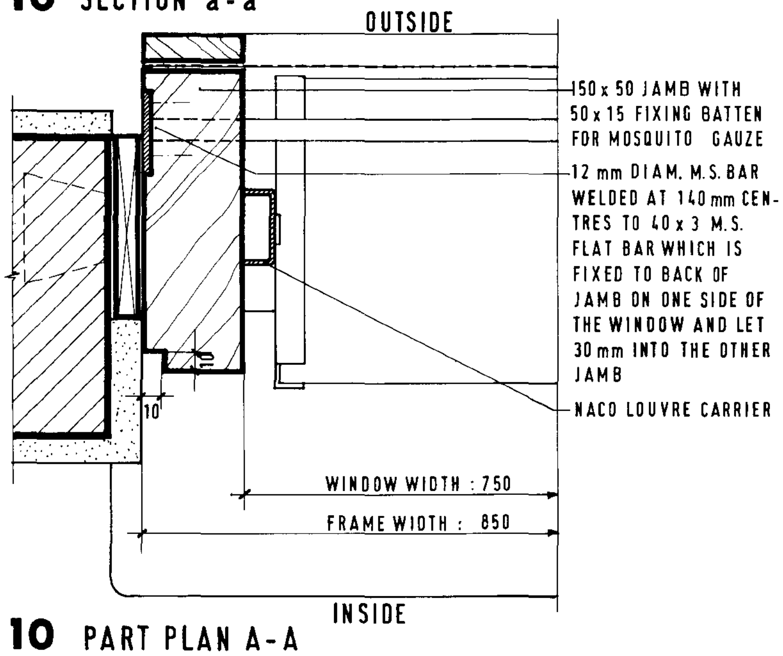


10 SECTION a-a

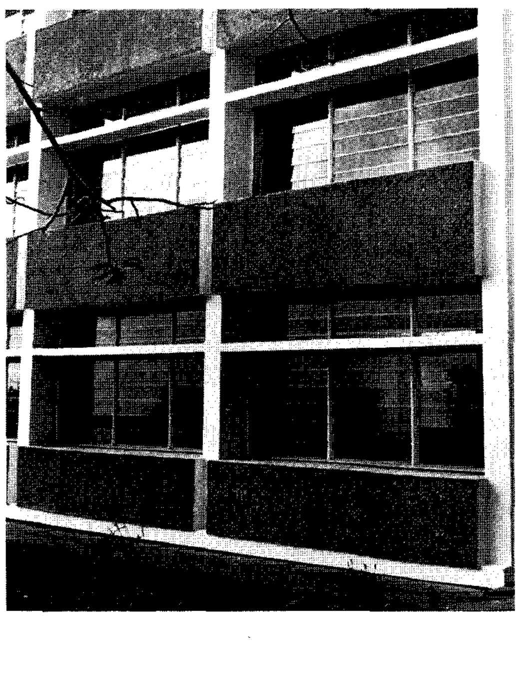


WINDOW 10 : ELEVATION FROM THE OUTSIDE IN CLOSED POSITION

NACO LOUVRE WINDOW IN TIMBER SUB-FRAME, SET IN BLOCKWORK WALL, WITH 9 BLADES, 150 mm WIDE, CLEAR GLASS, WITH MOSQUITO WIRE NETTING AND BURGLAR PROOFING AS PART OF THE FRAME, WITH NACO LOUVRE CARRIERS.



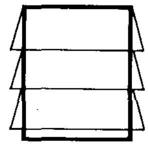
10 PART PLAN A-A

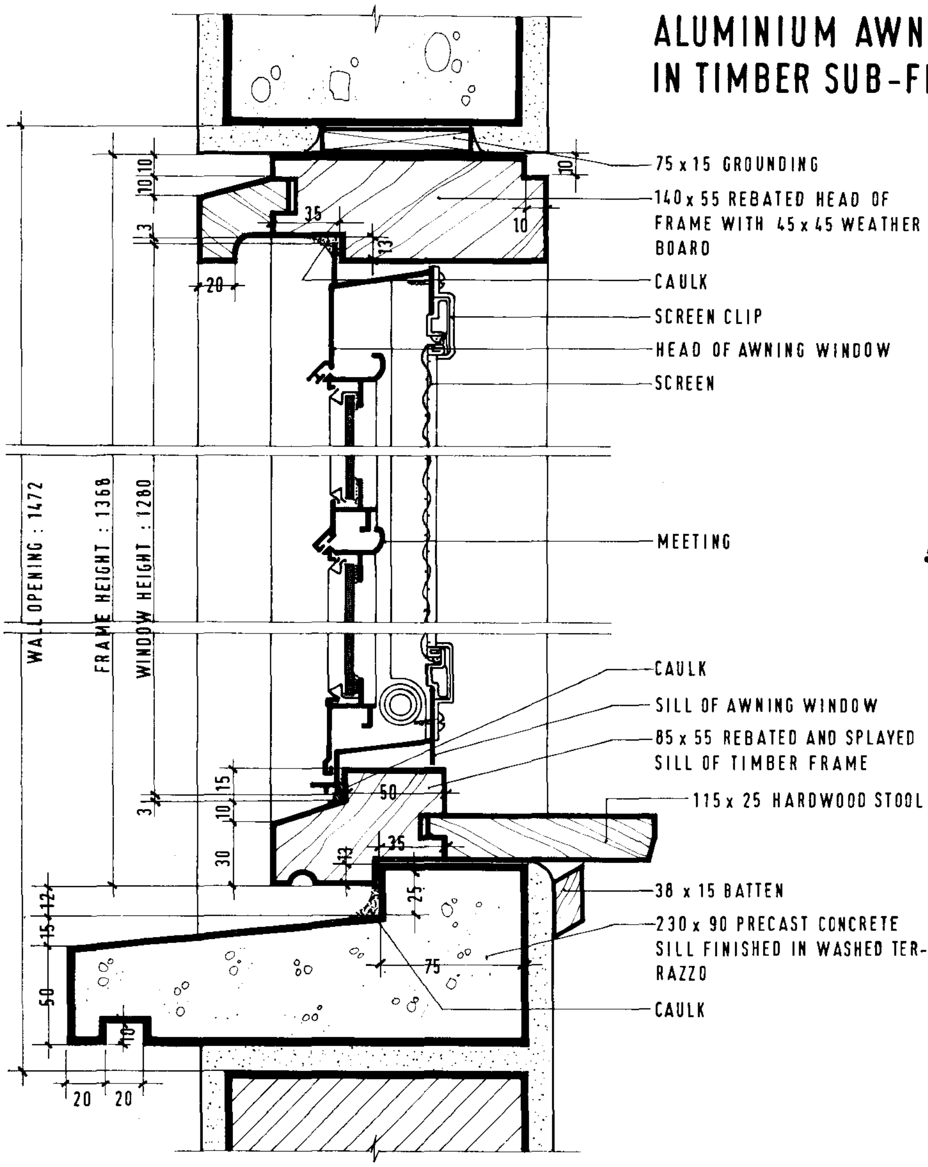


5.4.5 WINDOWS

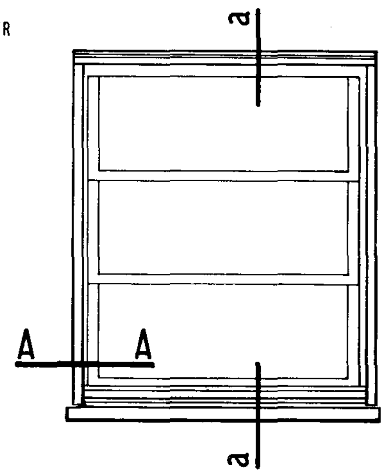
SCALE AS FOR WINDOW 9

ALUMINIUM AWNING WINDOW IN TIMBER SUB-FRAME



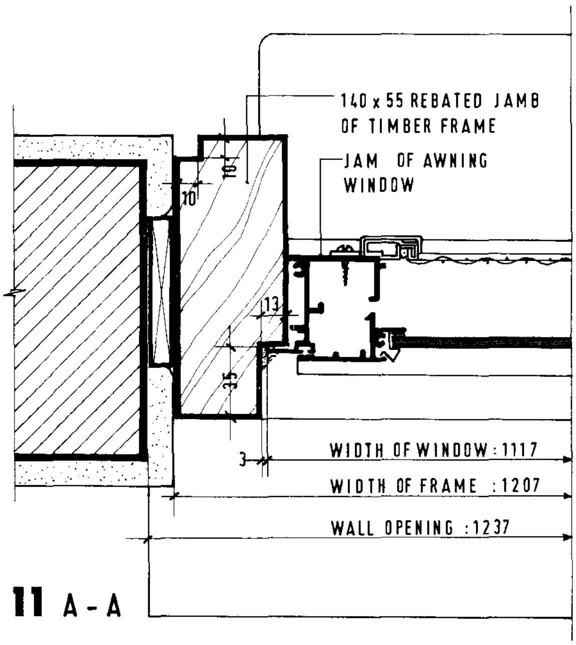


11 a - a

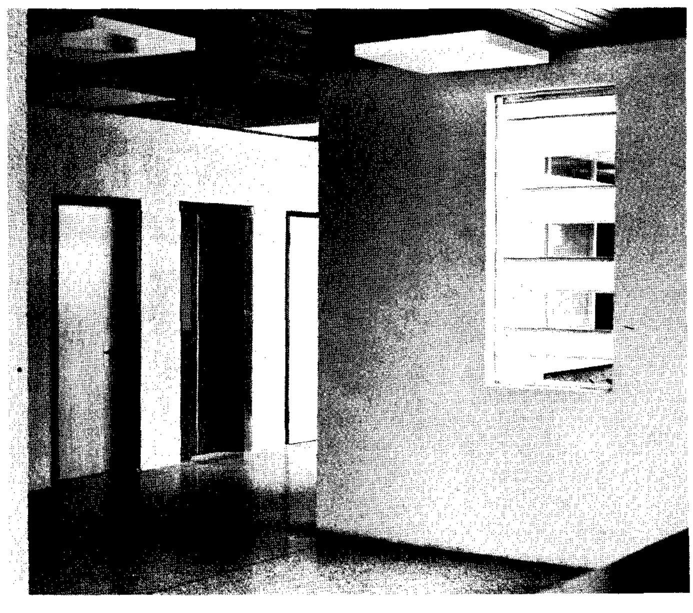


WINDOW 11 : ELEVATION FROM THE OUTSIDE IN CLOSED POSITION

"STANLEY" ALUMINIUM AWNING WINDOW WITH THREE VENTS AND CLIPPED-ON MOSQUITO SCREEN. THE WINDOW IS FIXED TO A TIMBER FRAME.

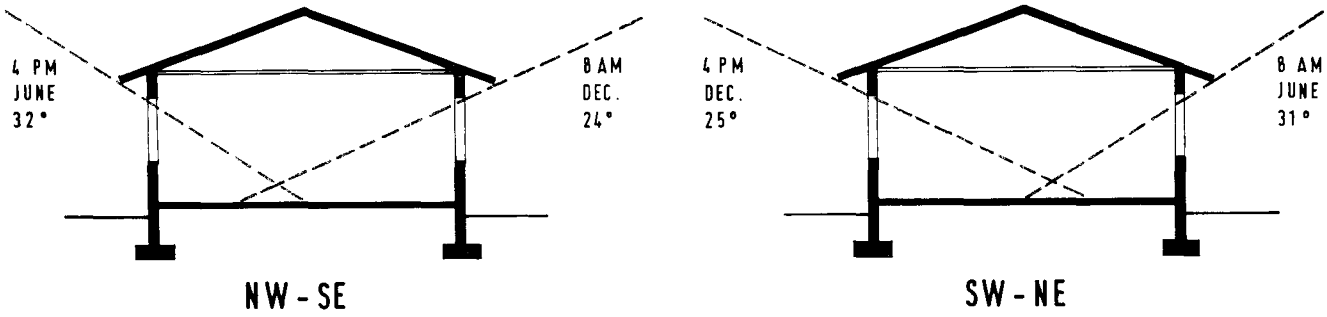


11 A - A

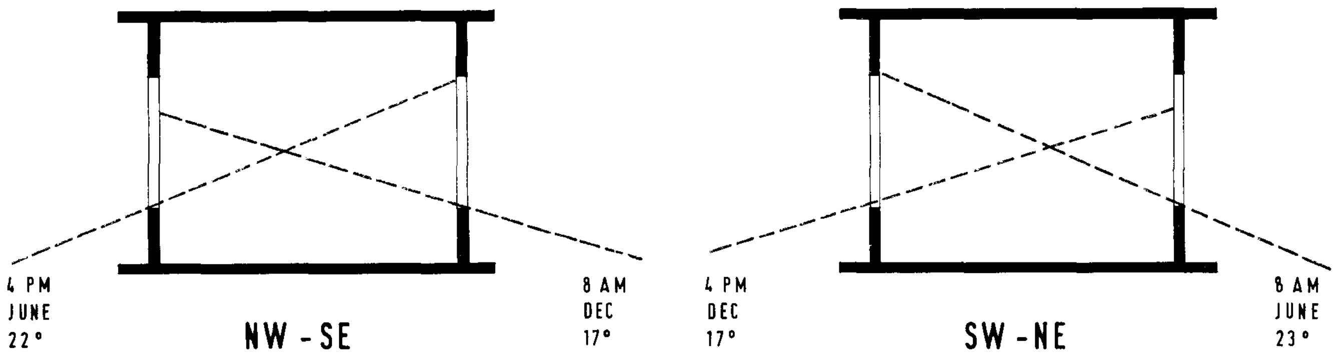


5.4.6 SUN SHADING

FIG. 324 : VERTICAL AND HORIZONTAL SHADOW ANGLES, LAT. 6°N AND 12°N :



VERTICAL SHADOW ANGLES AT 8 A.M. AND 4 P.M. DURING THE CRITICAL MONTHS OF DECEMBER AND JUNE FOR LATITUDE 6°N IN GHANA (KUMASI, ACCRA, CAPE COAST, KOFORIDUA).



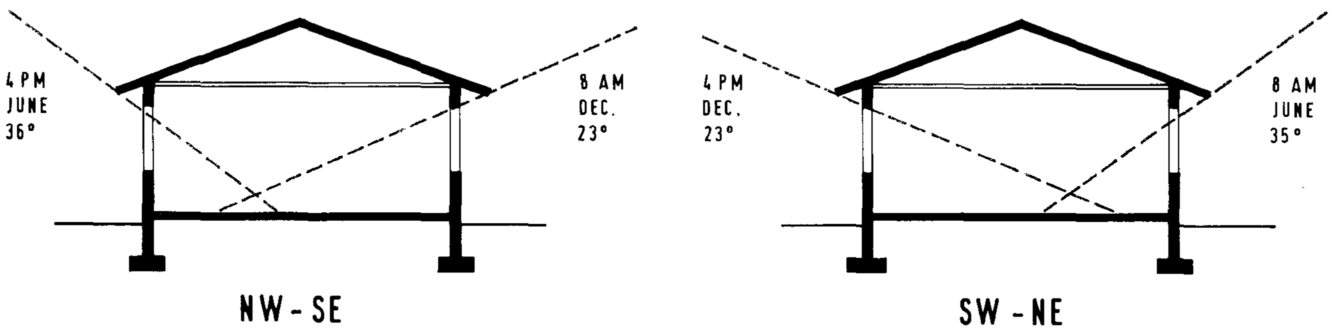
HORIZONTAL SHADOW ANGLES AT 8 A.M. AND 4 P.M. DURING THE CRITICAL MONTHS OF DECEMBER AND JUNE FOR THE SAME LATITUDE.

VERTICAL SHADOW ANGLE :

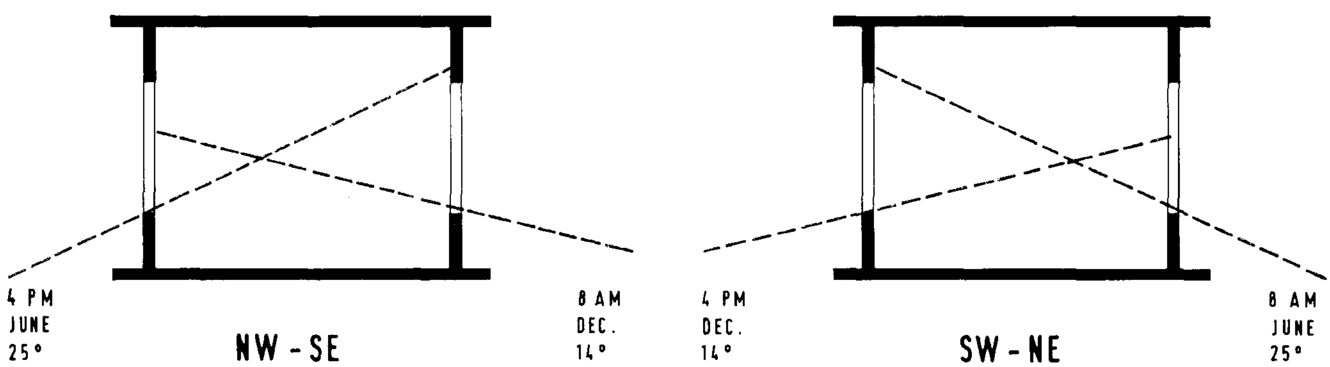
ANGLE BETWEEN THE SUN'S DIRECT RAYS AND A HORIZONTAL PLANE DRAWN PERPENDICULAR TO THE HORIZONTAL FACE OF THE WALL.

HORIZONTAL SHADOW ANGLE :

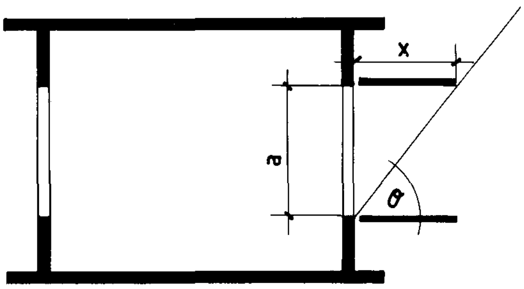
ANGLE BETWEEN THE SUN'S DIRECT RAYS AND A VERTICAL PLANE DRAWN PERPENDICULAR TO THE FACE OF THE WALL.



VERTICAL SHADOW ANGLES AT 8 A.M. AND 4 P.M. DURING THE CRITICAL MONTHS OF DECEMBER AND JUNE FOR LATITUDE 12° IN GHANA (BAWKU, UPPER REGION).



HORIZONTAL SHADOW ANGLES AT 8 A.M. AND 4 P.M. DURING THE CRITICAL MONTHS OF DECEMBER AND JUNE FOR THE SAME LATITUDE.

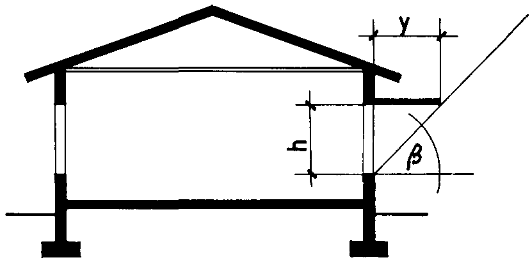


PLAN : VERTICAL PROTECTIVE DEVICES

THE MINIMUM WIDTH (x) OF A VERTICAL PROJECTION REQUIRED TO SHADE COMPLETELY AN OPENING (a) IN PLAN IS GIVEN BY :

$$x = a \cot \theta$$

WHERE a = WIDTH OF OPENING
x = WIDTH OF PROJECTION REQUIRED
θ = HORIZONTAL SHADOW ANGLE



SECTION : HORIZONTAL PROTECTIVE DEVICES

THE MINIMUM WIDTH (y) OF A HORIZONTAL PROJECTION REQUIRED TO SHADE COMPLETELY AN OPENING OF HEIGHT (h) IN SECTION IS GIVEN BY :

$$y = h \cot \beta$$

WHERE y = WIDTH OF PROJECTION
h = HEIGHT OF OPENING
β = VERTICAL SHADOW ANGLE

FIG.325 : **VERTICAL AND HORIZONTAL PROTECTIVE DEVICES AND THEIR SIZES**

In the introduction to 5.4 the function of the external envelope or skin of the building as a filter or screen for environmental impacts was described. Each part of the "building skin" contributes to the proper functioning of the filter. In a tropical environment the desired indoor comfort of the occupants of a building can be achieved if the elevation of the building can, as nearly as possible, be shaded completely. This may be done in a single-storey structure with a specific roof design. But it may not be possible to completely shade those portions of the building which are exposed to the highest solar radiation at critical angles. In such cases artificial sun shading devices or "sun-breakers" must be introduced for shading complete walls or window and door openings.

Sun-breakers have become as important architectural elements in tropical countries as the chimney is an element of domestic architecture in countries with cold climates. Marcel Breuer has this to say: "The sun control device has to be on the outside of the building, an element of the facade, an element of architecture. And because this device is so important a part of our open architecture, it may develop into as characteristic a form as the Doric column." (From: "Solar Control and Shading Devices" by A. & V. Olgyay, Princeton University Press, New Jersey, 1957).

Methods for calculating the size of shading devices are well developed and can be found in the form of solar charts which have been produced by Building Research Institutes in different tropical countries (e.g. West African Building Research Institute – now B.R.R.I. – Note No. 6: "Aids to the Design of Shading Devices for Latitudes 4°N to 12°N"). Fig. 324 and 325 show the vertical and horizontal shadow angles at 8 a.m. and 4 p.m. during the critical months of December and June for latitude 6°N (Kumasi, Koforidua, Accra and Cape Coast) and for latitude 12°N (Bawku – Upper Region) in Ghana. At the same time they explain vertical and horizontal protective devices and their calculation.

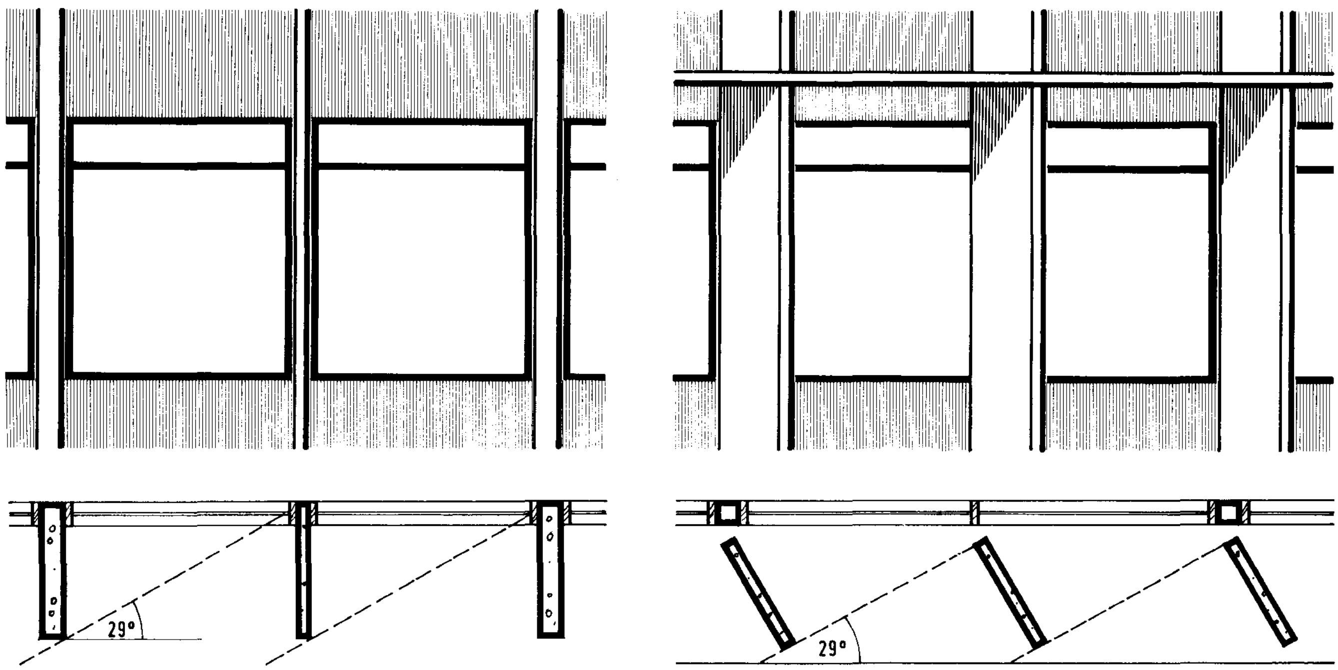
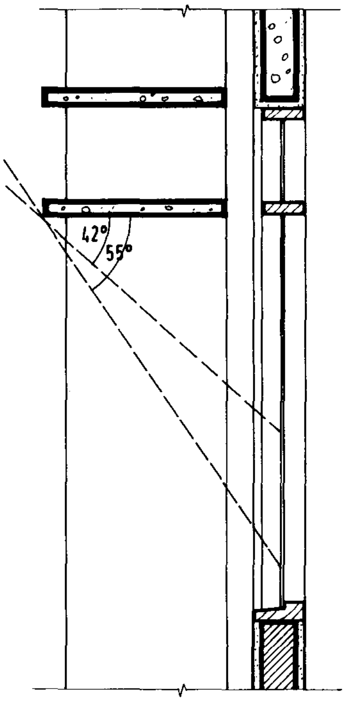


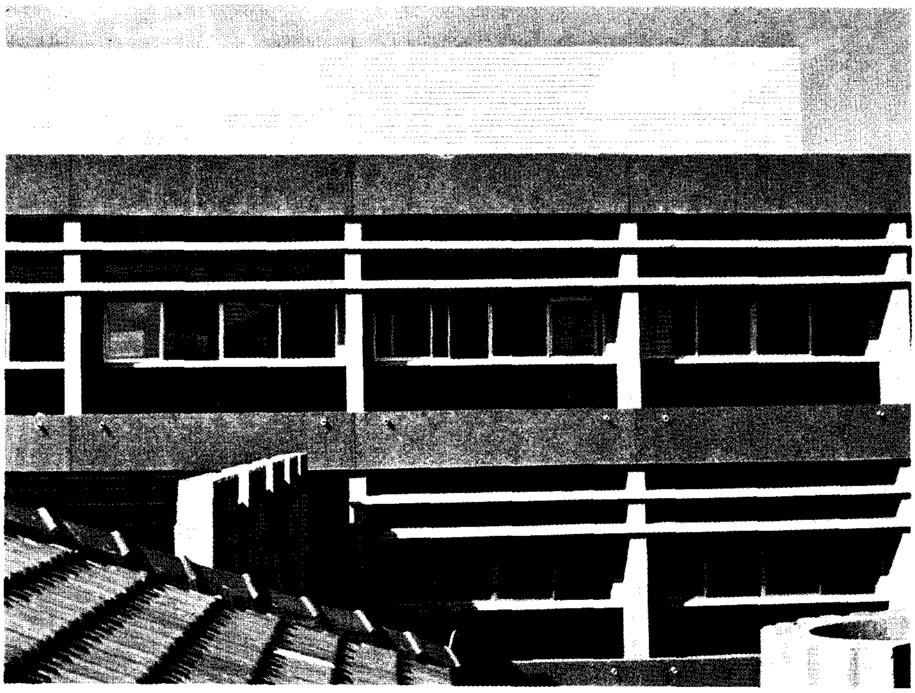
FIG.326 : **FIXED VERTICAL FINS** : SOLID VERTICAL FINS OF REINFORCED CONCRETE CAN BE PART OF THE STRUCTURAL FRAMEWORK OF THE BUILDING OR FIXED (AS SHOWN ON THE PLAN AND ELEVATION OF THE FINS SET OBLIQUELY TO THE WALL) BETWEEN THE CANTILEVERED FLOOR SLABS.

5.4.6 SUN SHADING

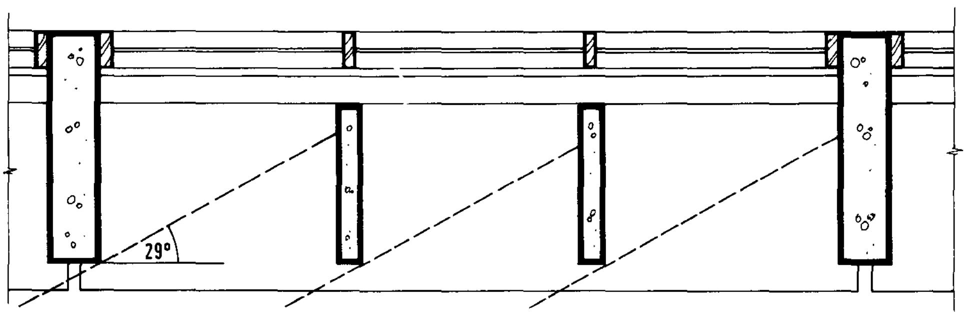


SECTION

SOLID HORIZONTAL SHADING DEVICES, NORMALLY OF REINFORCED CONCRETE, FIXED BETWEEN COLUMNS, SPANNING THE WIDTH OF THE STRUCTURAL GRID.

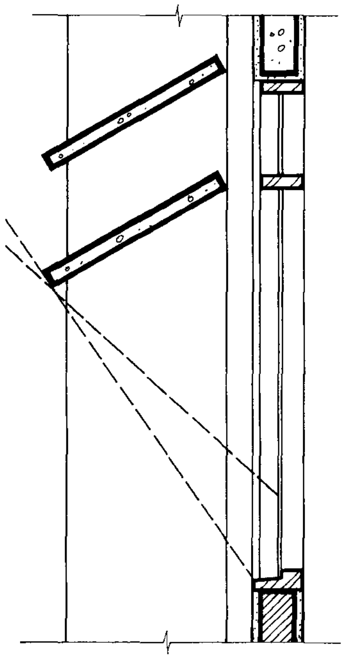


For Fig. 327: Southeast elevation of the westwing of Parliament House, Accra, 1972. Architect: HANNAH SCHRECKENBACH.



PART PLAN

SECTION AND PLAN SHOW THE CRITICAL VERTICAL AND HORIZONTAL SHADOW ANGLES FOR A BUILDING FACING NORTH - SOUTH. THE SHADING DEVICES REQUIRED TO SHADE A BUILDING FACING SOUTHWEST - NORTHEAST OR SOUTHEAST-NORTHWEST WOULD BE OF UNECONOMICAL SIZE. IT IS, MOREOVER, USUAL TO COMBINE FIXED HORIZONTAL DEVICES WITH FIXED VERTICAL FINS AS SHOWN.



SECTION

TILTED HORIZONTAL FINS OF REINFORCED CONCRETE ARE FIXED BETWEEN VERTICAL SUPPORTS OR COLUMNS. THE DEVICES SPAN THE WIDTH OF THE STRUCTURAL GRID AND CAN BE CAST SIMULTANEOUSLY WITH THE COLUMNS.

FIG. 327 : FIXED HORIZONTAL SHADING DEVICES

5.4.6.1 SHADING DEVICES:

There are a large variety of different shading devices:

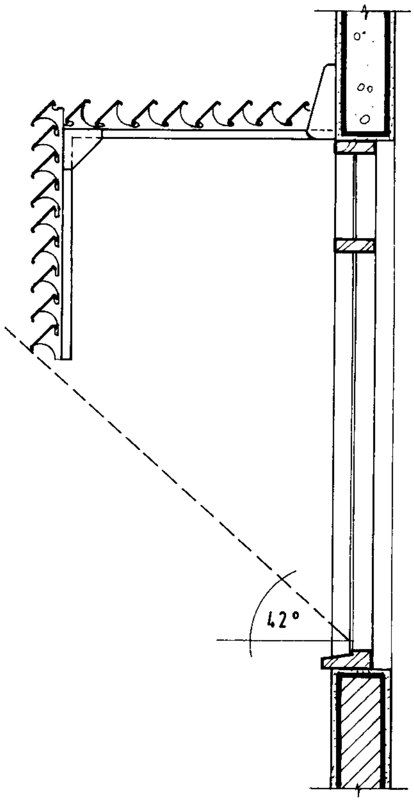
- Fixed vertical fins;
- Fixed horizontal devices;
- Combined fixed vertical and horizontal devices;
- Movable vertical devices;
- Movable horizontal devices.

Fixed Vertical Fins (Fig. 326): These can be designed as part of the structural framework of the building by providing a system of slender and protruding columns or thin vertical reinforced concrete fins which are fixed between cantilevered floor slabs either at right angles to the wall or obliquely.

Fixed Horizontal Devices (Fig. 327 *to* 329): These can be solid or partially solid overhangs, or horizontal or tilted fins fixed between vertical supports, or tilted louvres of different materials fixed in panels parallel to the wall or horizontal or tilted louvres hanging from a solid or partially solid cantilever.

Combined Fixed Vertical and Horizontal Devices (Fig. 330): These are also known as an egg-crate device and can be designed in different ways, the smallest appearing like a perforated "curtain wall" in front of the elevation,

5.4.6 SUN SHADING



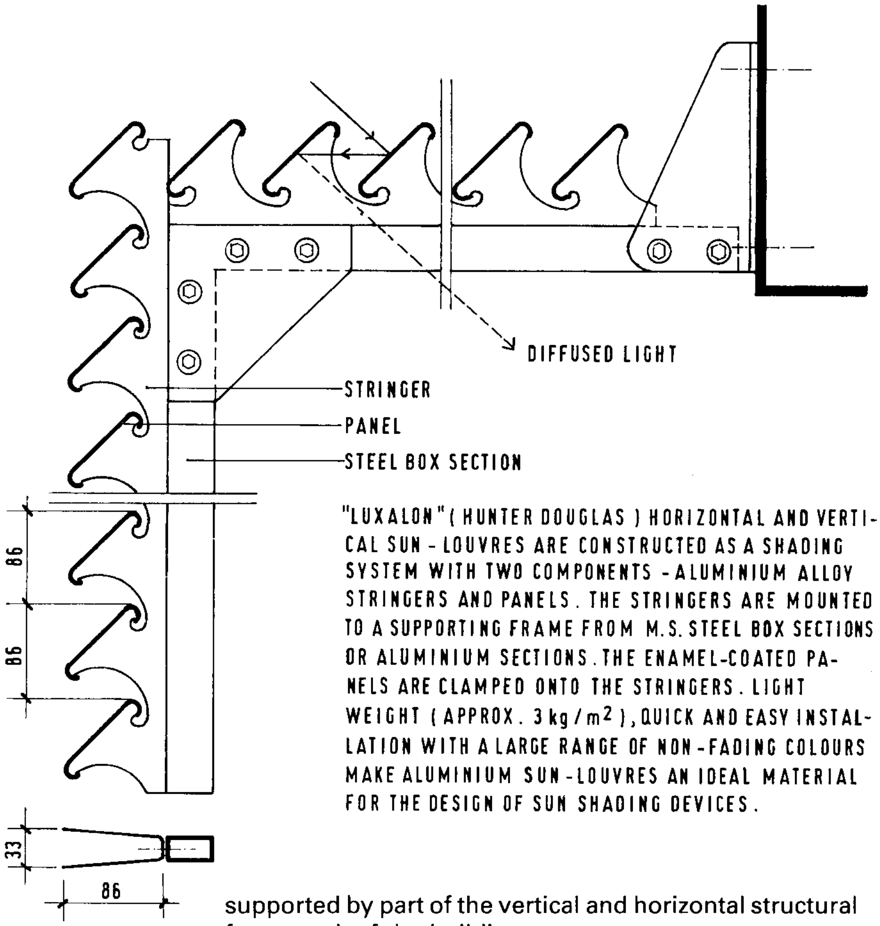
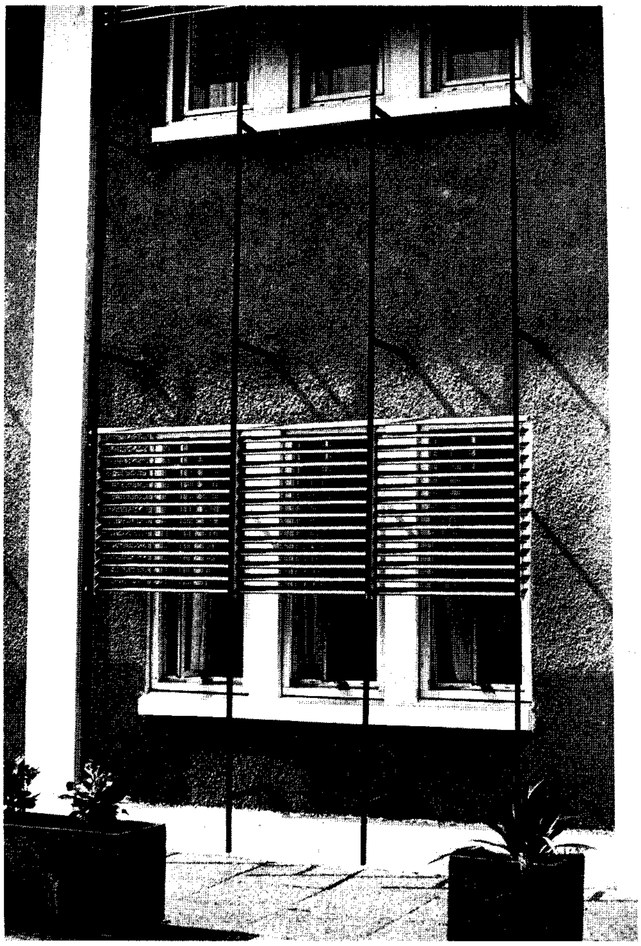


FIG. 328 : ALUMINIUM SUN - LOUVRES



For Fig. 328: Aluminium sun louvres, east-wing of Parliament House, Accra, 1982.

supported by part of the vertical and horizontal structural framework of the building.

Movable Vertical Devices (Fig. 331): There are a number of metal window producing firms which manufacture different types of vertical movable fins that can shade the whole wall or open up in any desired direction by the action of vertical pivots.

Movable Horizontal Devices: These work on the horizontal pivot principle.

It is, of course, possible to combine fixed and movable devices in shading a building. One of the oldest and most effective methods of sun control is the louvred jalousie. Louvred jalousies are not only used as suitable windows for tropical developing countries but also as shading screens on the southwest and west elevations of single storey domestic structures, under a slat pergola.

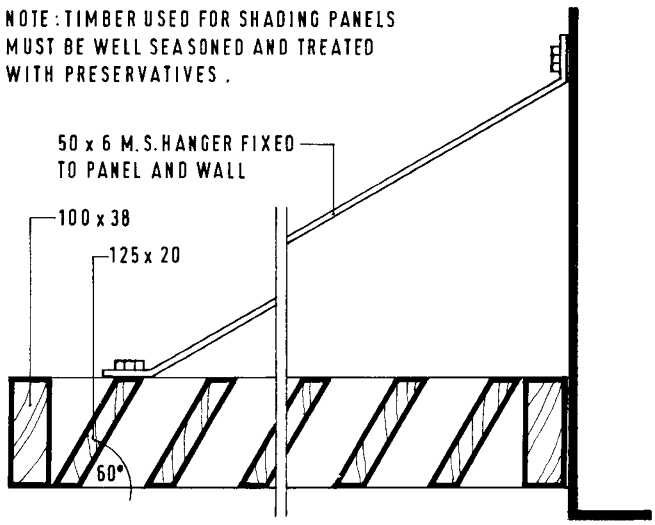


FIG. 329 : HORIZONTAL SHADING DEVICE WITH TILTED TIMBER LOUVRES

5.4.6 SUN SHADING

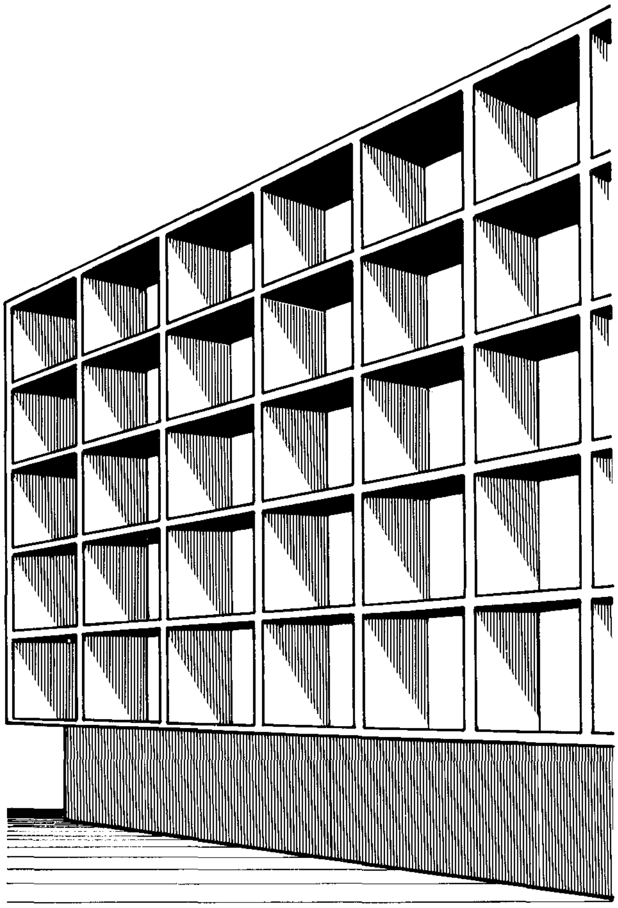
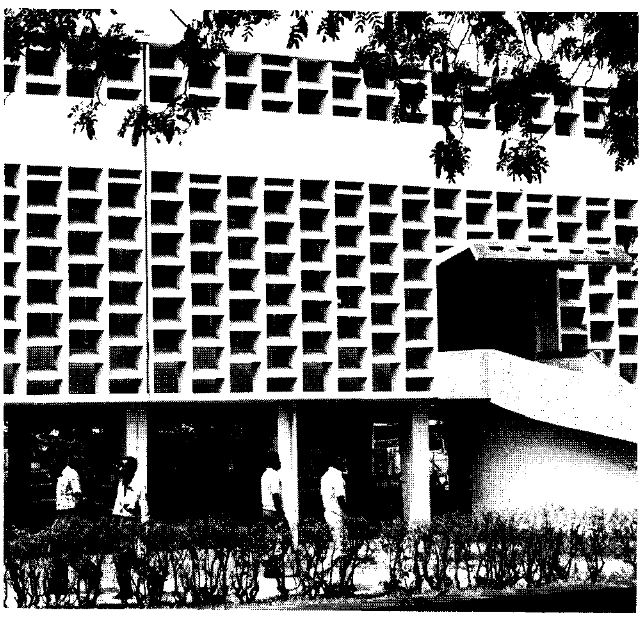
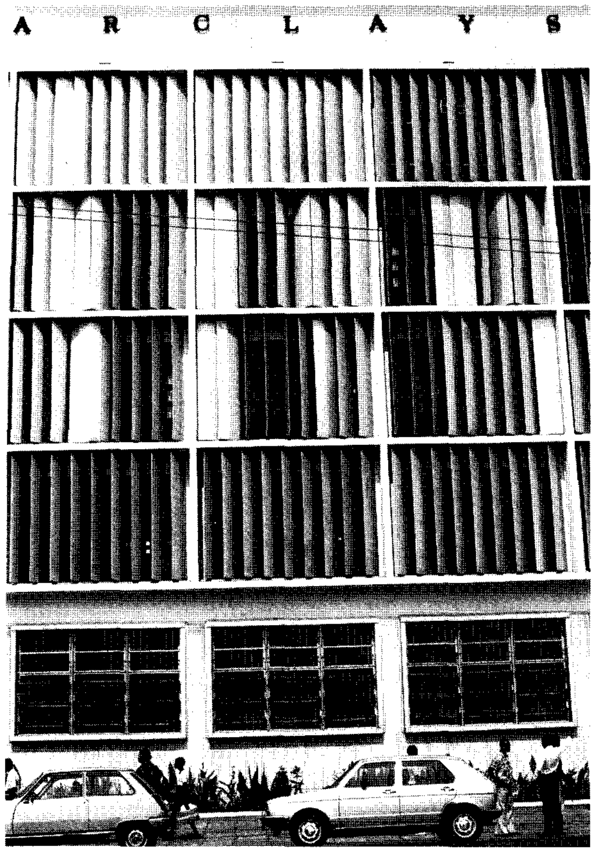


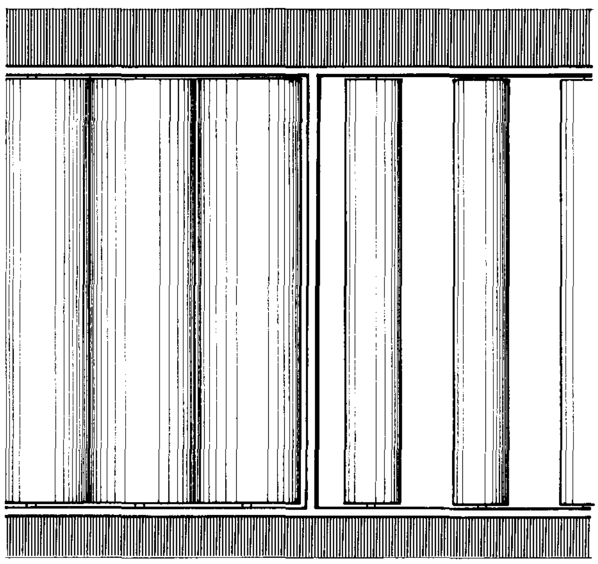
FIG.330 : COMBINED FIXED VERTICAL AND HORIZONTAL SHADING DEVICES



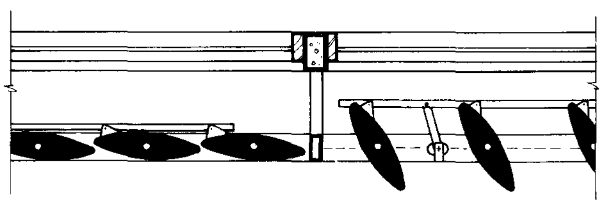
For Fig. 330: Accra Library, entrance elevation, 1982. Architects: NICKSON & BORIS.



For Fig. 331: South elevation of Barclays Bank, High Street, Accra, 1982. Architects: HARRISON, BARNES & HUBBARD.



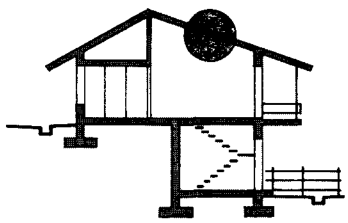
"NACO" ELLIPSOID ALUMINIUM SHEET VERTICAL MOVABLE SUN LOUVRES WITH ALUMINIUM FRAME.



CLOSED POSITION OPEN POSITION

FIG.331 : MOVABLE VERTICAL SHADING DEVICES

5.4.7 ROOF STRUCTURES AND FINISHES



The roof is the element of the building which is most closely associated with the concept of shelter. "Not having a roof over one's head" means practically to be at the mercy of the elements, to be without cover, without shelter. The roof, more than any other part of the building, must effectively shelter the occupants from the elements and give them a feeling of safety and comfort.
(H. King and E. Peters in "AJ-Handbook of Building Enclosure", Technical Study, Roofs 1, "A roof over one's head")
Besides its structural function, which is to span space, the roof in a tropical environment has to fulfil various functions at the same time:

- To shade the external walls;
- To insulate against solar heat penetration;
- To shed rainwater quickly or to collect it in areas where water is precious;
- To withstand wind.

SHADING

If the elevations of a building can be shaded by the roof structure (this applies to single-storey structures; for multi-storey structures other means of shading are used), a considerable drop in temperature can be achieved inside the building. For this purpose a large overhang of the roof is normally sufficient in addition to sun shading devices for the walls facing east and west. An additional advantage would be an "umbrella" roof construction, that is a roof which does not form part of the actual building enclosure, but provides an umbrella for the whole structure (Fig. 332). The actual building has a separate ceiling which could consist of a flat mud roof, a thin concrete slab, or precast concrete units, or a timber structure etc. Provision must be made, though, for draining off rain water which may be driven into the gap between the "umbrella" and ceiling during heavy rainstorms accompanied by strong winds. The umbrella can be designed so that it cantilevers considerably longer than a normal roof structure and like this will shade the complete building. The external walls and the ceiling of the structure do not receive direct solar radiant heat and their temperature therefore differs little from the indoor temperature which remains cool.
Fig. 333 shows the Regional Library in Bolgatanga (designed by Max Bond, U.S.A.) which incorporates an umbrella roof. The building has been in use since 1968, and it has been confirmed that this building provides the highest indoor comfort for its occupants and many users without any air-conditioning throughout the different seasons of the year, especially during the long hot and dry season, compared with other public buildings in the area. Indoor temperatures measured around 27°C when the outside temperatures were 37°C and higher. At a humidity of 50%, 28°C equals an effective temperature of 24.5°C (or lower – the lower the humidity). This is – in this region – a comfortable temperature for people who work in such an environment. It is interesting to note that the only part of the building which is not covered by the umbrella roof – the lecture hall – requires a high-powered air-conditioning unit and is out of use most of the time since the electricity supply in the area is not reliable.

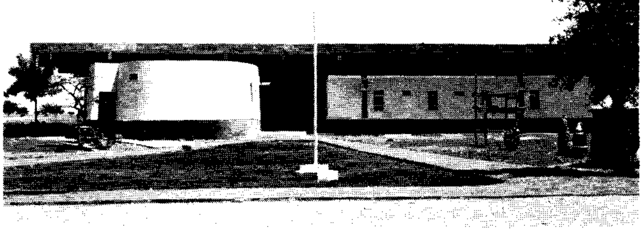


Fig. 333: Regional Library, Bolgatanga, 1968. Architect: MAX BOND.

The "Umbrella Roof Concept" is a very expensive method of construction. On the other hand, especially for public buildings like libraries, community centres, etc., it saves the provision of mechanical air-conditioning and at the same time, by providing an air gap between the umbrella and roof of the structure, fulfills the function of insulation very efficiently.

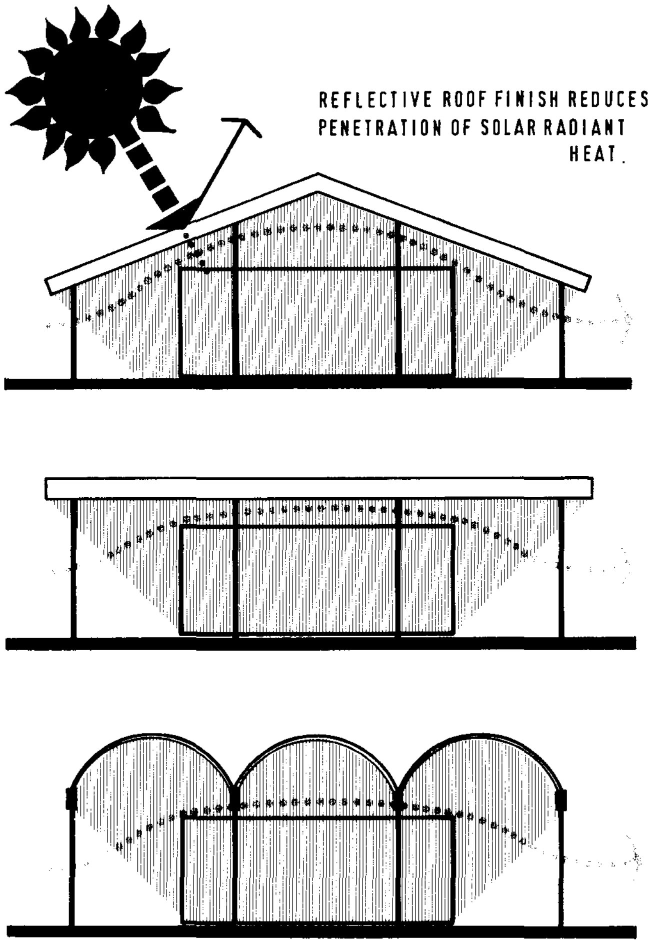
INSULATION

Solar heat penetration through the roof structure into the building below can be reduced in a number of ways. The most common method is to design the roof structure with a suspended ceiling below (with a ventilated space between the two). In addition the roof covering can be specified to be of dense material or to incorporate insulative material between the roof structure and the covering (e.g. wood-wool slabs or fibre board). This will also help to reduce the noise (drumming of rain on a corrugated aluminium or iron sheet roof, or the cracking of metal covering due to temperature changes). Roof coverings can also be painted with special light reflective paints. Roof vents or roof lights are better avoided in tropical climates except in buildings where they are absolutely necessary. Vent openings can be fixed at gable ends at ridge level and along the soffits of the eaves' overhang. Such vents must be covered with wire netting to keep out lizzards, snakes, rats, etc.

RAINWATER DISPOSAL (Fig. 334)

A tropical rainstorm may be of short duration, but can be of great intensity with up to 150mm of rain per hour. Rainwater therefore must be shed off a roof surface quickly and, if collected, discharged into suitable containers effectively. This is normally done with the help of eaves gutters of reinforced concrete, aluminium sheeting, zinc, asbetos, sheet iron or pressed galvanized steel with gargoyles and down-pipes of P.V.C. The rainwater can be discharged into receptacles or underground water tanks from where it is pumped into a high level reservoir with a simple hand pump for use. The design of a roof drainage system depends on the amount of water to be drained, which in turn depends on the intensity and duration of the rainfall in the particular location. Tables for maximum rainfall figures are normally available from the Meteorological Services of each country.

(a) **Eaves Gutters** (Fig. 335): These are fixed at the eaves of a roof. They are made to standard design: Halfround (H.R.), ogee (O.G.) and moulded sections. The gutter



SOLAR RADIANT HEAT WHICH HAS PENETRATED THROUGH THE ROOF WILL BE REMOVED THROUGH THE AIR CIRCULATING UNDER THE ROOF. NO HEAT PENETRATION THROUGH THE EXTERNAL WALLS WHICH ARE COMPLETELY SHADED BY UMBRELLA ROOF FOR THE WHOLE DAY.

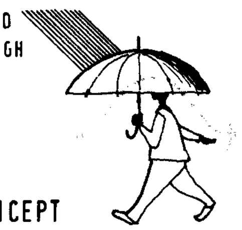
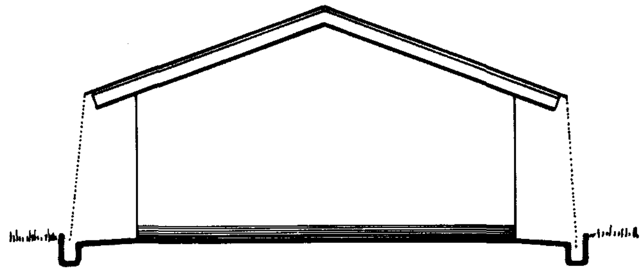
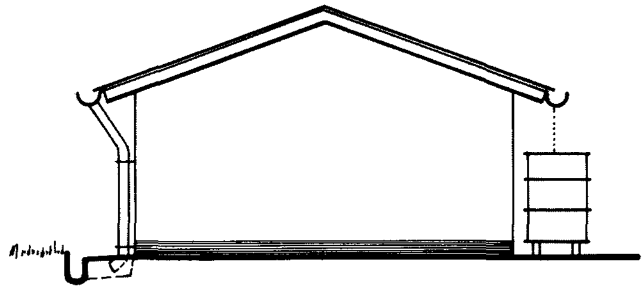


FIG. 332 : THE UMBRELLA ROOF CONCEPT

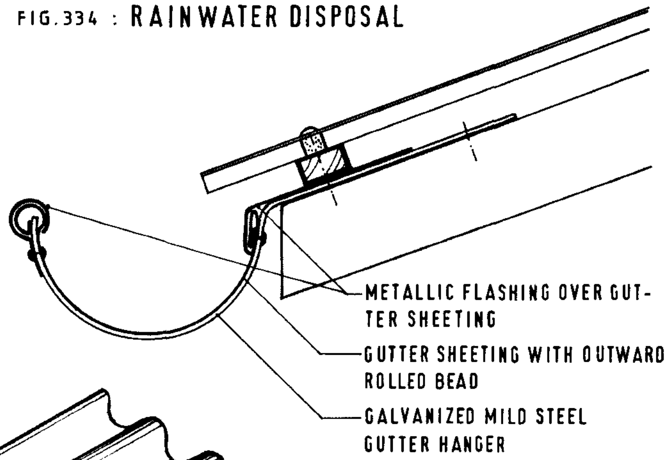


1 DISCHARGE OF RAINWATER WITHOUT GUTTER STRAIGHT INTO OPEN DRAINS AROUND THE BUILDING.



2 DISCHARGE OF RAINWATER INTO EAVES GUTTER AND FROM THERE THROUGH DOWNPIPES INTO OPEN OR COVERED DRAINS OR INTO COLLECTION RECEPTACLES.

FIG. 334 : RAINWATER DISPOSAL



SECTION THROUGH AN EAVES GUTTER

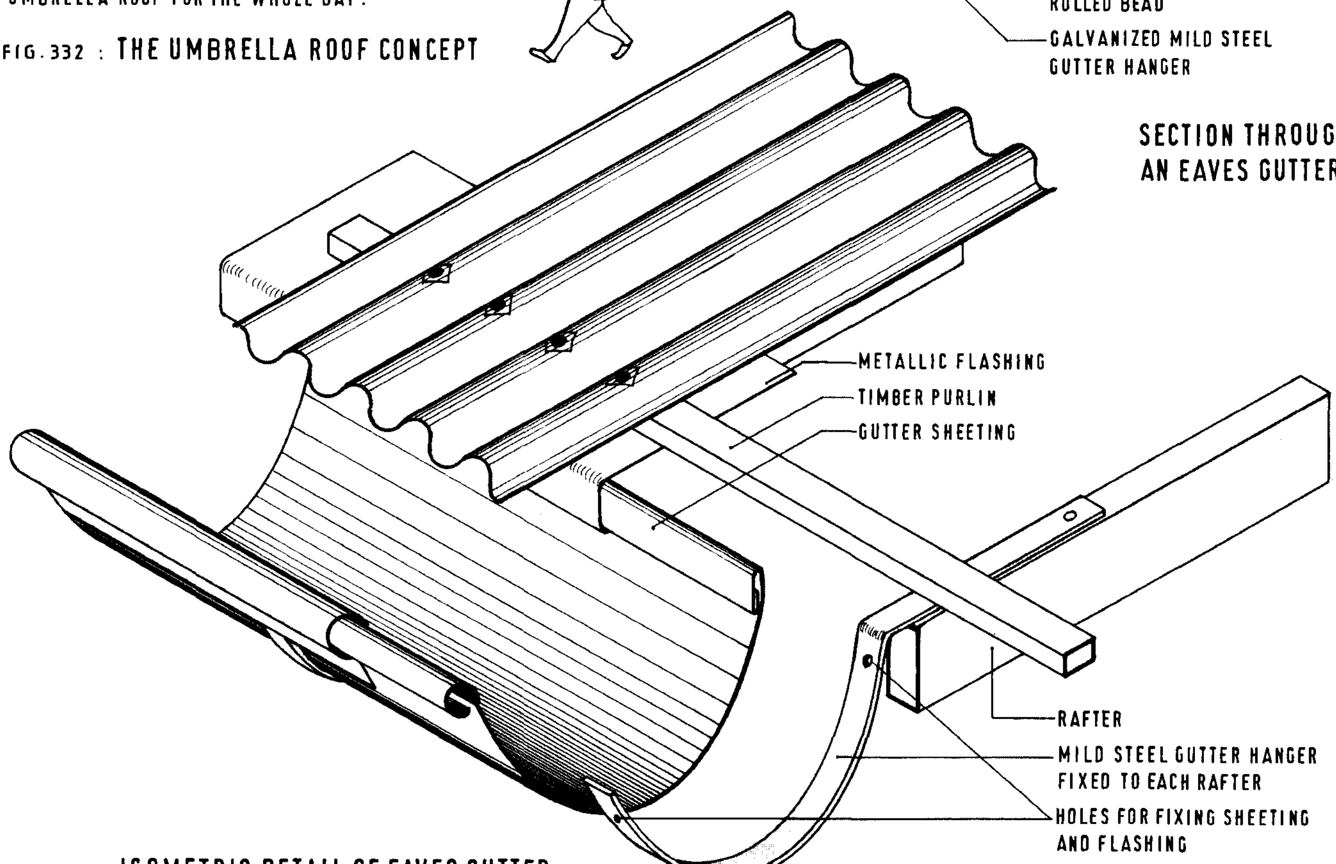
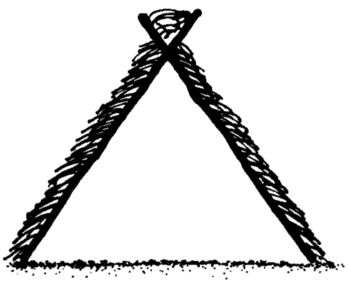


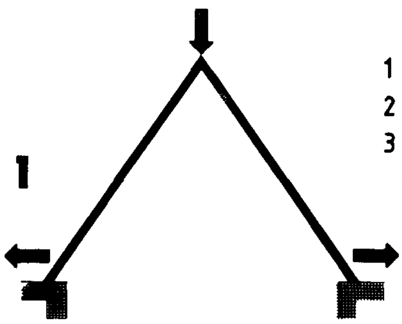
FIG. 335 : ISOMETRIC DETAIL OF EAVES GUTTER

5.4.7 ROOF STRUCTURES AND FINISHES

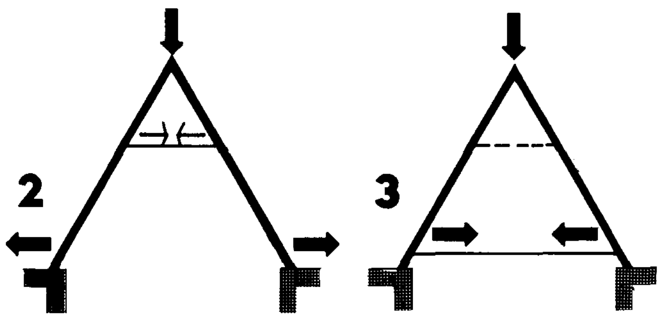
FIG. 336 : DEVELOPMENT OF FRAMED TIMBER ROOF SYSTEMS :

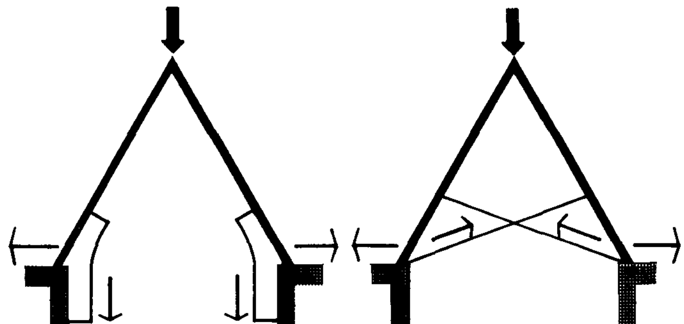


THE ORIGINAL STAKE HUT



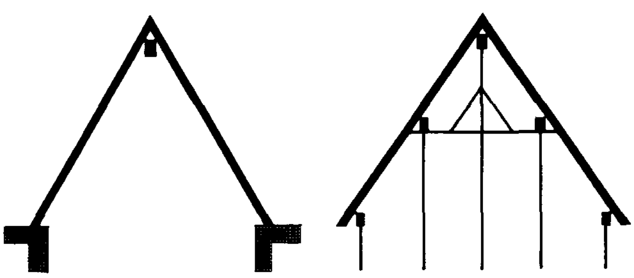
1 COUPLE ROOF
2 WITH COLLAR TIE
3 WITH CELLAR TIE
(RELIEVING THE WALLS OF THRUST, COLLAR TIE OPTIONAL IN THIS CASE)



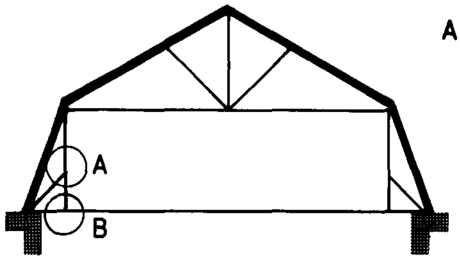


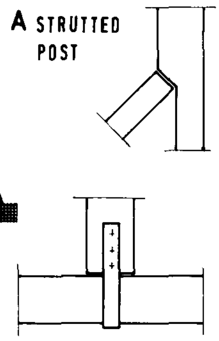
ARCH BRACES
TAKING PART OF LOAD TO THE WALLS

SCISSOR BEAM



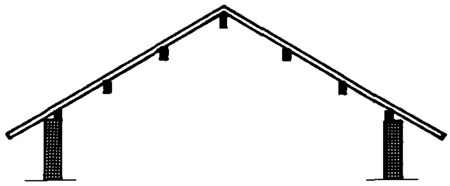
PURLIN AND RIDGE - POLE TYPE ROOFS :
RAFTERS ACT AS SIMPLE BEAMS SUPPORTED BY THE RIDGE POLE, PURLINS AND WALLS. ROOF PITCH IS GENERALLY LOWER THAN WITH RAFTER ROOF FRAMING TYPES.



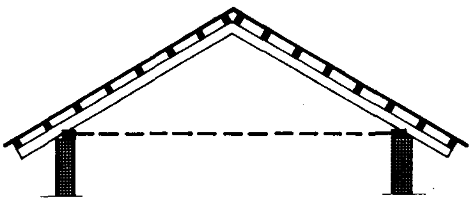


THE MANSARD ROOF
UTILIZES ROOF SPACE AND REDUCES PITCH. DEVELOPED WITH NEARLY FLAT TOP IN LATE RENAISSANCE AND BAROQUE PERIOD.

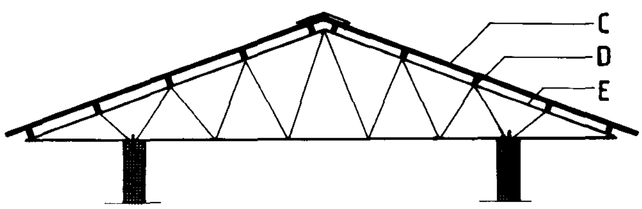
B HANGER STRAPS SUPPORTING TIE BEAM



PURLIN SYSTEM : SIMPLE PURLIN ROOFS USE SAWN TIMBER PURLINS SPANNING BETWEEN WALLS. THEY ARE UNECONOMIC FOR SPANS EXCEEDING 4.8 m. SYSTEMS OF BUILT-UP PURLIN GIRDERS WITH LIGHT RAFTERS ARE MORE COMMONLY USED.



RAFTER SYSTEM : UNSUPPORTED RAFTER SYSTEMS ARE SUITABLE ONLY FOR SHORT SPANS (LIMITATIONS IN LENGTHS OF SAWN TIMBER) UP TO 6.3 m, INCORPORATING A TIE. IN EUROPE AND U.S.A. TRUSSED RAFTER SYSTEMS FOR LIGHT ROOF CONSTRUCTION AT 600 mm CENTRES ARE MASS-PRODUCED, ESPECIALLY FOR TIMBER FRAME HOUSING.



TRUSSED RAFTER-PURLIN SYSTEM :
C ROOFING
D PURLINS
E TRUSS

THIS IS A POPULAR CONVENTIONAL ROOF SYSTEM FOR MEDIUM SIZED AND LARGE BUILDINGS. THE LIGHT TRUSSES ARE FIXED TO THE WALLS AT 1.8 TO 2.4 m CENTRES. PURLIN SPACING IS DICTATED BY THE ROOFING MATERIAL, AND THE PURLIN SIZE BY THE SPACING ADOPTED. BUILT-UP PURLINS OR PURLIN STRUTTING CAN BE USED FOR WIDER TRUSS SPACINGS.
THE PURLINS NORMALLY CARRY THE ROOFING MATERIAL DIRECT.

sheeting is fixed on to mild steel hangers which are fixed to each rafter. A roof with copper sheeting should not drain into aluminium sheet gutters since aluminium is liable to be attacked by water running from copper surfaces. Pressed galvanized steel gutters are used for drainage of large factory or warehouse roofs.

(b) **Valley Gutters**: These are used in valleys between sloping roofs.

(c) **Box Gutters**: These are made of box sections with parallel sides.

(d) **Parapet Gutters**: These are fixed or constructed on the inner sides of parapet walls when it is inadvisable for gutters to project beyond the wall face (first floor verandah roof or "roof garden").

(e) **Reinforced Concrete Gutters**: These are very often used nowadays in structures higher than single storey in conjunction with reinforced concrete or P.V.C. spouts (not higher than two-storey) or P.V.C. down-pipes and outlet gratings.

Gutters must be regularly checked, cleaned and maintained. They must have sufficient fall so that no stragnant water remains in them, causing mosquitoes to breed. Where rainwater is not collected and drains straight off a roof, a system of covered or open drains must be provided around the building with solid aprons, so that splashing water does not dirty and erode the base of the building. The surface water drains must effectively discharge the water into larger stormwater drains or soakaways. They must be large enough and built with sufficient fall to drain water off the roof as quick as possible without flooding or stagnant pools forming in them.

WIND PROTECTION

Section 4.9.4 **(Timber and Timber Frame Construction Roofing)** describes the "Monroe-effect" of strong winds on a roof structure and the necessary precautions against it. It is extremely important in all tropical climates where rainstorms are normally accompanied by very strong winds or in areas which are liable to experience typhoons, to take great care that the roof is firmly anchored to the building structure and the roof covering is properly secured to the roof structure, especially in the case of the modern lightweight roofing and coverings.

5.4.7.1 DEVELOPMENT OF ROOF STRUCTURES

In the early beginnings of man's building the circular or elongated stake hut was the first framed roof system. It was shelter and roof in one unit. In all forest areas of the world timber was primarily and often the only material, influencing the shape and pitch of a roof (from thatch, stones, slates, shingles to burnt tiles, metal sheeting). Fig. 336 explains the development of framed roof systems. The development of medium and large-span trusses and girders from timber, steel and concrete, laminated timber structures, folded plate roof structures, domes, spaceframes, shells and hyperbolic paraboloid structures is not covered in this book.

5.4.7.2 TYPES OF ROOFS

Fig. 337 explains the different roof types which are common:

- **Single Pitch Roof**: This is a very simple roof structure in the rafter-purlin system or the purlin system (where purlins can be supported from cross walls).

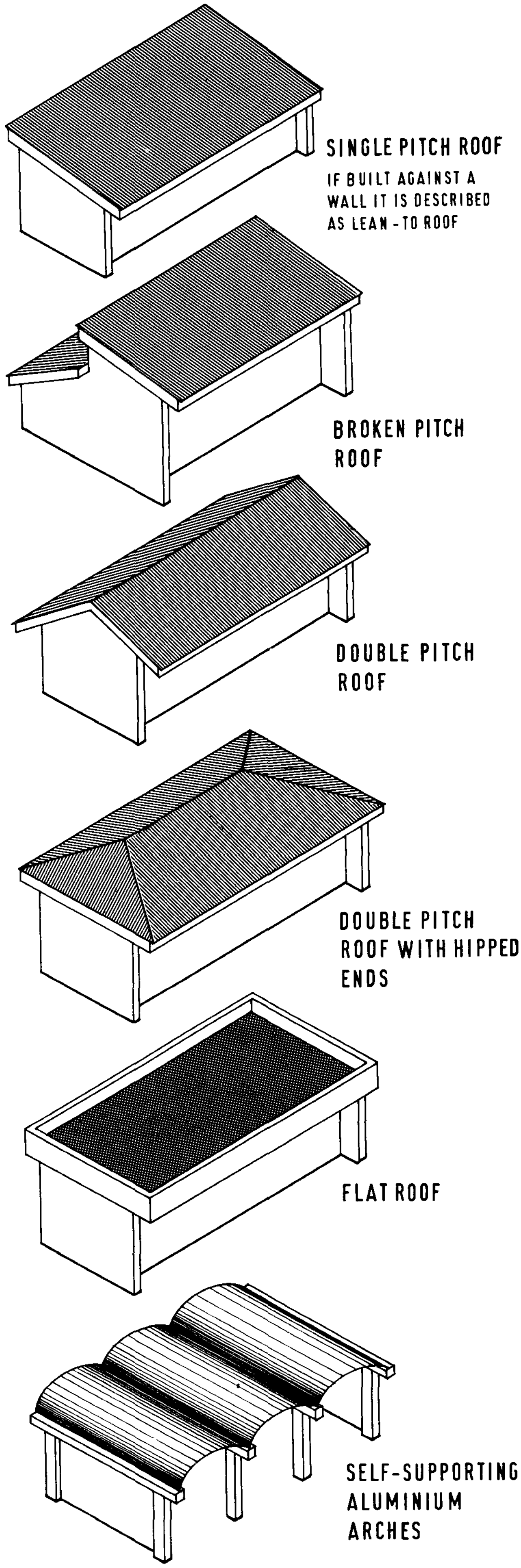


FIG. 337 : ROOF TYPES

- **Double Pitch Roof** (with gable ends): This is the most widely used of all pitched roofs with rafters and purlins or trusses and purlins. Depending on the slope of the roof the space below can be utilized as an additional living or storage area and serves as "insulative cushion" at the same time.
- **Double Pitch Roof** (with hipped ends): This is a traditional roof which in many areas of Ghana was introduced by missionaries, with straight vent openings below the ridge.
- **Broken Pitch Roof**: This roof structure is used to incorporate vent openings under the upper pitch to improve ventilation through the stack effect of the room below.
- **Barrel Roof**: Since the introduction of long span aluminium corrugated roofing sheets self-supporting arches can be built, very useful roof structures for single-storey buildings with a repetitive layout (schools, clinics) in tropical developing countries with their own aluminium sheet producing factories.

5.4.7.3 ROOF FINISHES

The largest single element of expenditure in low cost housing is the roof and especially the covering material used. This is one of the biggest problems in tropical developing countries in the urban areas of these countries where it is difficult to find the traditional materials which the rural builder finds in the vicinity of his village. Moreover, the farmer-builder uses mostly organic material for covering the roof, grasses, reeds, cereal straw, palm leaves. His occupation, being seasonal, allows him to repair or to renew the roof covering during the period when he is not farming. The urban house owner wants a durable and lasting roofing material, he has no time to spare for seasonal or yearly roof repairs. He depends on a larger variety of roof coverings offered, in conjunction with insulative materials and a roof structure which offers protection from sun, rain, storm and fire. These materials should be easily available, light to handle and to transport and easy to erect. Not all "modern" roofing materials are suitable in tropical climates; in fact, most of them, in order to fulfil the function of protection against solar heat transfer, will need additional insulative materials or incorporation of a suspended ceiling below the roof structure which increases the cost of the roof even more. Some of the traditional roofing finishes have already been described in part **2 (Traditional Building Methods)** and part **3 (Materials and their Uses in Construction)** as well as roofing materials from wastes.

An attempt is made in this section and the following detail drawings to show how traditional roof finishes can be improved to be more durable. Other construction details will explain how to reduce radiant heat transfer through the roof to a minimum to create a comfortable indoor climate for the occupants.

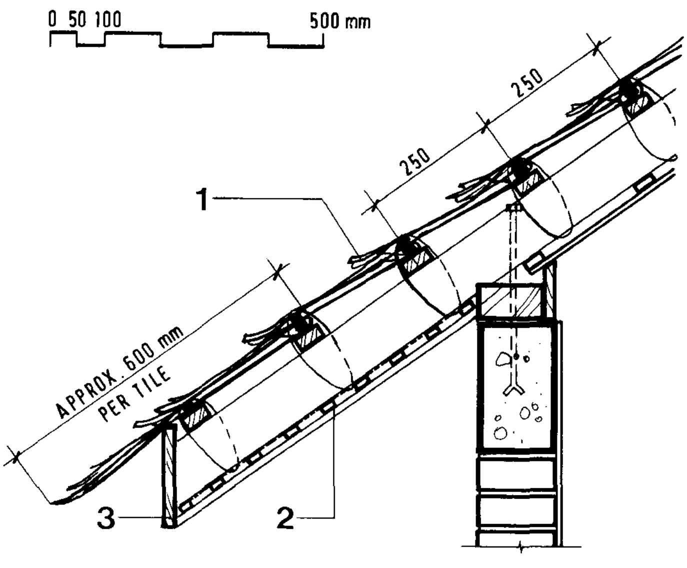
THATCH – pitch: Minimum 45°, normal 50°:

Thatch from different materials has been and still is the most common roofing material in tropical developing countries. The materials are a large variety of grasses (most common of these *Imperata Cylindrica*), leaves from the raphia palm *(Raphia Hookeri)*, cocosnut palm *(Cocos Nucifera)* or oil palm *(Elaeis Guineensis)*, reeds *(Phragmites Vulgaris)* and cereal straw (guinea corn, corn, millet).

A thatched roof needs regular maintenance and renewal of the top layer or complete renewal (palm leaf tiles) every two to three years. Palm leaf thatch which is produced in Ghana in tiles ready for laying lasts about five years.

Reed is the heaviest thatching material. A grass thatch roof needs a light substructure of timber, bamboo or ago beam *(Borassus Aethiopum)*. At eaves and gable ends (in case of a rectangular plan shape) tilting fillets should be fixed to the rafters (Fig. 338). Thatching starts from the eaves. If grass or cereal straw is used, 40 to 50 mm thick thatch panels which are rolled up into thicker bundles are tied with galvanized wire of 1.5 mm diameter to battens. Subsequent layers are laid over the eaves layer and tied down to the same and subsequent battens. In some areas it is common, in addition to using tilting fillets at the eaves, to lay down the first thatch layer heads first, so that the eaves layer is considerably thicker and more compressed than the upper layers. In some countries additional battens are tied over the thatch on top of it.

Thatch is a cheap roofing material in areas where suitable grasses, cereal straw, reeds or palm leaves are available. It is, however, a combustible material, prone to rot and weathering and can harbour insects. An application of fire retardant chemicals which are all water-soluble, has to be repeated practically every year since they are leached out by rain. An incombustible ceiling (some tropical hardwoods are fire retardant) should be provided under the roof structure. A ceiling below the roof would also keep out any insects. Termite protection in areas of subterranean termites should be included at the base level of the building.



1 PALMLEAF TILES TIED EVERY 200 mm PER TILE, THROUGH THE TILE BATTENS, TOGETHER WITH EACH OVERLAPPING TILE TO 50 x 25 mm PURLINS OR DIAM. 60 mm SPLIT POLES AND 100 x 55 (OR DIAM. 100 mm BAMBOO) RAFTERS. TILES HAVE TO BE RENEWED EVERY FOUR YEARS. A LIGHTWEIGHT SUSPENDED CEILING OF WOVEN BAMBOO MATS FIXED TO 50 x 15 BATTENS COULD BE RENEWED AT THE SAME TIME.

2 EAVES SOFFIT COVERED WITH WIRE NETTING FIXED TO RAFTERS WITH 30 x 15 mm BATTENS.

3 200 x 25 mm HARDWOOD FASCIA.

FOR FIG. 338 : PALMLEAF TILE ROOF

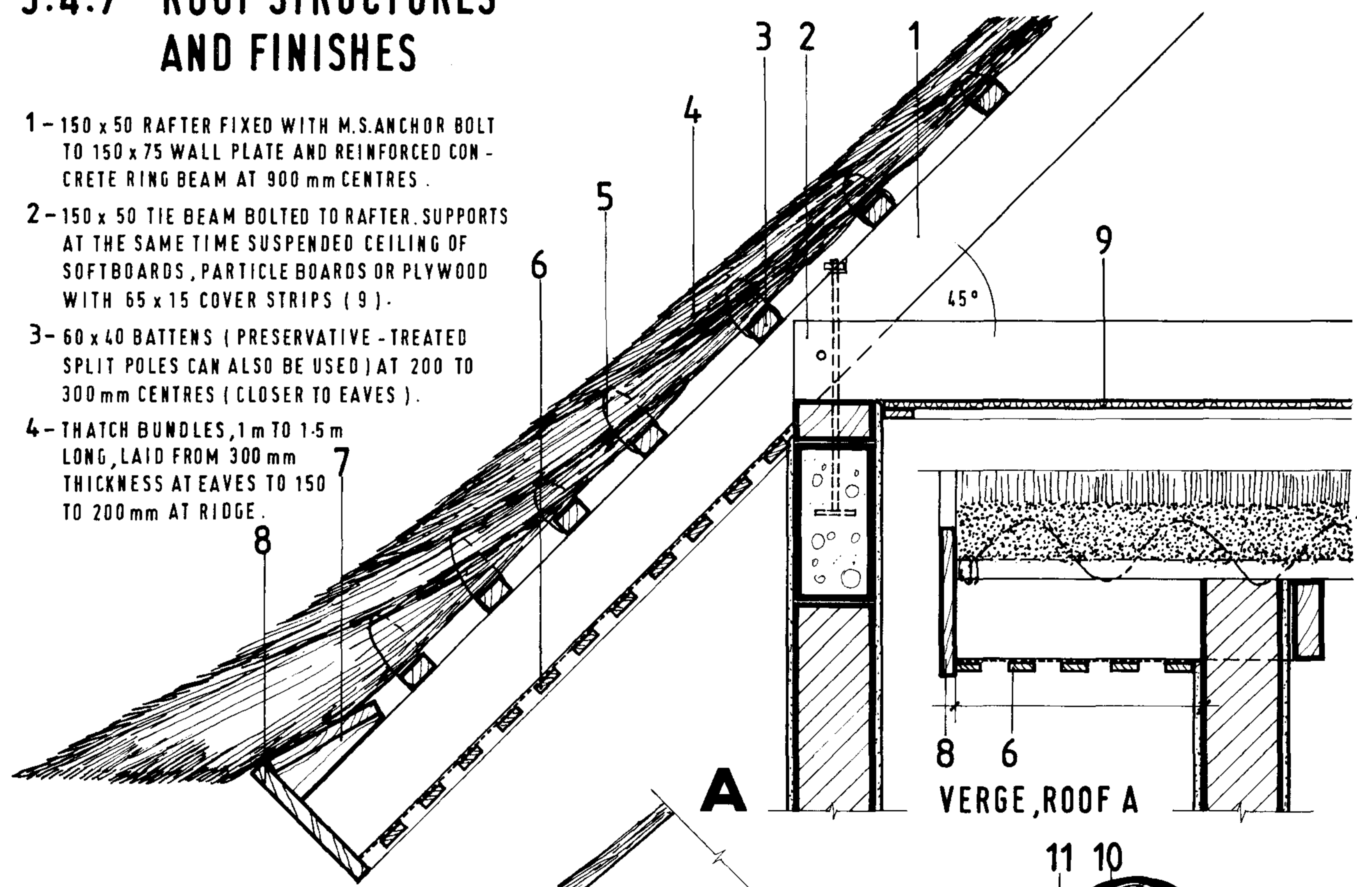
5.4.7 ROOF STRUCTURES AND FINISHES

1 – 150 x 50 RAFTER FIXED WITH M.S. ANCHOR BOLT TO 150 x 75 WALL PLATE AND REINFORCED CONCRETE RING BEAM AT 900 mm CENTRES.

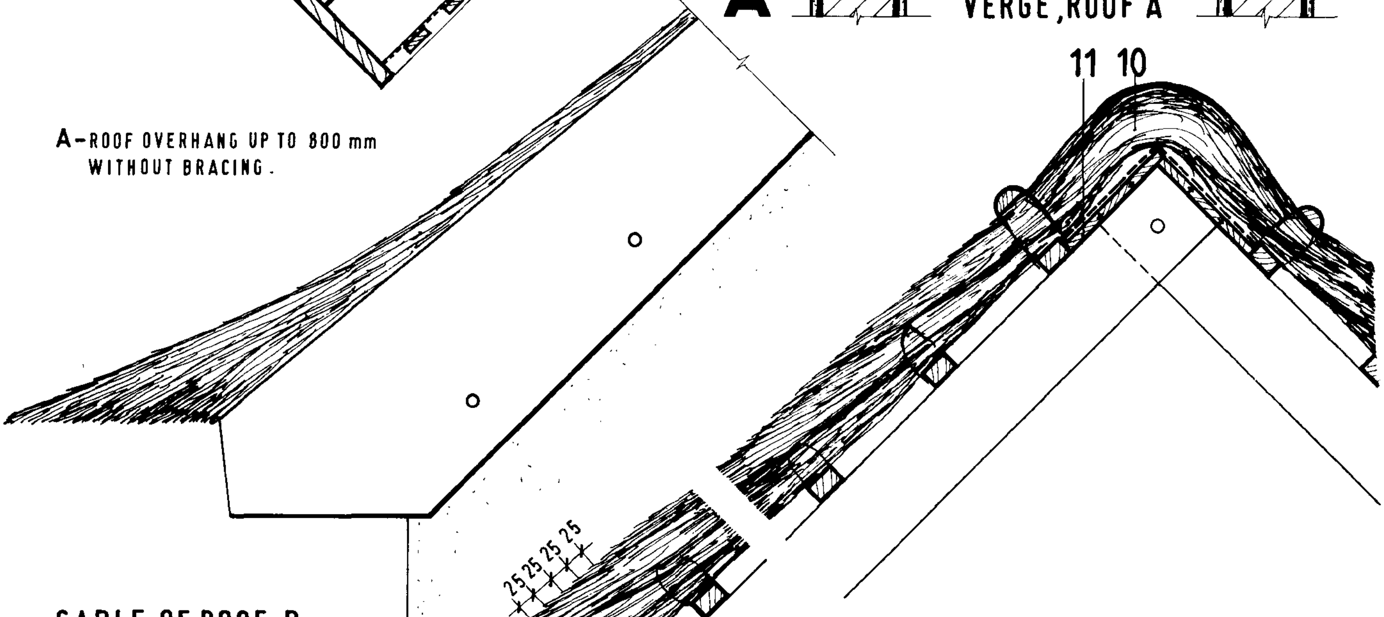
2 – 150 x 50 TIE BEAM BOLTED TO RAFTER. SUPPORTS AT THE SAME TIME SUSPENDED CEILING OF SOFTBOARDS, PARTICLE BOARDS OR PLYWOOD WITH 65 x 15 COVER STRIPS (9).

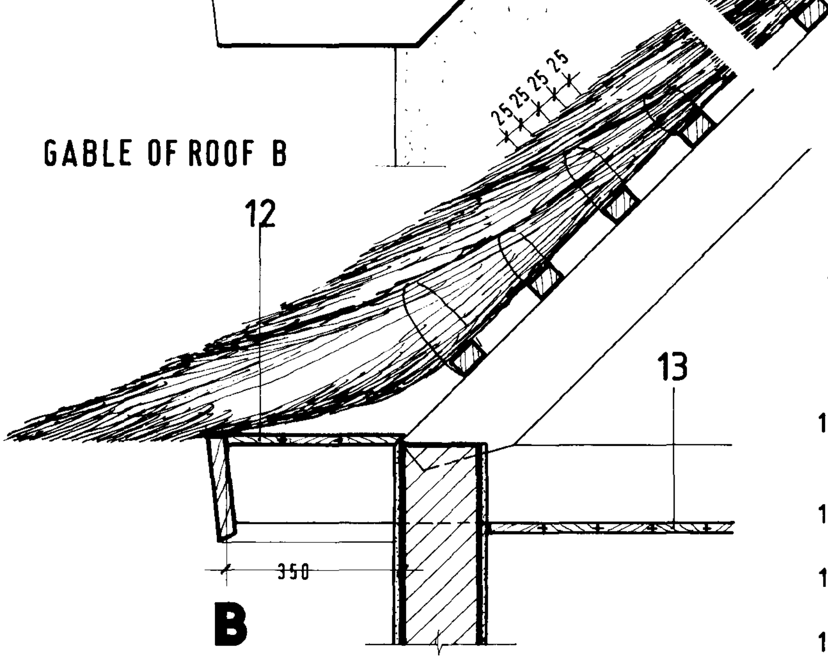
3 – 60 x 40 BATTENS (PRESERVATIVE-TREATED SPLIT POLES CAN ALSO BE USED) AT 200 TO 300 mm CENTRES (CLOSER TO EAVES).

4 – THATCH BUNDLES, 1 m TO 1.5 m LONG, LAID FROM 300 mm THICKNESS AT EAVES TO 150 TO 200 mm AT RIDGE.



A – ROOF OVERHANG UP TO 800 mm WITHOUT BRACING.





5 – 1.5 mm DIAMETER GALVANIZED STEEL WIRE FOR TYING THATCH TO BATTENS (2 TO 3 TIMES PER BUNDLE).

6 – 50 x 15 PRESERVATIVE-TREATED BATTENS COVERING WIRE NETTING AT EAVES AND GABLE SOFFITS.

7 – 230 x 25 TILTING BOARD FIXED TO 230 x 75 x 50 FILLETS.

8 – 280 x 32 WELL SEASONED AND PRESERVATIVE-TREATED FASCIA BOARD.

9 – SEE 2.

10 – RIDGE THATCH BUNDLES ADDITIONALLY TIED DOWN WITH 75 mm DIAMETER SPLIT POLE BATTENS OVER LAST ROOF BATTENS AT RIDGE.

11 – 85 x 20 PRESERVATIVE-TREATED RIDGE BOARDS COVERED WITH BITUMINOUS ROOFING FELT.

12 – 115 x 20 T. & G. EAVES BOARDS FIXED TO CANTILEVERED TIE BEAM TOGETHER WITH 200 x 32 FASCIA BOARD.

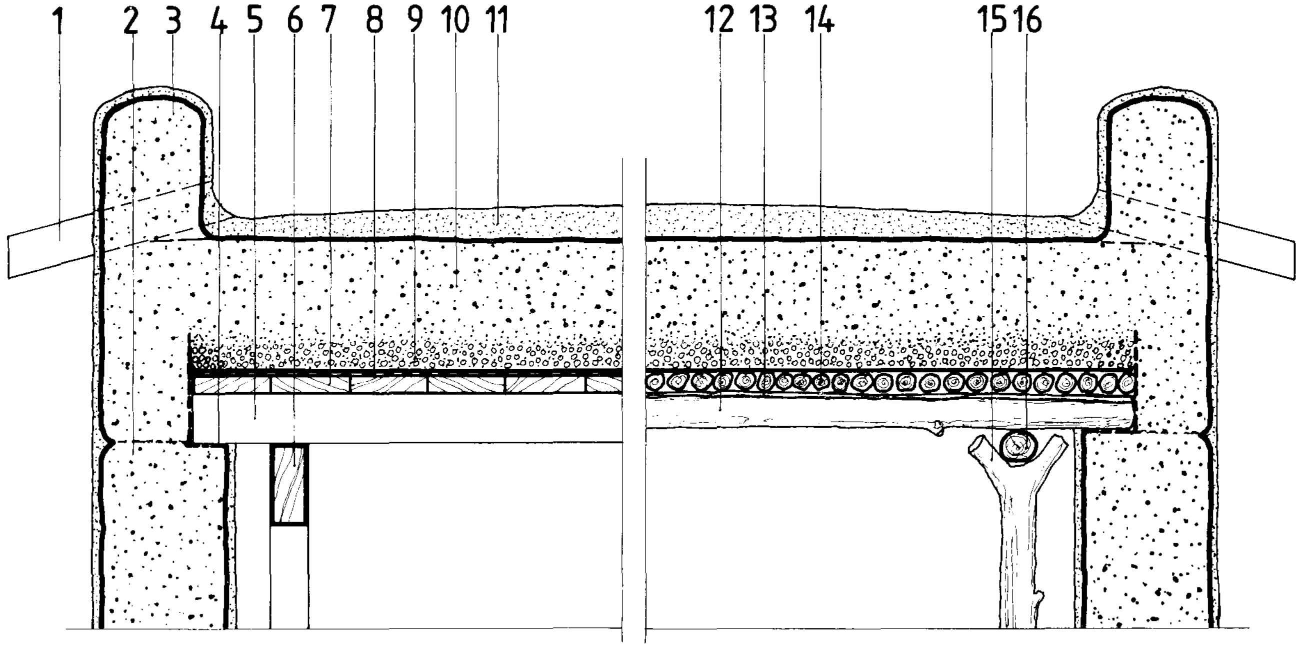
13 – 100 x 15 T. & G. HARDWOOD STRIP CEILING.

0 50 100 500 1000mm

FIG. 338 : THATCHED ROOF

5.4.7 ROOF STRUCTURES AND FINISHES

0 50 100 500 mm



FLAT MUD ROOF SUPPORTED BY POSTS AND BEAMS :

1 - 75 mm DIAMETER SPOUT OF ANY AVAILABLE SUITABLE MATERIAL, 400 TO 500 mm LONG, CAST INTO UPSTAND OF THE ROOF.

2 - 250 TO 300 mm THICK ATAKPAME WALL PLASTERED WITH SOIL / SAND AND 5% BITUMEN CUTBACK MIX FINISHED WITH LIMEWASH.

3 - 200 mm THICK PARAPET WALL, 300 mm HIGH.

4 - ONE LAYER OF BITUMINOUS FELT LAID UNDER RAFTERS AND AROUND HEADS OF RAFTERS AS SHOWN.

5 - 100 x 50 RAFTERS AT 750 mm CENTRES

6 - 150 x 75 BEAMS SUPPORTED BY 75 x 75 POSTS AT 750 mm CENTRES.

7 - 38 mm THICK 'WAWA' BOARDS (TRIPLOCHITON SCLEROXYLON), AS WIDE AS THEY ARE AVAILABLE. NOTE : POSTS, BEAMS, RAFTERS AND BOARDS MUST BE PRESERVATIVE TREATED.

8 - TWO LAYERS OF BITUMINOUS FELT OR JUTE SACKS DIPPED IN BITUMEN.

9 - 50 mm THICK LAYER OF COARSE GRAVEL / SOFT MUD MIXTURE

10 - 150 TO 200 mm THICK LAYER OF CLAY / SAND MIX

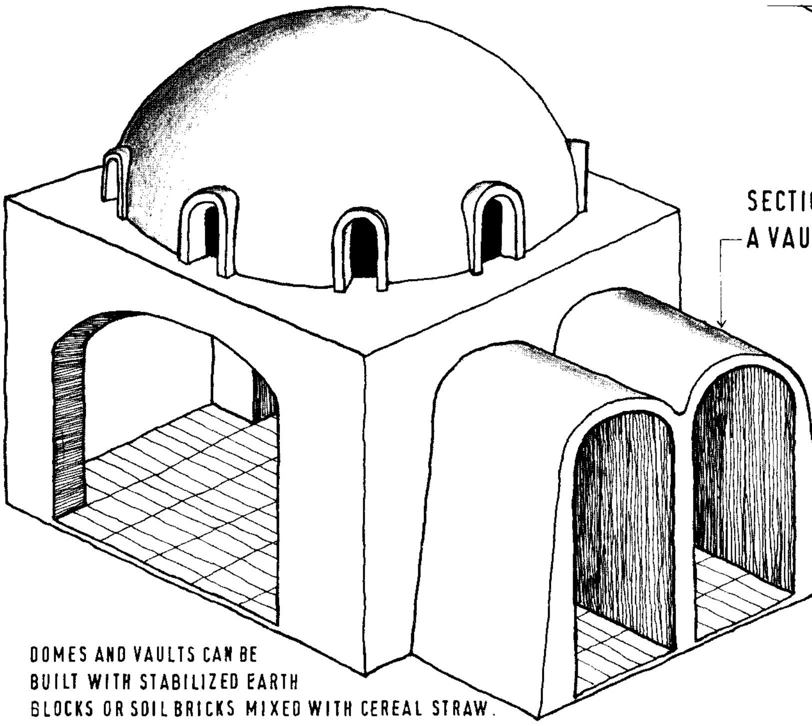
11 - 50 mm THICK CLAY / COW DUNG MIXTURE LAID TO FALL, STABILIZED WITH 5% BITUMEN CUTBACK AND FINISHED WITH ANY LOCALLY AVAILABLE WATERPROOFING VARNISH.

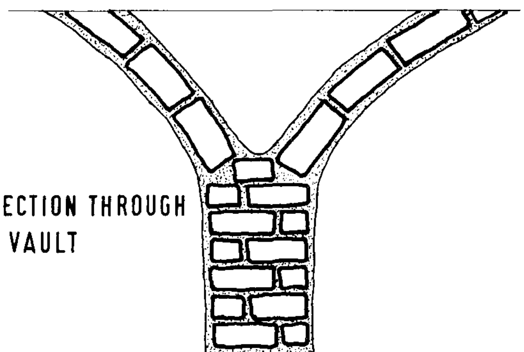
12 - BUSH POLE RAFTERS

13 - TWO LAYERS OF ZANA MATS

14 - LAYER OF TWIGS OR SPLIT BUSH POLES

15, 16 - BUSH POLE POSTS AND BEAMS





DOMES AND VAULTS CAN BE BUILT WITH STABILIZED EARTH BLOCKS OR SOIL BRICKS MIXED WITH CEREAL STRAW.

MUD DOMES AND VAULTS :

SUCH ROOFS HAVE BEEN USED FOR CENTURIES IN AREAS WHERE CONSTRUCTION TIMBER IS SCARCE. OUTSIDE WALLS SHOULD BE VERY THICK - UP TO 750 mm - TO RESIST THE OUTWARD THRUST OF THE VAULT OR DOME. A REINFORCED CONCRETE RING BEAM WILL ADD TO THE STRENGTH OF THE WALL AND WILL MAKE IT POSSIBLE TO REDUCE WALL THICKNESSES. FOR VAULT AND DOME CONSTRUCTION WITHOUT FORMWORK A FAST SETTING MORTAR (E.G. GYPSUM) IS NEEDED. THE DOME AND VAULT, AS WELL AS THE SUPPORTING WALLS MUST BE FINISHED WITH SMOOTH PLASTER AND LIMEWASH.

FIG. 339 : MUD ROOFS

5.4.7 ROOF STRUCTURES AND FINISHES

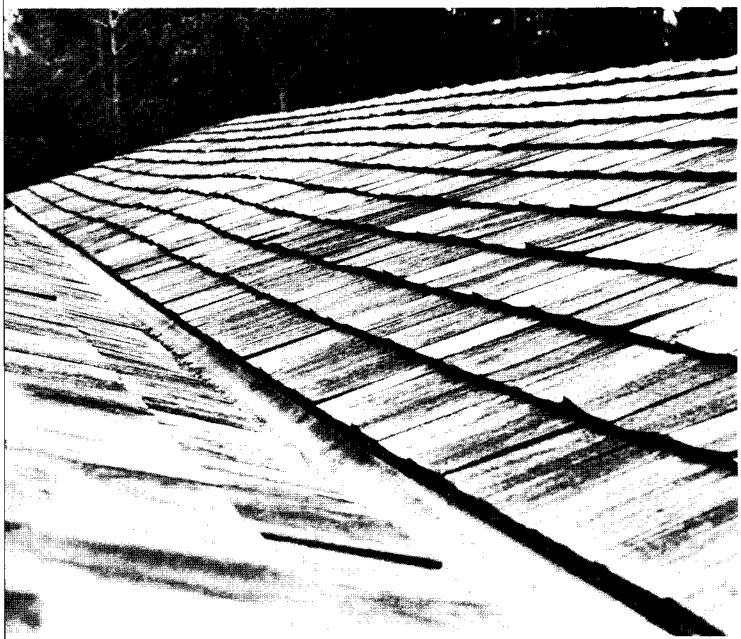
MUD – Slight pitch (from the screed laid to fall, Fig. 339):

This is another traditional roofing material in many tropical developing countries. If the atakpame wall building method is used, it is advisable to support the roof on posts and beams and not on the walls. This will ensure a longer life of the whole structure. This will, however, limit the span to about 3 to 3.50 m. The screed on top of the roof can be stabilized with an addition of 5% bitumen cutback to the sand/soil mix or by using traditional stabilizing agents (the residue meal of the shea nut – *Butyrospermum Parkii*). These, however, have to be regularly renewed. The screed should be laid to fall towards spouts or outlets which collect or drain off the rainwater quickly.

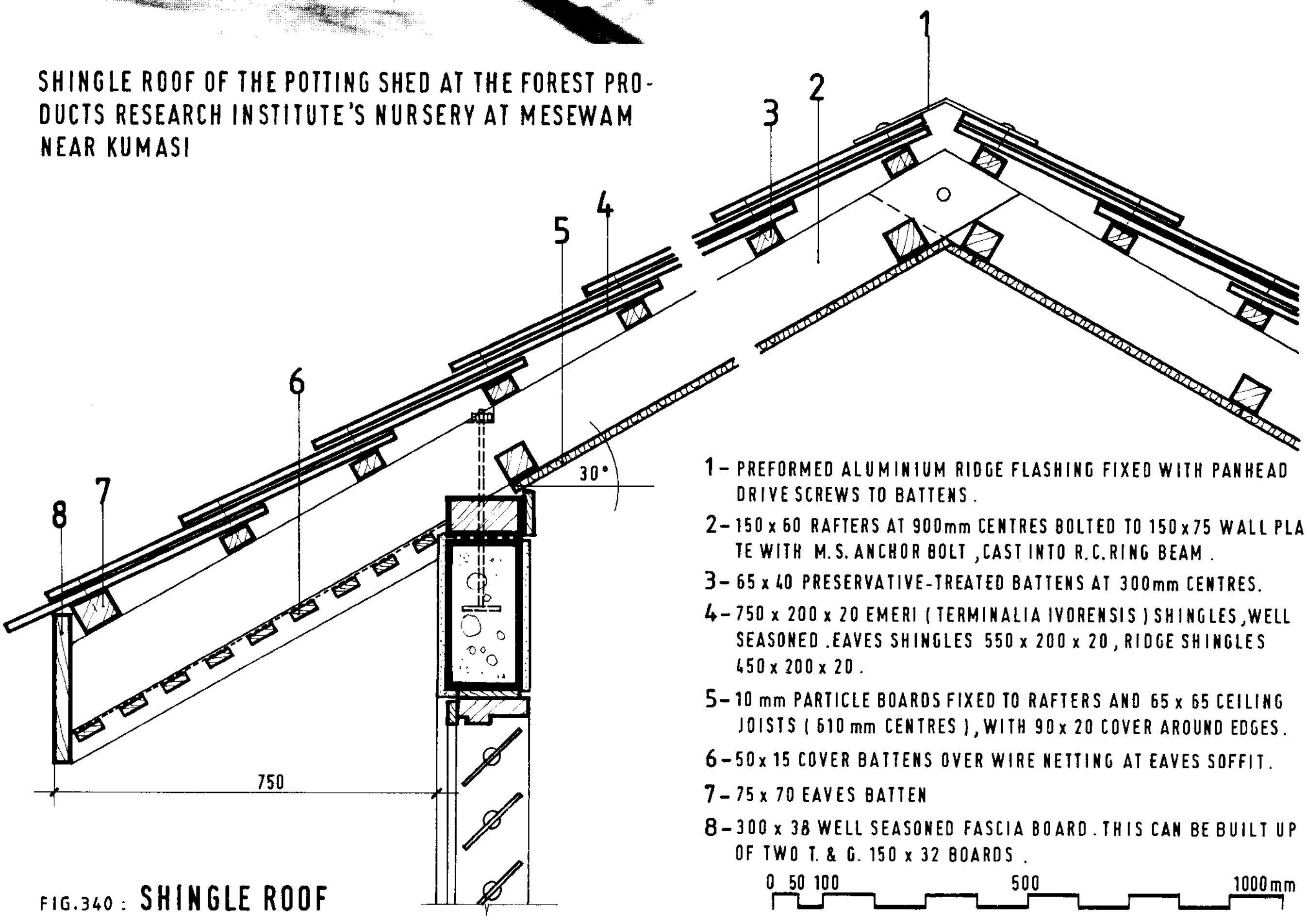
SHINGLES – pitch: Min. 25°, normal 30–35° (Fig. 340):

If properly laid this is a very durable and long lasting roofing material. Whilst in Europe, U.S.A. and Canada wood of the Red Cedar tree is used, a number of tropical hardwoods are suitable for use as shingle wood, e.g. Emeri *(Terminalia Ivorensis)*, Kokrodua *(Pericopsis Excelsa)*, Makore *(Tieghemella Heckelii)*, Kokoti *(Anopyxis Klaineana)*, Adwea *(Dacryodes Klaineana)*, Avodire *(Turreanthus Africanus)*. These timber species are durable and do not need to be treated with preservatives.

Shingles are normally 400 to 600 mm long and 100 to 300 mm wide, their thickness tapers from 20 to 10 mm. They are nailed with galvanized steel nails or wooden pegs to battens so that three shingles are nailed to one batten. Shingles are laid so that 3 to 6 mm spaces are left between them to allow for movement and air circulation. The roof ridge is constructed of alternative layers of butt jointed pairs of shingles covered with a metallic ridge flashing piece.



SHINGLE ROOF OF THE POTTING SHED AT THE FOREST PRODUCTS RESEARCH INSTITUTE'S NURSERY AT MESEWAM NEAR KUMASI

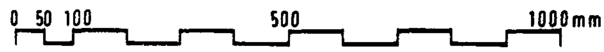


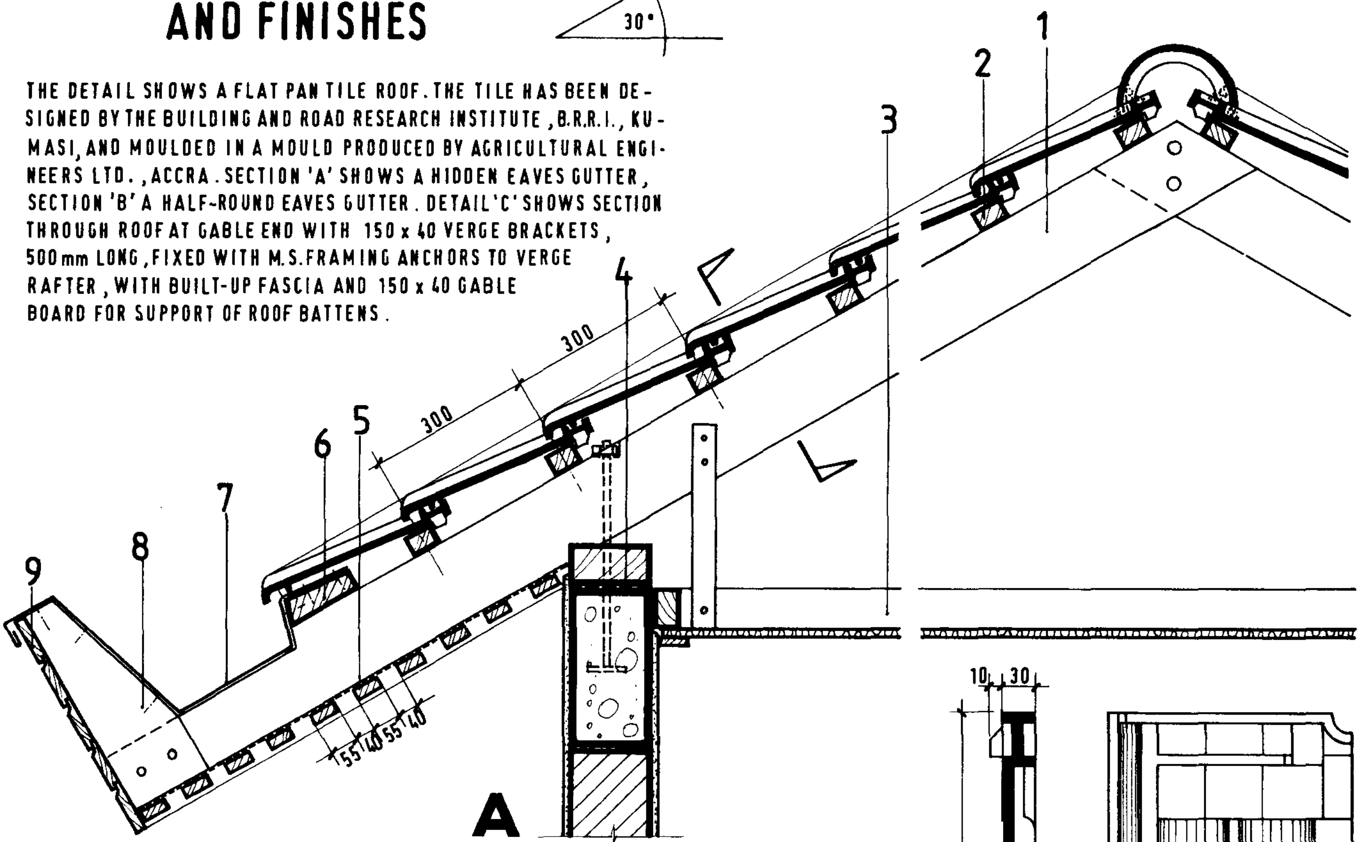
1 – PREFORMED ALUMINIUM RIDGE FLASHING FIXED WITH PANHEAD DRIVE SCREWS TO BATTENS.
2 – 150 x 60 RAFTERS AT 900mm CENTRES BOLTED TO 150 x 75 WALL PLATE WITH M.S. ANCHOR BOLT, CAST INTO R.C. RING BEAM.
3 – 65 x 40 PRESERVATIVE-TREATED BATTENS AT 300mm CENTRES.
4 – 750 x 200 x 20 EMERI (TERMINALIA IVORENSIS) SHINGLES, WELL SEASONED. EAVES SHINGLES 550 x 200 x 20, RIDGE SHINGLES 450 x 200 x 20.
5 – 10 mm PARTICLE BOARDS FIXED TO RAFTERS AND 65 x 65 CEILING JOISTS (610 mm CENTRES), WITH 90 x 20 COVER AROUND EDGES.
6 – 50 x 15 COVER BATTENS OVER WIRE NETTING AT EAVES SOFFIT.
7 – 75 x 70 EAVES BATTEN
8 – 300 x 38 WELL SEASONED FASCIA BOARD. THIS CAN BE BUILT UP OF TWO T. & G. 150 x 32 BOARDS.

FIG.340: **SHINGLE ROOF**

5.4.7 ROOF STRUCTURES AND FINISHES

THE DETAIL SHOWS A FLAT PAN TILE ROOF. THE TILE HAS BEEN DESIGNED BY THE BUILDING AND ROAD RESEARCH INSTITUTE, B.R.R.I., KUMASI, AND MOULDED IN A MOULD PRODUCED BY AGRICULTURAL ENGINEERS LTD., ACCRA. SECTION 'A' SHOWS A HIDDEN EAVES GUTTER, SECTION 'B' A HALF-ROUND EAVES GUTTER. DETAIL 'C' SHOWS SECTION THROUGH ROOF AT GABLE END WITH 150 x 40 VERGE BRACKETS, 500 mm LONG, FIXED WITH M.S. FRAMING ANCHORS TO VERGE RAFTER, WITH BUILT-UP FASCIA AND 150 x 40 GABLE BOARD FOR SUPPORT OF ROOF BATTENS.





1 – 150 x 55 RAFTERS FIXED AT 900mm CENTRES TO 150 x 75 WALL PLATE WITH M.S. ANCHOR BOLT, CAST INTO REINFORCED CONCRETE RING BEAM.

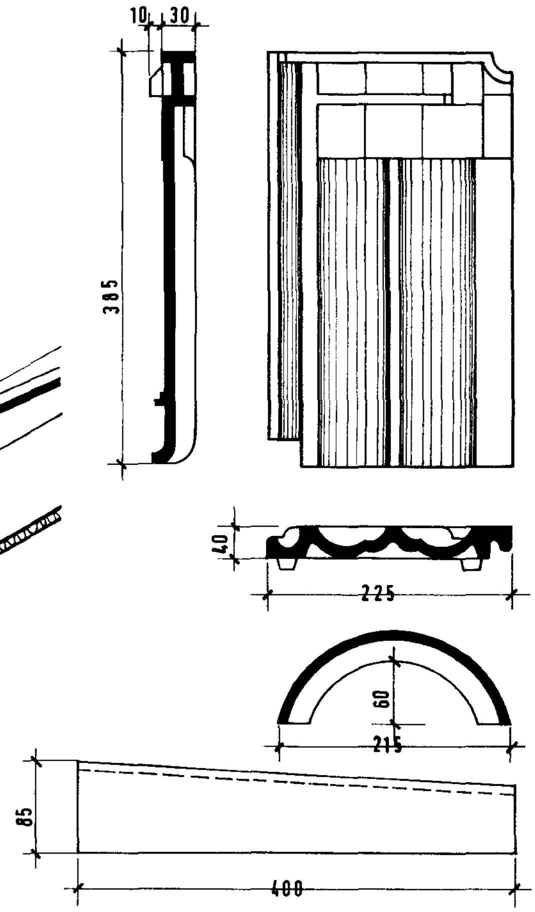
2 – 60 x 40 TIMBER BATTENS AT 300mm CENTRES

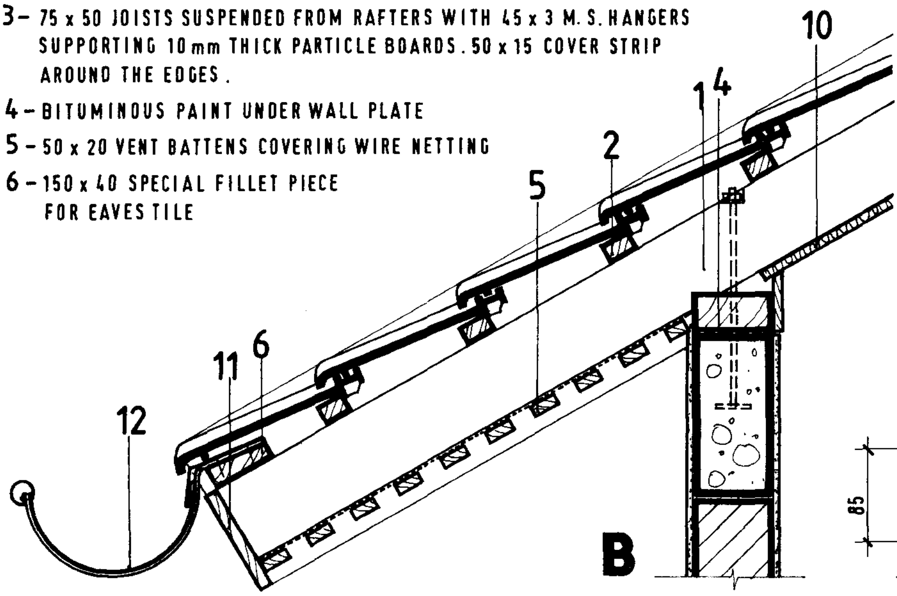
3 – 75 x 50 JOISTS SUSPENDED FROM RAFTERS WITH 45 x 3 M.S. HANGERS SUPPORTING 10mm THICK PARTICLE BOARDS. 50 x 15 COVER STRIP AROUND THE EDGES.

4 – BITUMINOUS PAINT UNDER WALL PLATE

5 – 50 x 20 VENT BATTENS COVERING WIRE NETTING

6 – 150 x 40 SPECIAL FILLET PIECE FOR EAVES TILE





DETAILS OF PAN TILE AND RIDGE CAPPING

7 – EAVES GUTTER FIXED TO FILLET PIECE AND GUTTER BOARD

8 – 400 x 150 x 50 GUTTER FIXING BOARD BOLTED TO THE SIDES OF EACH RAFTER

9 – FASCIA MADE UP AT EAVES OF 5 N°S 90 x 20 HORIZONTAL HARDWOOD STRIPS (3 N°S AT GABLES) WITH REBATED SHIPLAP FIXING.

10 – 10 mm THICK PARTICLE BOARDS FIXED STRAIGHT TO RAFTERS WITH 115 x 20 COVER STRIP OVER WALL PLATE.

11 – 200 x 25 WELL SEASONED HARDWOOD FASCIA BOARD

12 – H.R. EAVES GUTTER FIXED WITH FLASHING TO M.S. GUTTER HANGERS

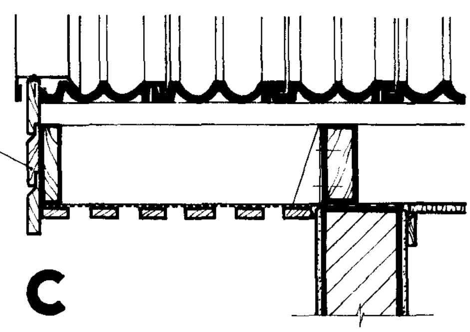


FIG. 341 : **BURNT CLAY TILE ROOF**

BURNT CLAY TILES and CONCRETE TILES – pitch: Min. 30° (Fig. 341 *to* 343):

There are many different types and sizes of tiles from both materials, produced as interlocking flat pan tiles to be supported on timber battens which in turn are fixed to rafters. Concrete tiles are produced from Portland cement and sand which has a high quartizite content. Both roof finishes, although needing a strong substructure, are very durable with a very long life. If laid properly, they need little or no maintenance.

CORRUGATED GALVANIZED STEEL SHEETS – pitch: 20°:

Popularly known as "iron sheets", corrugated galvanized steel sheets were the most commonly used roofing material before the advent of aluminium and before the introduction of an aluminium manufacturing industry in Ghana. They are made from galvanized mild steel sheets in gauges from 16 to 26 with corrugations of 76mm pitch and 127mm pitch (pitch = width from centre to centre of the crown of corrugations). Sheet sizes: lenghts from 1200mm onwards. Widths:

- 8 corrugations, 76mm pitch: 660mm;
- 5 corrugations, 127mm pitch: 711mm;
- 10 corrugations, 76mm pitch: 813mm;
- 6 corrugations, 127mm pitch: 838mm.

The sheets should be fixed with two side slaps in tropical conditions, similar to aluminium sheets, with bolts, self-tapping screws with washers. Plain or corrugated ridge pieces are available.

If the galvanized steel sheets are used in areas which are exposed to sea air or acid vapour they should be covered with a zinc coating or be painted with any oxide paint. If painted at intervals (about every five years), corrugated steel sheets should have a life span of about 60 years.

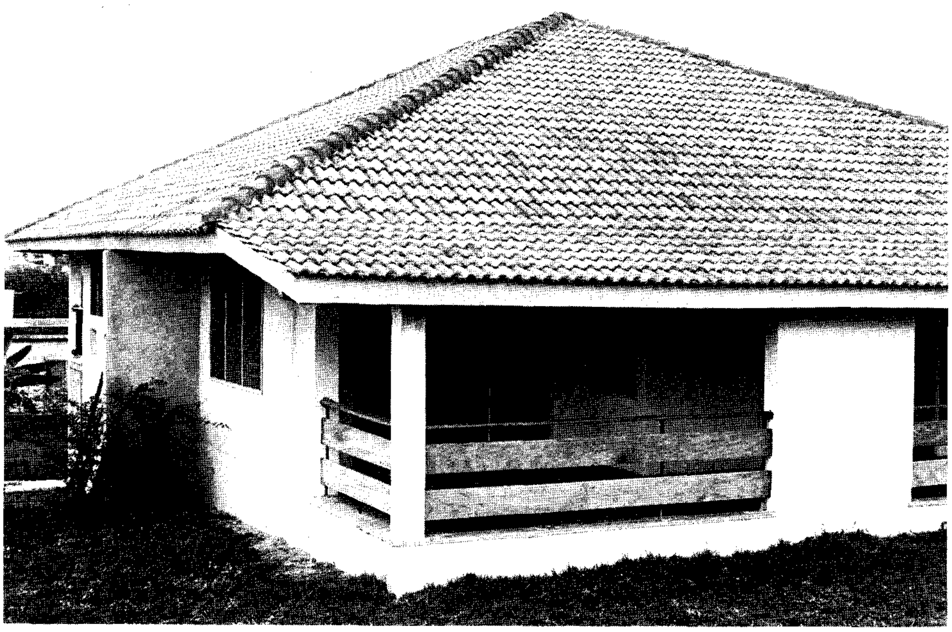


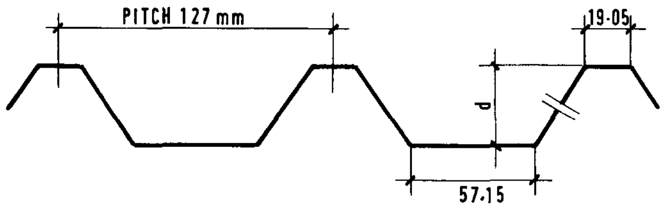
Fig. 342: Concrete tile roof.

Fig. 343: Concrete roofing tile manufactured by J. Monta, Ltd., Kumasi, 1980.

5.4.7 ROOF STRUCTURES AND FINISHES

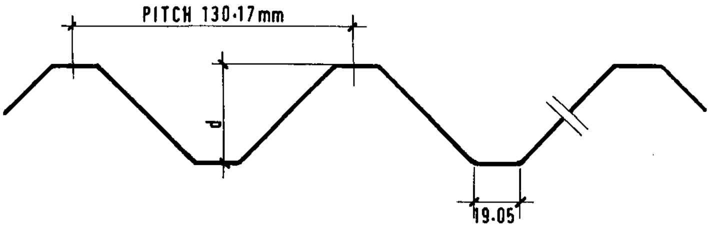
1 CIRCULAR CORRUGATED SHEETS :

PITCH 76 mm , DEPTH d : 19.05 AND 25mm . SHEET SIZE : d = 19·05mm : 3124 x 813 mm ; d = 25 mm : 2820 x 736 mm , FROM 18 SWG TO 26 SWG (RECOMMENDED 20 SWG). PURLIN SPACING FROM 900 TO 1500 mm . EFFECTIVE COVERAGE IN TROPICAL COUNTRIES = 2 CORRUGATIONS .



2 INDUSTRIAL SHEETS :

PITCH 127 mm , DEPTH d : 38·10 mm , WIDTH OF SHEET 635 mm , LENGTH UP TO 6096mm, 20 SWG . PURLIN SPACING FROM 1500 mm TO 2130 mm . NORMAL SIDELAP = 1 CORRUGATION .



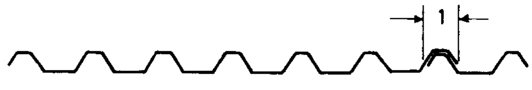
3 DEEP TROUGH SHEETS :

PITCH 130·17mm , DEPTH d : 44·45 mm , WIDTH OF SHEET 650 .87 mm , LENGTH UP TO 9144 mm , FROM 18 SWG TO 22 SWG FOR ROOFING AND 24 SWG FOR VERTICAL CLADDING . PURLIN SPACING ABOVE 2130 mm. NORMAL SIDELAP = 1 CORRUGATION .

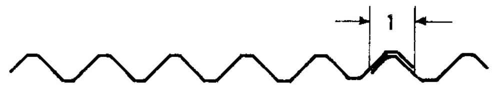
LAP 1 CORRUGATION (FOR VERTICAL CLADDING)

LAP 1½ CORRUGATIONS (FOR ROOFING)

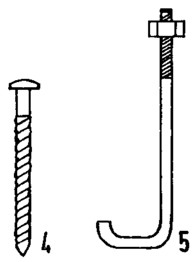
LAP 2 CORRUGATIONS (RECOMMENDED FOR ROOFING IN TROPICAL COUNTRIES)



SHEET WIDTHS OF INDUSTRIAL SHEETS 5, 6 OR 7 CORRUGATIONS WITH 1 CORRUGATION SIDELAP



SHEET WIDTHS OF DEEP TROUGH SHEETS 5 OR 6 CORRUGATIONS WITH 1 CORRUGATION SIDELAP



4 PANHEAD DRIVE SCREWS :

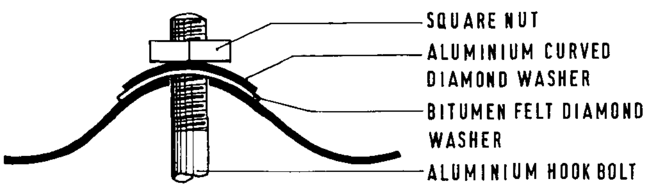
14 WIRE NAIL GAUGE IN LENGTHS OF 50, 56 AND 63 mm, 16 WIRE NAIL GAUGE IN LENGTHS OF 76 AND 90 mm.

5 HOOK BOLT WITH NUT :

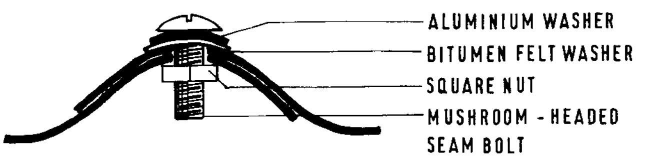
8 mm DIAMETER , LENGTHS FROM 63 TO 200 mm .

THE SURFACE OF ALUMINIUM ROOFING SHEETS IS FINISHED WITH STUCO ANTIGLARE FINISH WHICH GREATLY REDUCES THE SUN GLARE FROM THE METAL WITHOUT REDUCTION IN THE TOTAL REFLECTIVITY. WHERE IT IS DESIRED CHEMICALLY TREATED SHEETS CAN BE PRODUCED WITH GREEN COLOUR , WHICH FURTHER REDUCE THE SUN GLARE .

A LARGE NUMBER OF ALUMINIUM FLASHINGS ARE AVAILABLE : PLAIN RIDGE , ANGLE RIDGE , ROLL - TOP RIDGING , SPLIT ROLL - TOP RIDGING, RIDGE FINALS AND PLAIN ANGLE FLASHING. A RIDGE AND EAVES FILLER OF BITUMINOUS RUBBER , EXPANDED P.V.C. OR EXPANDED POLYSTYRENE , 610 mm LONG , IS ALSO AVAILABLE .



6 HOOK BOLT FASTENER : FOR FASTENING SHEETS TO PURLINS .



7 MUSHROOM - HEADED SEAM BOLT :

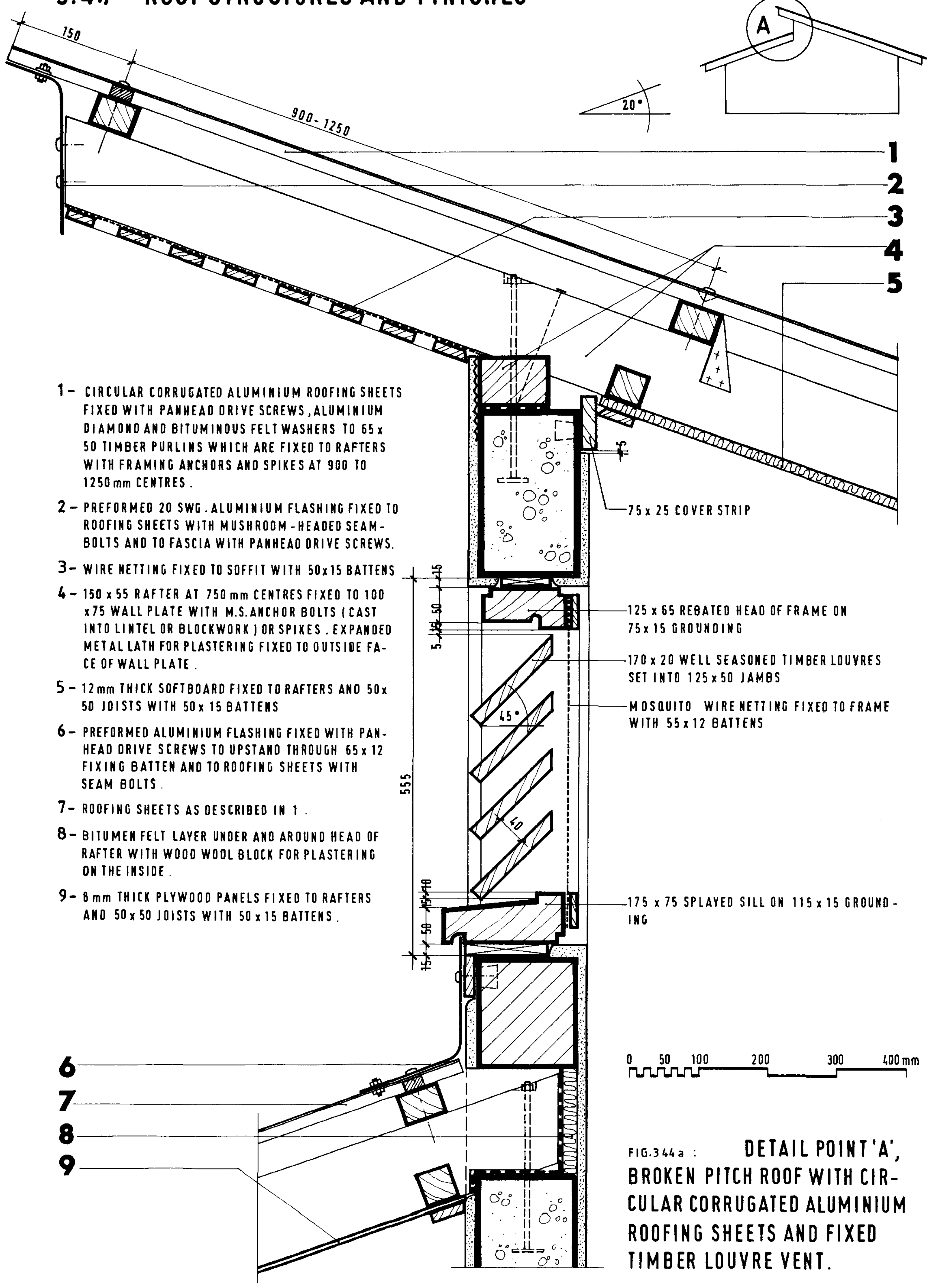
FOR FASTENING SHEET TO SHEET IN ONE CORRUGATION SIDELAP, OR FLASHING TO SHEET . 6·5 mm DIAMETER , 12·5 , 19 AND 25·5 mm IN LENGTHS .

CORRUGATED ALUMINIUM SHEETS – pitch: 15° to 20° (or self-supporting arches):

If well insulated and ventilated, this is an economic, light and durable roofing material in countries which have aluminium sheet pressing factories. It does not require a heavy substructure. Aluminium corrugated sheets are produced in an increasingly wide range of profiles and gauges which are used in residential, public, institutional, industrial and agricultural buildings with different accessories (Fig. 344). Corrugated sheets should be fixed with a side lap of not less than two full corrugations, troughed sheets should be fixed with one single side lap in tropical conditions. Figs. 345 and 346 show an "umbrella"-type, self-supporting aluminium arch roof using deep trough industrial sheets.

FIG. 344 : ALUMINIUM ROOFING AND ACCESSORIES
(FROM GHANA ALUMINIUM PRODUCTS LIMITED)

5.4.7 ROOF STRUCTURES AND FINISHES



1 – CIRCULAR CORRUGATED ALUMINIUM ROOFING SHEETS FIXED WITH PANHEAD DRIVE SCREWS, ALUMINIUM DIAMOND AND BITUMINOUS FELT WASHERS TO 65 x 50 TIMBER PURLINS WHICH ARE FIXED TO RAFTERS WITH FRAMING ANCHORS AND SPIKES AT 900 TO 1250 mm CENTRES.

2 – PREFORMED 20 SWG. ALUMINIUM FLASHING FIXED TO ROOFING SHEETS WITH MUSHROOM-HEADED SEAM-BOLTS AND TO FASCIA WITH PANHEAD DRIVE SCREWS.

3 – WIRE NETTING FIXED TO SOFFIT WITH 50 x 15 BATTENS

4 – 150 x 55 RAFTER AT 750 mm CENTRES FIXED TO 100 x 75 WALL PLATE WITH M.S. ANCHOR BOLTS (CAST INTO LINTEL OR BLOCKWORK) OR SPIKES. EXPANDED METAL LATH FOR PLASTERING FIXED TO OUTSIDE FACE OF WALL PLATE.

5 – 12 mm THICK SOFTBOARD FIXED TO RAFTERS AND 50 x 50 JOISTS WITH 50 x 15 BATTENS

6 – PREFORMED ALUMINIUM FLASHING FIXED WITH PANHEAD DRIVE SCREWS TO UPSTAND THROUGH 65 x 12 FIXING BATTEN AND TO ROOFING SHEETS WITH SEAM BOLTS.

7 – ROOFING SHEETS AS DESCRIBED IN 1.

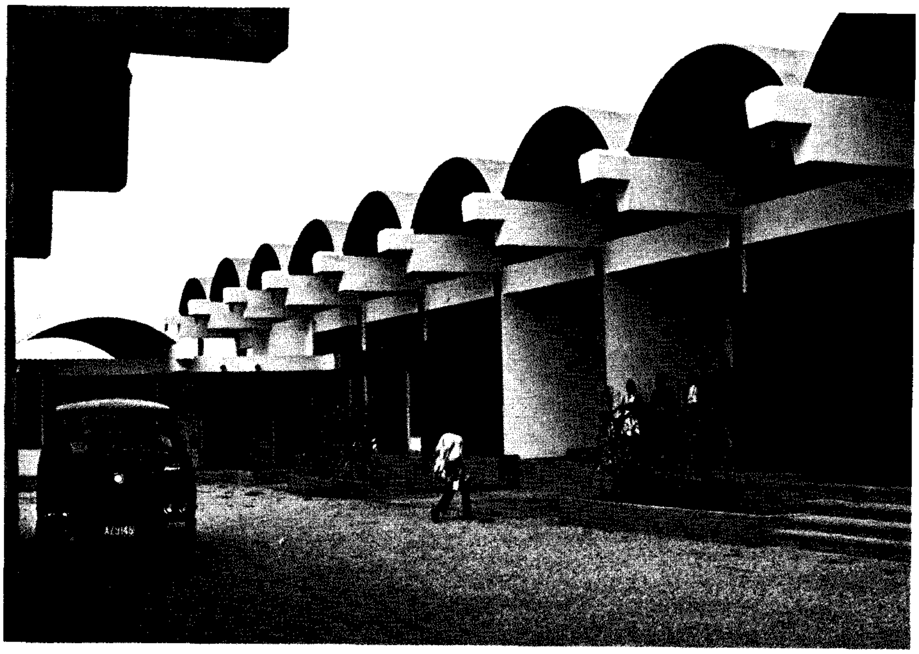
8 – BITUMEN FELT LAYER UNDER AND AROUND HEAD OF RAFTER WITH WOOD WOOL BLOCK FOR PLASTERING ON THE INSIDE.

9 – 8 mm THICK PLYWOOD PANELS FIXED TO RAFTERS AND 50 x 50 JOISTS WITH 50 x 15 BATTENS.

FIG. 344 a : **DETAIL POINT 'A', BROKEN PITCH ROOF WITH CIRCULAR CORRUGATED ALUMINIUM ROOFING SHEETS AND FIXED TIMBER LOUVRE VENT.**

CORRUGATED ASBESTOS – CEMENT SHEETS – pitch: 10° to 25°:

Asbestos – cement is composed of fibreized asbestos and Portland cement. The incombustible mineral is quarried from the rock, crushed, fibreized and graded in shaking screens. Sheets used for roofing are built up in rolling mills from layers of cement and uniformly distributed asbestos fibres. The product increases in strength with age, but tends to grow rather brittle after longer exposure under tropical conditions. The sheets can be finished in different colours or with embossed finishes in a factory applied process. Roofing sheets sizes are from 1220 to 2440mm lengths with a width of 975mm and 14 corrugations, or from 1220 to 3050mm lengths with a width of 1000mm and 8 corrugations. A great number of accessories are produced: Ridge pieces, barge boards, filler pieces, flashings etc. Corrugated asbestos – cement sheets are fixed with drive screws and fibre plugs to concrete purlins; with "American nails" (special aluminium alloy nails with hollow dome heads) and bituminous washers to timber purlins (some corrosion takes place in the initial stages, but passes with the maturing of the asbestos-cement and appears to have little effect on the life of the nail); with aluminium or galvanized hook – bolts to steel purlins. Asbestos – cement sheets should be holed by drilling, not punching, at the crown of corrugations. Various types of washers are used to keep the holes watertight. Maximum overhang of the sheets is 300mm (Fig. 347).



For Fig. 346: Yard of the Mamprobi Post Office in Accra, 1975.

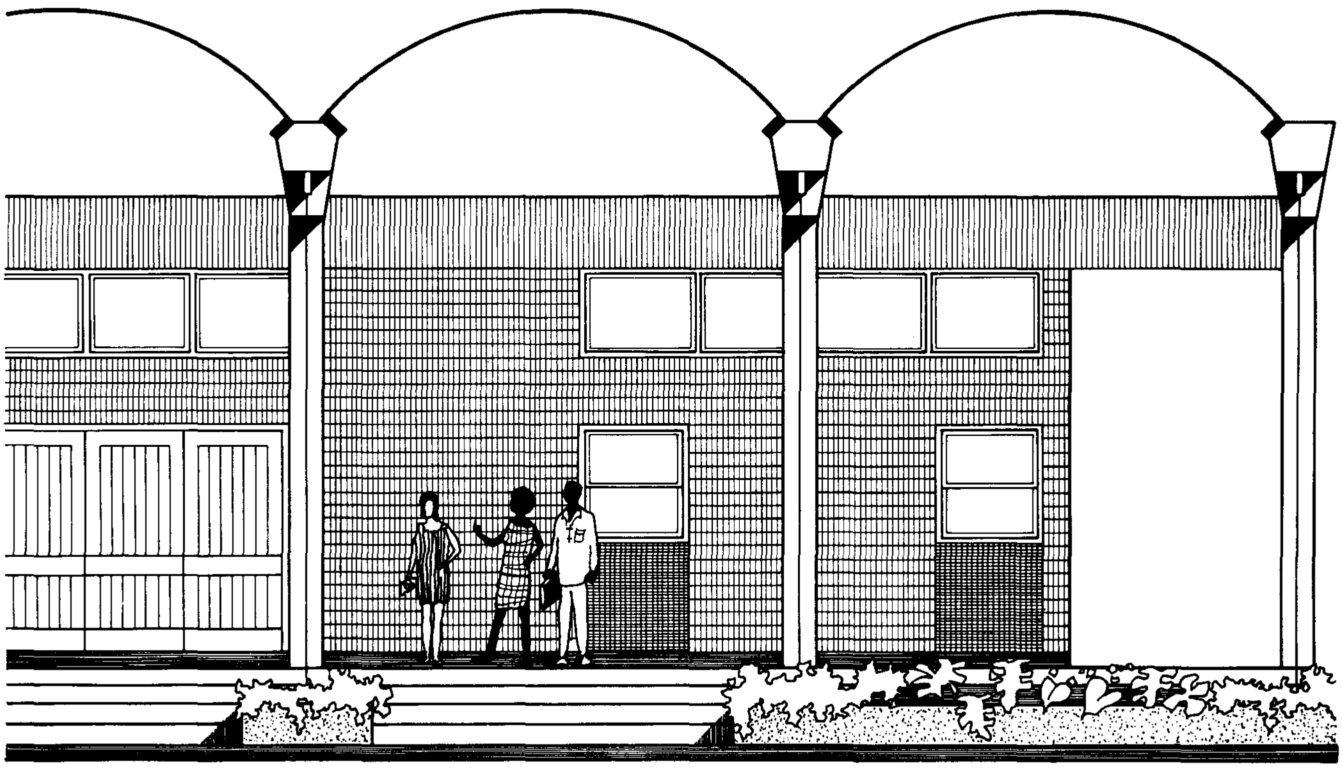
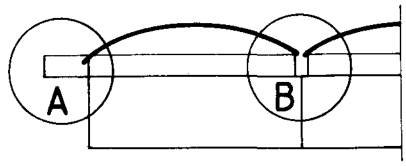
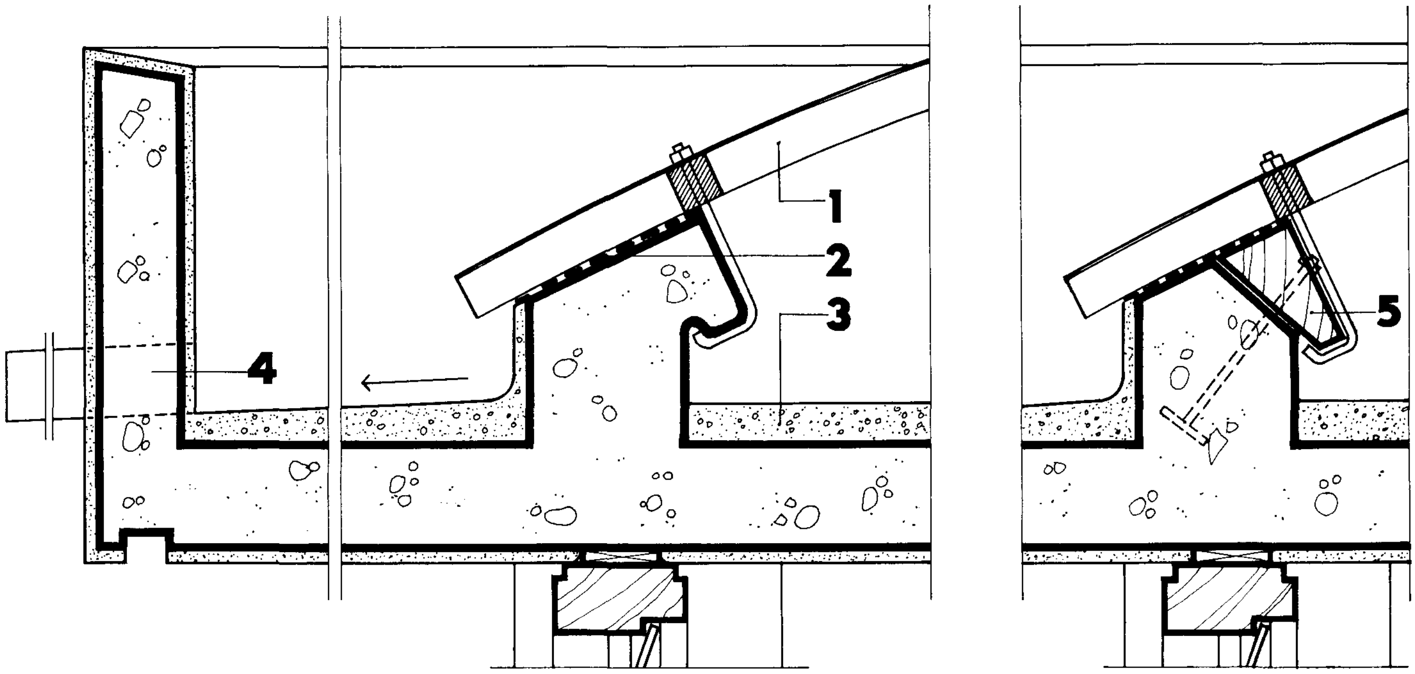


FIG. 345 : **UMBRELLA ROOF OF THE MAMPROBI POST OFFICE IN ACCRA** - ARCHITECT : HANNAH SCHRECKENBACH, 1972. THE UMBRELLA ROOF IS CONSTRUCTED WITH DEEP TROUGH, SELF - SUPPORTING ALUMINIUM ARCHES WHICH ARE FIXED TO REINFORCED CONCRETE GUTTER BEAMS. THESE BEAMS CARRY AT THE SAME TIME THE CONCRETE ROOF SLAB OF THE POST OFFICE.

5.4.7 ROOF STRUCTURES AND FINISHES





A EAVES DETAILS

1 – DEEP TROUGH INDUSTRIAL ALUMINIUM ARCH PANELS FIXED TO REINFORCED CONCRETE EAVES BEAM AND GUTTER BEAM WITH 8 mm DIAMETER ALUMINIUM ALLOY HOOK BOLTS AT THE RATE OF ONE IN THE CREST OF EACH CORRUGATION WITH ALUMINIUM AND BITUMINOUS FELT WASHERS AND BITUMINOUS RUBBER EAVES FILLERS.

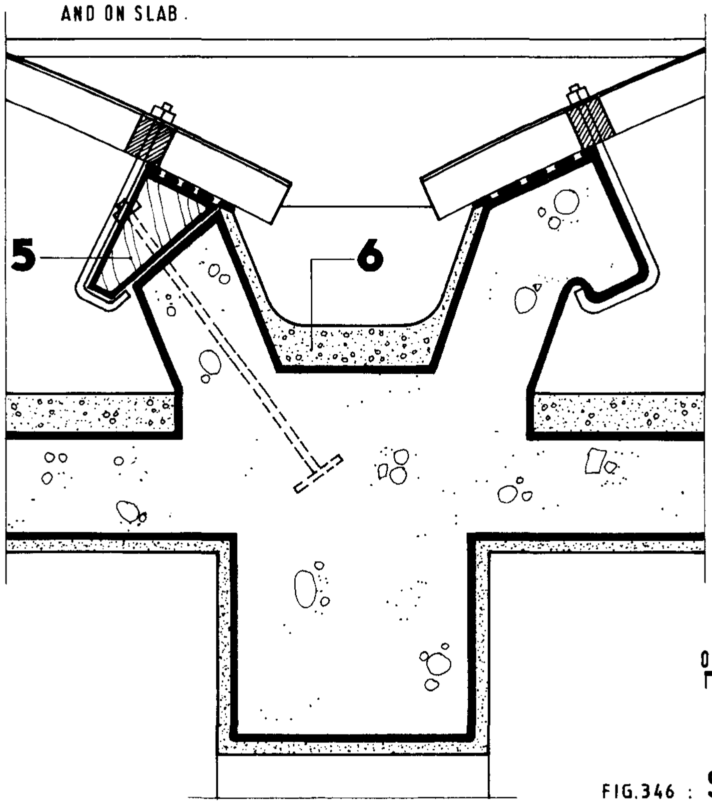
2 – BITUMINOUS PAINT

3 – MAX. 50 mm CEMENT-SAND SCREED LAID TO FALL IN GUTTER AND ON SLAB.

4 – 65 mm DIAMETER P.V.C. SPOUT, 250 mm LONG, CAST INTO REINFORCED CONCRETE FASCIA.

5 – 125 x 75 mm TIMBER PURLIN AS ALTERNATIVE FIXING METHOD. THE PURLIN IS FIXED TO EAVES AND GUTTER BEAMS WITH GALVANIZED STEEL ANCHOR BOLTS.

6 – MAX. 50 mm CEMENT-SAND SCREED LAID TO FALL IN VALLEY OF GUTTER BEAM, FINISHED, AS SCREED IN EAVES GUTTER AND ON SLAB WITH 2 COATS OF GREY "FLINTKOTE".



SELF-SUPPORTING ARCHES :

SHEETS FOR ARCHES CAN BE CIRCULAR CORRUGATED, 16 AND 20 SWG. FOR A MAXIMUM SPAN OF 7.00 m (FOR DEEP TROUGH SHEET, FOR CIRCULAR CORRUGATED SHEETS 5.50 m). THE SPAN-TO-RISE RATIO OF AN ARCH SHOULD BE ABOUT 4 (UP TO $4^1/_2$ FOR DEEP TROUGH SHEETS) TO GIVE THE BEST LOADING CHARACTERISTICS. GUTTER BEAMS CAN HAVE DIFFERENT SHAPES :

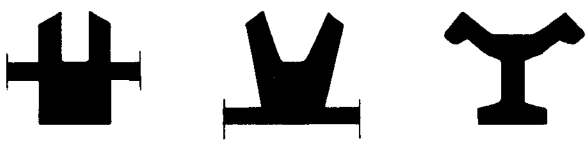
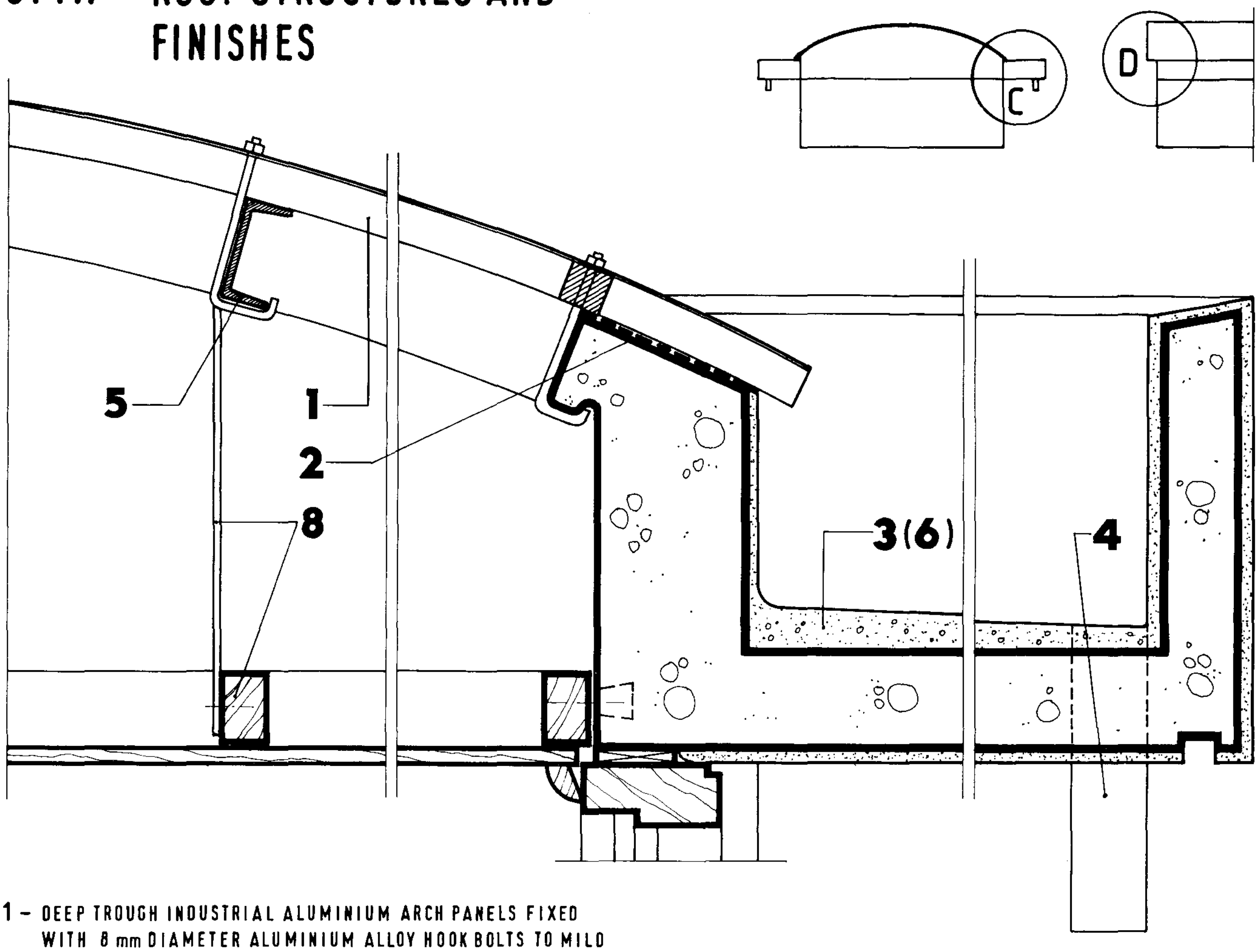


FIG. 346 : SELF-SUPPORTING ALUMINIUM ARCHES (OPEN, WITH REINFORCED CONCRETE ROOF SLAB)

B GUTTER BEAM DETAIL

5.4.7 ROOF STRUCTURES AND FINISHES



1 – DEEP TROUGH INDUSTRIAL ALUMINIUM ARCH PANELS FIXED WITH 8 mm DIAMETER ALUMINIUM ALLOY HOOK BOLTS TO MILD STEEL CHANNEL PURLINS WITH ALUMINIUM AND BITUMINOUS FELT WASHERS.

2 – BITUMINOUS PAINT

3 – MAX. 50 mm THICK CEMENT-SAND SCREED LAID TO FALL, FINISHED TWO COATS GREY "FLINTKOTE" (SIMILAR TO 6 IN DETAIL 3).

4 – 75 mm DIAMETER P.V.C. SPOUT, 300 mm LONG, CAST INTO GUTTER TO DISCHARGE STRAIGHT DOWN.

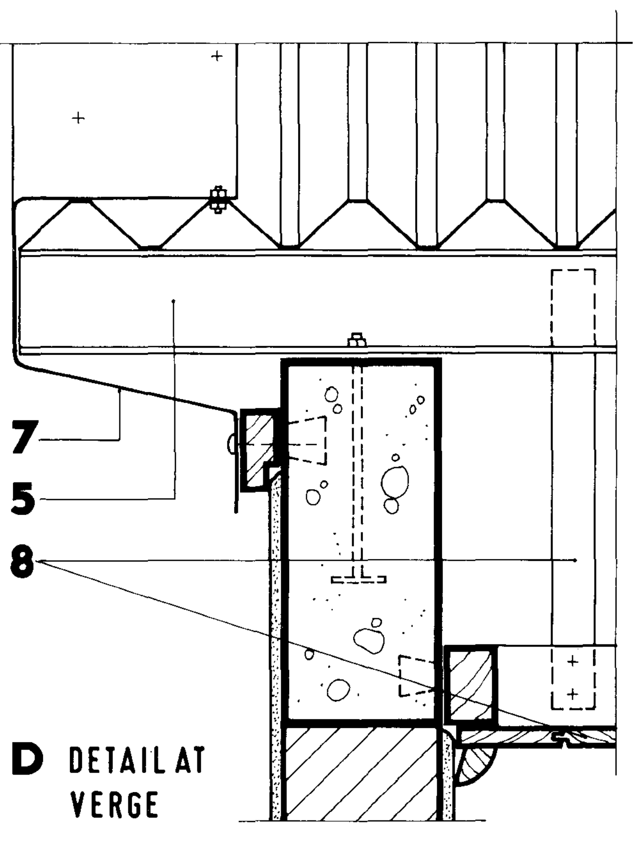
5 – 100 x 45 mm MILD STEEL CHANNEL PURLIN BOLTED TO REINFORCED CONCRETE BEAM WITH ANCHOR BOLTS. PURLIN SPACING: EVERY 2·50 m.

7 – PREFORMED ALUMINIUM BARGE BOARD FIXED TO ROOFING SHEETS WITH SEAM BOLTS AT STAGGERED CENTRES AND WITH PANHEAD DRIVE SCREWS TO 75 x 40 mm GABLE BOARD.

8 – 40 x 5 mm MILD STEEL HANGERS WELDED TO PURLINS TO SUPPORT SUSPENDED CEILING OF 75 x 55 CEILING JOISTS AND 100 x 20 T. AND G. HARDWOOD CEILING STRIPS, WITH 35 x 35 COVER BATTEN ALONG THE WALL.

C EAVES DETAIL

ALUMINIUM ARCHES CAN BE FIXED SELF-SUPPORTING (DETAIL 3) TO REINFORCED CONCRETE GUTTER BEAMS AS "UMBRELLA" ROOF WITH OPEN ARCHES AND A ROOF SLAB BENEATH OR TO PURLINS AND ON ALL SIDES ENCLOSED, WITH A SUSPENDED CEILING AS SHOWN IN THIS DETAIL. SCALE SIMILAR TO DETAIL 3.



D DETAIL AT VERGE

DEEP TROUGH INDUSTRIAL ALUMINIUM ARCH PANELS FIXED TO PURLINS (CLOSED, WITH SUSPENDED CEILING)

FIG. 346 a

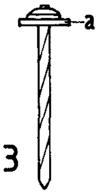
5.4.7 ROOF STRUCTURES AND FINISHES

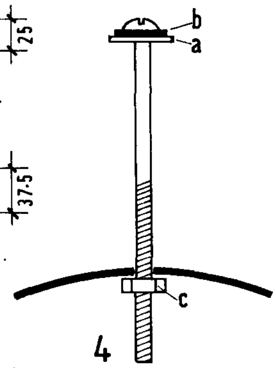
1 - 14 CORRUGATIONS : SHEET LENGTHS FROM 1·22 TO 2·44 m, WIDTH 975 mm, PURLIN SPACING 1150 mm. SIDELAP : 2 CORRUGATIONS.

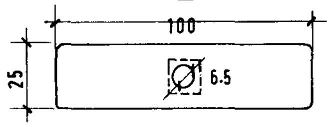
2 - 8 CORRUGATIONS : SHEET LENGTHS FROM 1·22 TO 3·05 m, WIDTH 1000 mm, PURLIN SPACING 1150 mm. SIDELAP : 1 CORRUGATION. 200 mm OVERLAP FOR 1 AND 2 TYPES OF SHEET. LAPS TO BE SEALED WITH MASTIC EXTRUSION.

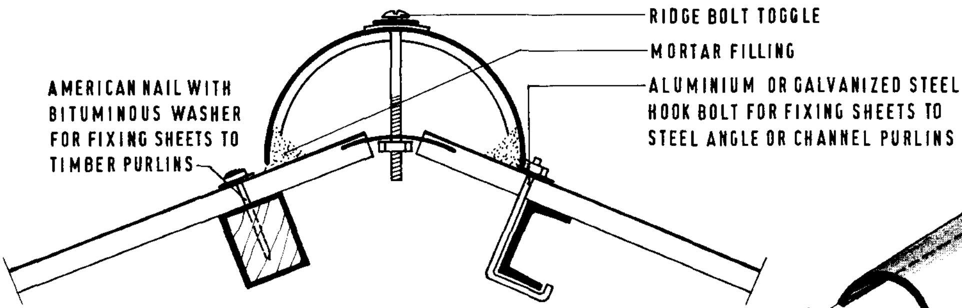
3 - AMERICAN NAIL : TWISTED ALUMINIUM ALLOY NAIL WITH HOLLOW DOME HEAD AND BITUMINOUS WASHER a.

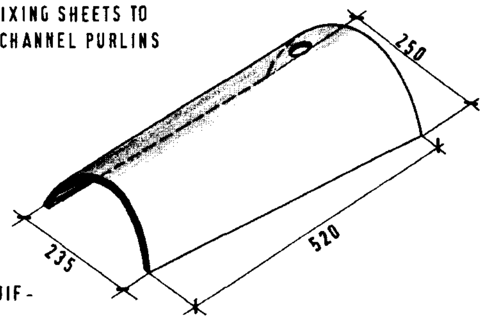
4 - RIDGE BOLT TOGGLE : FOR FIXING RIDGES TO ROOFING SHEETS AT RIDGE, WITH GALVANIZED WASHER b AND BITUMINOUS WASHER a AND SQUARE NUT c.





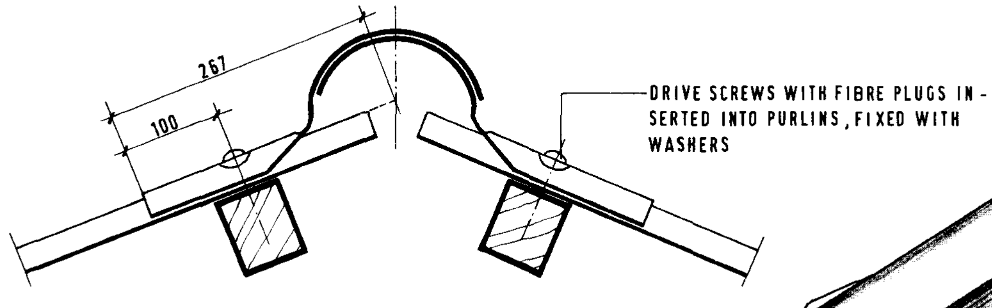


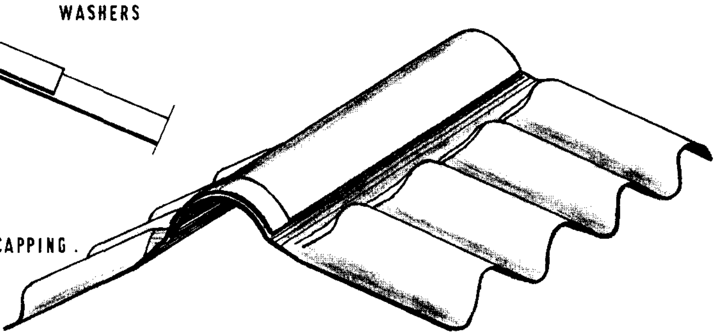




5 - RIDGES : HALF-ROUND RIDGE

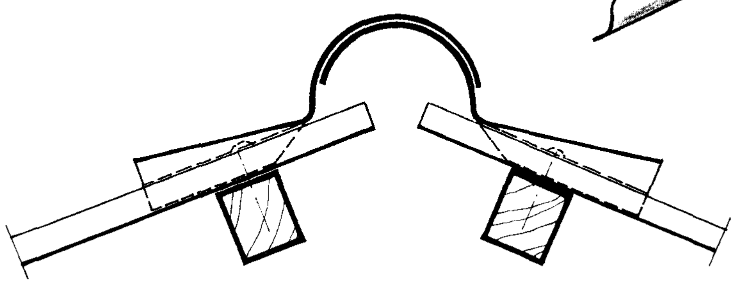
THE ROOF PITCH FOR THIS RIDGE TYPE SHOULD BE MIN. 20°. THE DETAIL SHOWS TWO DIFFERENT PURLIN FIXING METHODS.

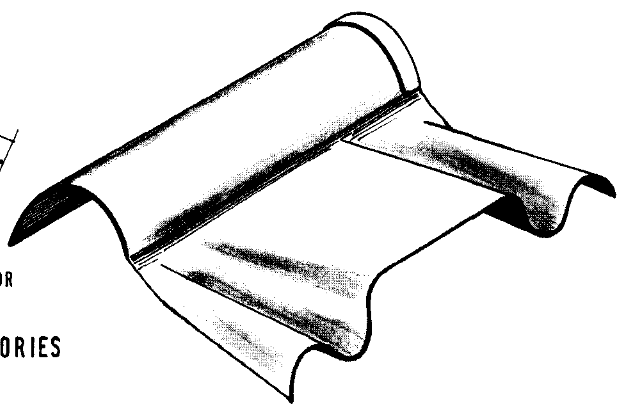




6 - TWO-PIECE RIDGE

THIS IS A CLOSE-FITTING TYPE OF ASBESTOS-CEMENT RIDGE CAPPING.



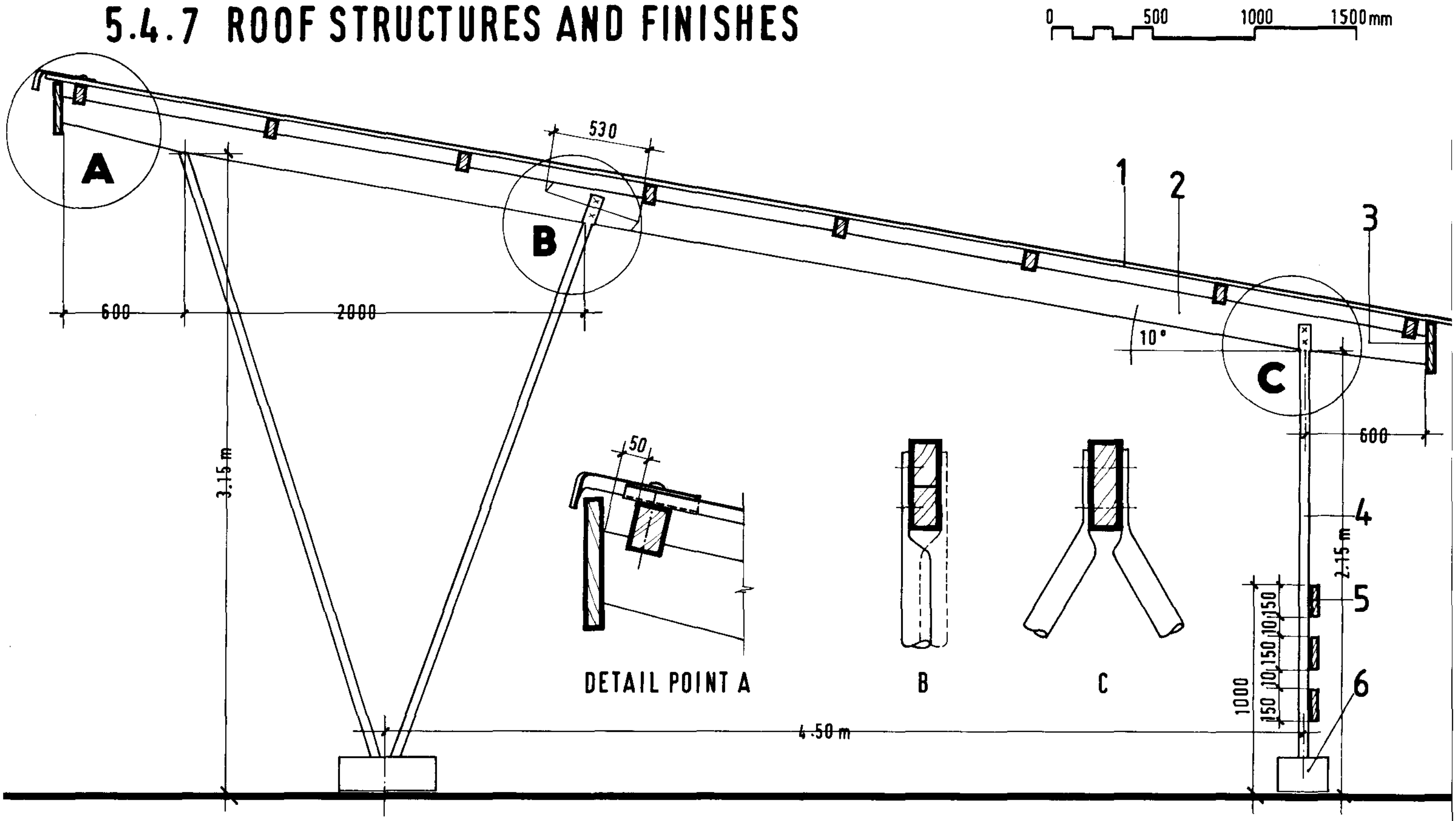


7 - VENTILATING TYPE OF RIDGE CAPPING IN TWO-PIECE FORM

DIFFERENT FLASHING PIECES (GABLE ANGLES AND PITCH COVERS) FROM FLAT OR CORRUGATED ASBESTOS CEMENT, AND EAVES FILLERS ARE AVAILABLE.

FIG. 347 : CORRUGATED ASBESTOS-CEMENT SHEETS AND ACCESSORIES

5.4.7 ROOF STRUCTURES AND FINISHES



SECTION THROUGH THE CAR PORT

1- CORRUGATED ASBESTOS - CEMENT SHEETS (14 CORRUGATIONS) FIXED WITH AMERICAN NAILS AND BITUMINOUS WASHERS TO 100 x 65 PURLINS WHICH ARE NOTCHED INTO THE RAFTERS.

2- 175 x 65 SPLICED RAFTERS FIXED AS SHOWN IN DETAIL POINTS 'B' AND 'C' TO TUBULAR STEEL SUPPORTS.

3- 230 x 40 WELL SEASONED FASCIA BOARD

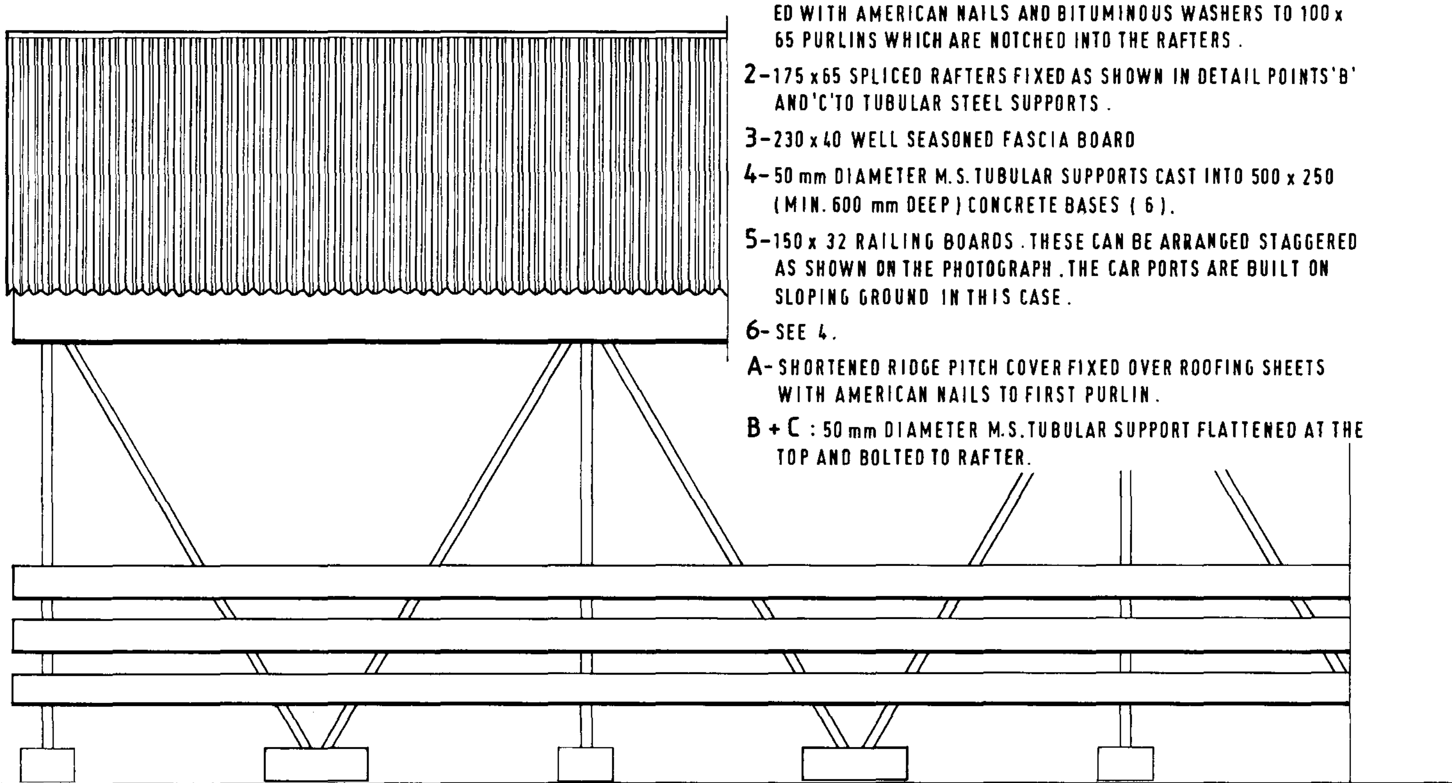
4- 50 mm DIAMETER M.S. TUBULAR SUPPORTS CAST INTO 500 x 250 (MIN. 600 mm DEEP) CONCRETE BASES (6).

5- 150 x 32 RAILING BOARDS. THESE CAN BE ARRANGED STAGGERED AS SHOWN ON THE PHOTOGRAPH. THE CAR PORTS ARE BUILT ON SLOPING GROUND IN THIS CASE.

6- SEE 4.

A- SHORTENED RIDGE PITCH COVER FIXED OVER ROOFING SHEETS WITH AMERICAN NAILS TO FIRST PURLIN.

B + C : 50 mm DIAMETER M.S. TUBULAR SUPPORT FLATTENED AT THE TOP AND BOLTED TO RAFTER.

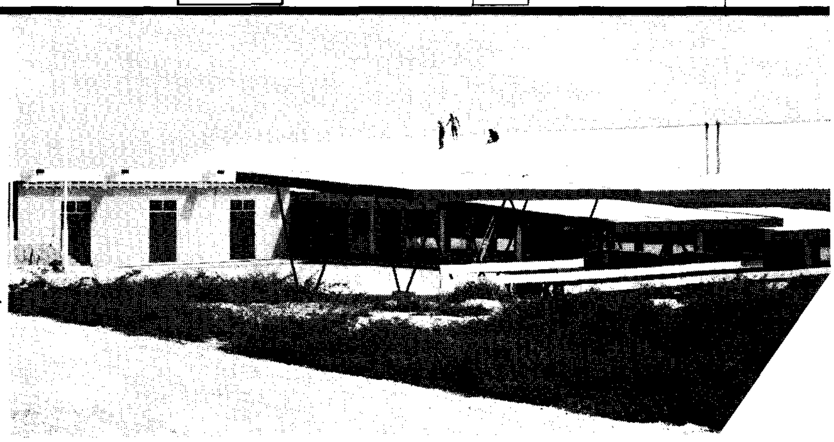


PART OF BACK ELEVATION OF CAR PORT

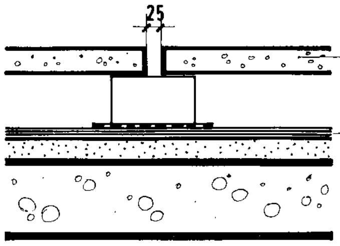
THE PHOTOGRAPH SHOWS CAR PORTS AT THE NAUTICAL COLLEGE ENGINEERING WORKSHOP (NUNGUA) IN THE FOREGROUND. THEY ARE OF DIFFERENT HEIGHT AND BUILT ON SLOPING GROUND.

ARCHITECT : HANNAH SCHRECKENBACH.

FIG. 347 a : CORRUGATED ASBESTOS - CEMENT ROOF

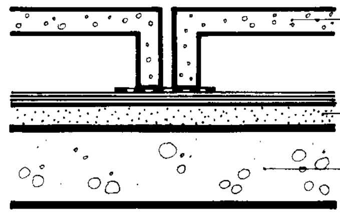


5.4.7 ROOF STRUCTURES AND FINISHES



400 x 400 x 50 PRECAST CONCRETE SOLAR SLABS LAID ON 150 x 150 x 100 CONCRETE STOOLS WITH 180 x 180 LOOSE FELT LAID UNDER STOOLS.

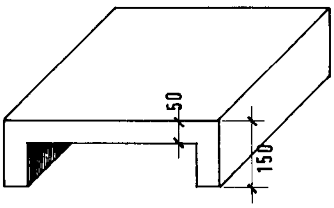
3 LAYERS OF HIGH TENSILE BITUMINOUS ROOFING FELT BONDED WITH BITUMINOUS COMPOUND.



450 x 450 SOLAR SLAB AS SHOWN BELOW SET ON LOOSE FELT

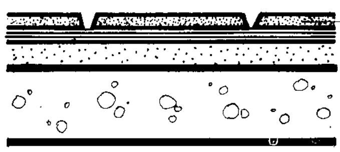
MIN. 40mm THICK SAND-CEMENT SCREED

REINFORCED CONCRETE SLAB



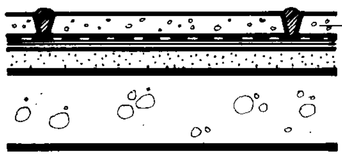
HIGH TENSILE BITUMINOUS ROOFING FELT = 18 kg / 10 m. INSTEAD OF 3 LAYERS HIGH TENSILE FELT ONE LAYER OF 18 kg / 10 m AND ONE LAYER OF 32 kg PER ROLL CAN BE USED.

1 - SOLAR SLABS : PITCH 1 IN 60



300 x 300 x 25 ASBESTOS-CEMENT THERMOTILES LAID ON 3 LAYERS OF HIGH TENSILE BITUMINOUS ROOFING FELT, OR AS DESCRIBED ABOVE, OVER MIN. 40 mm SAND-CEMENT SCREED.

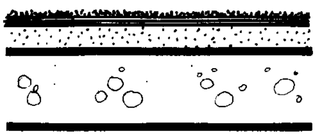
2 - THERMOTILES : PITCH 1 IN 60



450 x 450 x 40 PRECAST CONCRETE OR TERRAZZO SLABS ON ONE LAYER "POSOLEN" AND TWO LAYERS OF HIGH TENSILE BITUMINOUS ROOFING FELT.

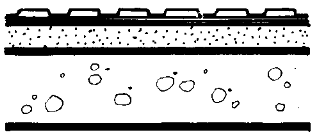
POSOLEN : WATERPROOF MEMBRANE, ELASTIC, RESISTANT TO CHEMICALS, LIQUIDS, SALT, WATER, ORGANIC MATTER, RUST.

3 - PROMENADE ROOF : PITCH 1 IN 60



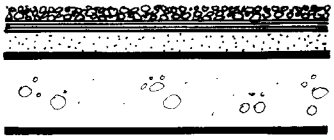
4 - MINERAL-SURFACED ROOFING FELT : 1 IN 10

TOP LAYER OF MINERAL-SURFACED ROOFING FELT ON TWO LAYERS OF HIGH TENSILE ROOFING FELT



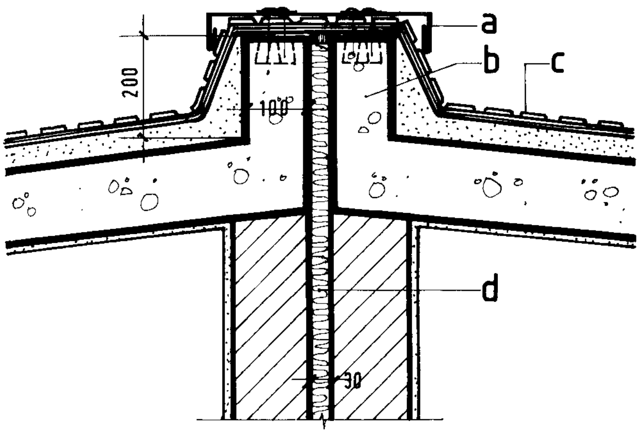
5 - METAL-FACED ROOFING FELT : 1 IN 10

TOP LAYER OF METAL-FACED ROOFING FELT ON TWO LAYERS OF HIGH TENSILE ROOFING FELT.



25 mm THICK LAYER OF LIGHT REFLECTIVE CHIPPINGS ON THREE LAYERS OF HIGH TENSILE ROOFING FELT BONDED WITH BITUMEN COMPOUND OVER MIN. 40 mm SAND-CEMENT SCREED.

6 - LIGHT REFLECTIVE CHIPPINGS : PITCH 1 IN 30



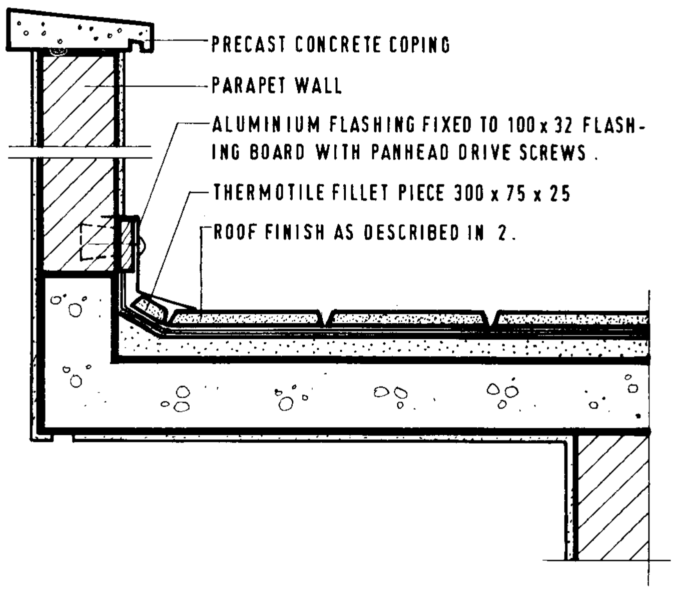
a - ALUMINIUM FLASHING PIECE FIXED WITH PANHEAD DRIVE SCREWS AND FELT WASHERS TO STAGGERED TIMBER PLUGS CAST INTO CONCRETE UPSTAND.

b - MIN. 100 mm WIDE AND 150 mm HIGH CONCRETE UPSTAND.

c - METAL FACED ROOFING FELT ON TWO LAYERS OF HIGH TENSILE BITUMINOUS ROOFING FELT.

d - 30 mm EXPANSION JOINT FILLED WITH SUITABLE EXPANSION JOINT MATERIAL.

7 - EXPANSION JOINT DETAIL



8 - CANTILEVERED CONCRETE ROOF WITH THERMOTILE FINISH AND PARAPET WALL

FIG. 348 : **BUILT-UP FLAT CONCRETE ROOFS**

CONCRETE – pitch 1 in 10 to 1 in 60:

Concrete roofs are not particularly suitable in tropical conditions unless they have a suspended ceiling with a ventilated space below the concrete slab. A built-up-concrete roof requires first class workmanship to make sure it is impermeable. Concrete roofs should not be completely flat. They should be laid to fall to:

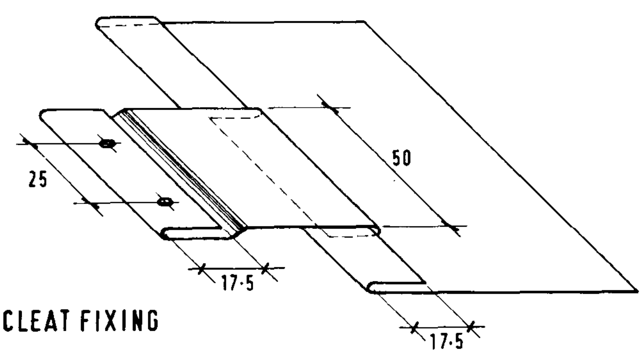
- 1 in 60 for a concrete slab with solar slabs, thermotiles or a promenade roof;
- 1 in 30 for a concrete slab with high tensile roofing felt and light-reflective chippings;
- 1 in 10 for a concrete slab with high tensile, metal faced or mineral surfaced roofing felt (Fig. 348).

It has been found that bituminous roofing felt does not last long under exposed tropical conditions. Metal faced membranes are manufactured by laminating a surface layer of thermo-compensated aluminium or copper foil, 0.075mm thick, to a polyester based membrane. The metal foil is embossed and fully adhered by a continuous process. The polyester base is impregnated and coated with improved bitumens for all-season working. This membrane has better performance characteristics for tropical climates, but has normally to be imported. This applies equally to mineral surfaced roof decking or other roofing material which is made from **Posolen** sheets which are reinforced with interwoven glass wool.

There are a number of different plastic liquids and membranes which can be brush- or spray-applied or fixed in the form of sheeting with liquid finish to concrete roofs or to concrete gutters.

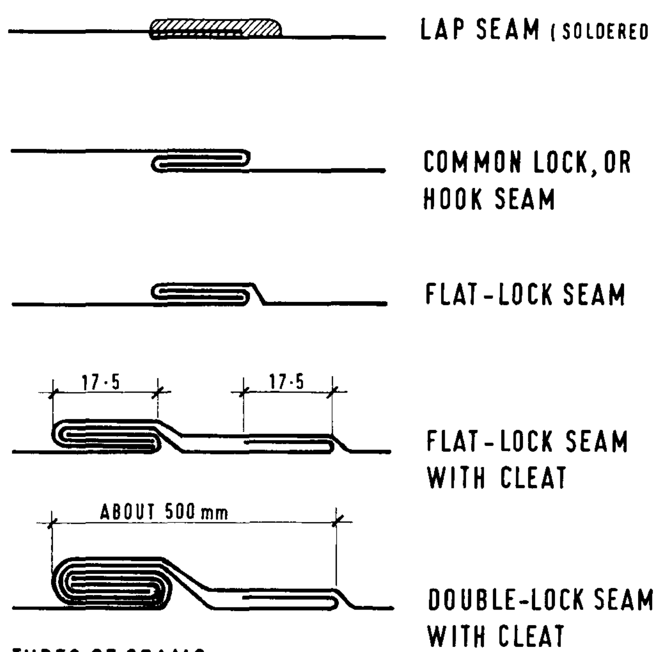
COPPER – any pitch:

Copper is one of the oldest roofing materials. It is very expensive when compared with other roofing materials but very durable and, if properly installed, practically maintenance-free. It has, however, been more or less replaced by other less expensive roofing materials and is only used on special buildings (e.g. church roofs or on buildings acting as radio beacon for aircraft directing). Weathering of copper produces a blue-green patina which protects the surface from further corrosion. Copper is highly ductile and can easily be used on curved (domes) and other irregular surfaces. Copper is light in weight and requires a light substructure. It is normally laid on minimum 25mm thick T & G timber boarding. For a slope of less than 20° the boards should be laid either in the direction of the fall or diagonally to it. The surface must be smooth and free of all projections and absolutely dry. If copper is laid on concrete a heavy coat of asphaltic paint and building paper should be applied to the completely dry and smooth concrete surface. Copper clips and cleats are fixed into inset dovetail battens or plugs (Fig. 349).



CLEAT FIXING

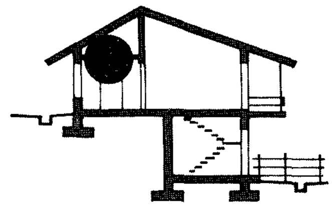
CLEATS ALLOW FREE MOVEMENT OF SHEETS. ALL FIXING OF COPPER SHEETS MUST BE DONE WITH COPPER NAILS, COPPER ALLOY NAILS OR BRASS SCREWS.



TYPES OF SEAMS

FIG.349: COPPER ROOFING

5.4.8 SUSPENDED CEILINGS



The two main functions of suspended ceilings in tropical conditions is to provide an additional insulative barrier against solar heat penetration through the roof structure or against sound transmission, and to incorporate services (airconditioning ducts etc.) in multi-storey structures or in buildings which require central airconditioning.

Suspended ceilings can be built:

- Jointless;
- In modular panels (preferred size 300mm^2);
- In strips.

All are supported by a system of hangers (either from timber or flat mild steel bars) or different proprietary support systems from the roof structure or floor structure.
Insulative ceilings should be of dense material and sound absorbing ceilings of perforated lightweight insulation boards.

JOINTLESS CEILINGS: These are quite heavy, when plastered metal lathing is used. Stretched plastic ceiling membranes (stretched between P.V.C. extrusions) are also used or self stretching fibre glass reinforced P.V.C. sheeting, clipped to extruding wall fixing battens for single spans from 4 to 15m.

CEILING BOARDS AND PANELS: A large variety of different insulative boards (soft board, particle board), mineral or wood fibre panels, asbestos sheets, with their own suspension systems (steel or timber hangers with joists or battens) are used.

STRIP CEILINGS: These are from hardwood, metal or plastic strips with their own fixing systems (Fig. 350 and 351). Hardwood strips are normally fixed tongued and grooved to ceiling joists. There are a large number of decorative tropical hardwoods which make a very attractive ceiling. Aluminium strip ceilings are functional and durable. The strips are finished with baked enamel paint in various colours. A metal strip suspended ceiling can lower the ceiling height in connecting buildings or rooms, cover an ungainly concrete ceiling with beams, pipes or wiring, yet it permits the installation of built-in light fittings. The strips are simply clipped over aluminium carrier profiles. These suspended ceilings are suitable in schools, libraries, hotels, hospitals, shops.

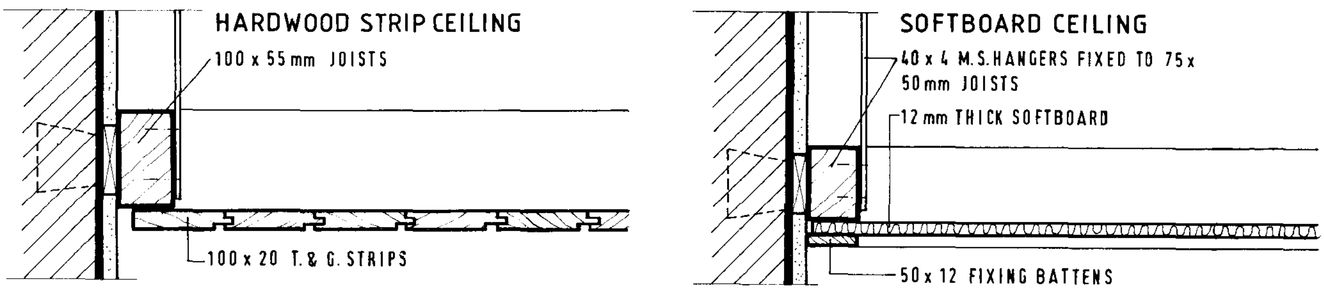
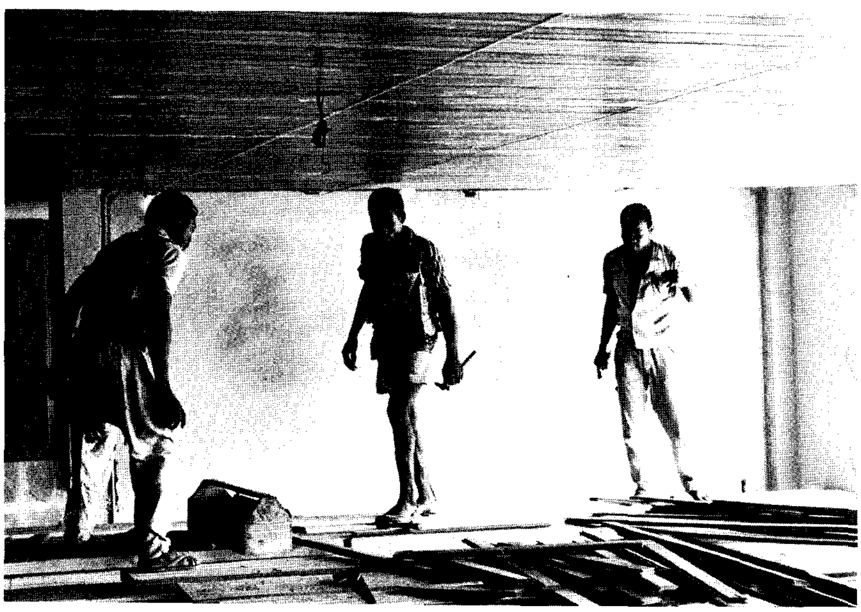


FIG.350 : SUSPENDED CEILINGS



For Fig. 350: Fixing of a suspended hardwood strip ceiling in the entrance hall of Parliament House, Accra, 1970.

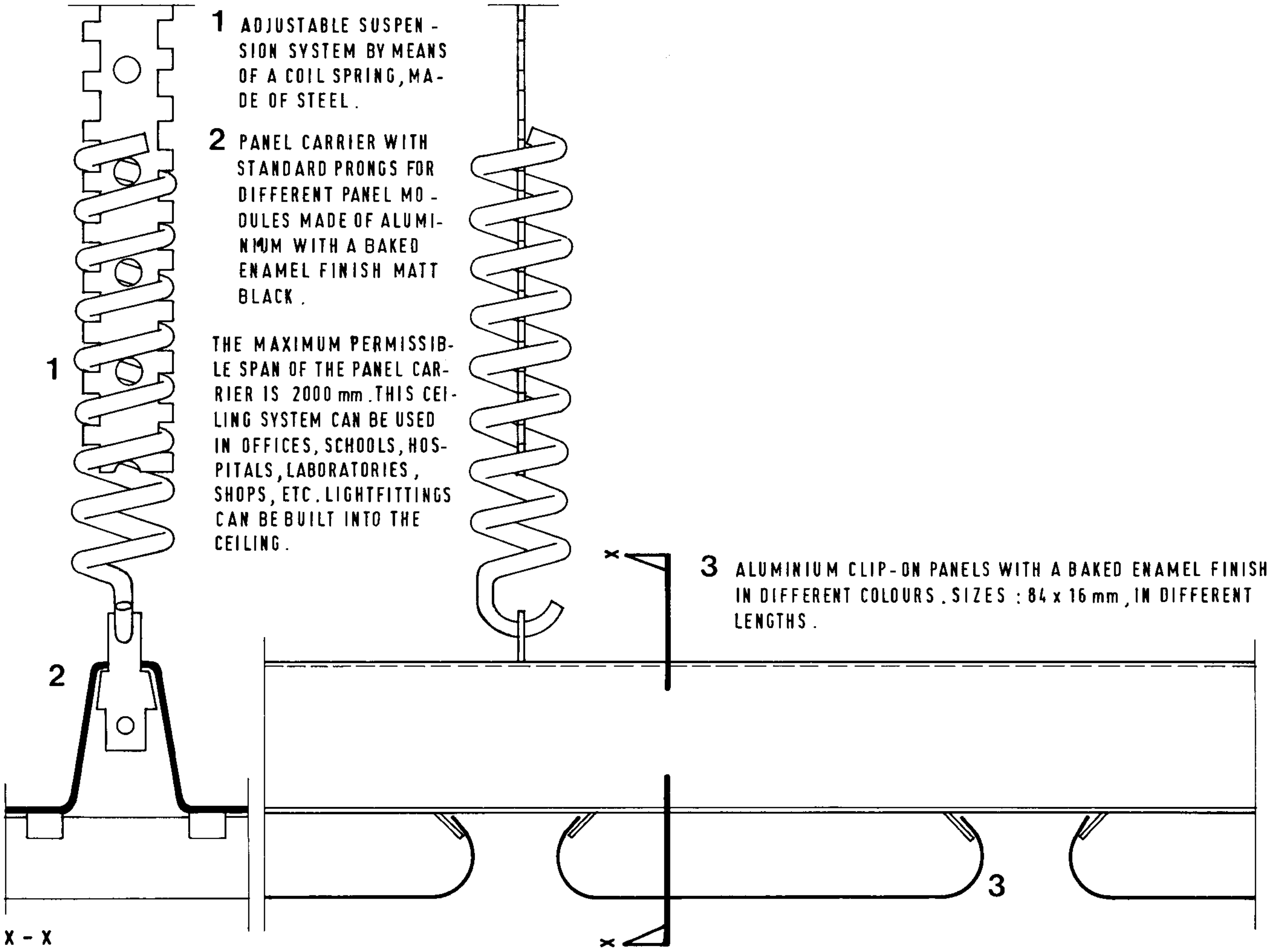


FIG.351 : ALUMINIUM PANEL CEILING (PATENT HUNTER DOUGLAS-LUXALON)

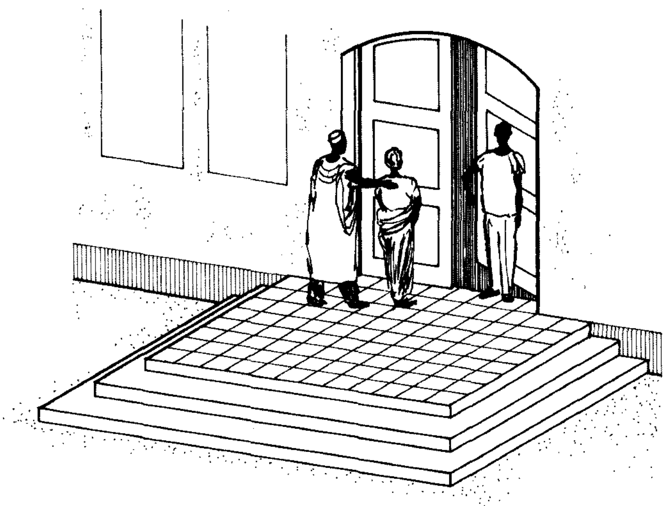
For Fig. 351: Aluminium strip ceiling of the Conference Room, Great Hall, U.S.T., 1982. Architects: GERLACH & GILLIES REYBURN.

5.4.9 STAIRCASES FIG.352 : DIFFERENT TYPES OF STAIRS

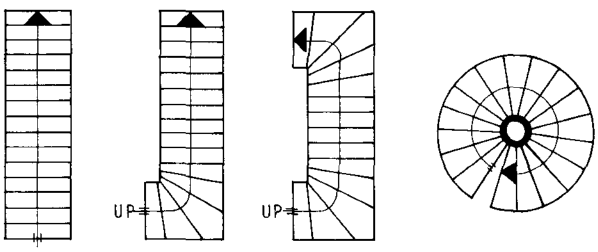
A staircase is a means of vertical communication. It is described as "staircase" or "stairs" when it has more than three steps leading up a maximum angle of 45°. Anything steeper is described as "ladder-stairs" (e.g. "ship-stairs", "ship-ladder") or "ladder".

There are different types of stairs (Fig. 352):

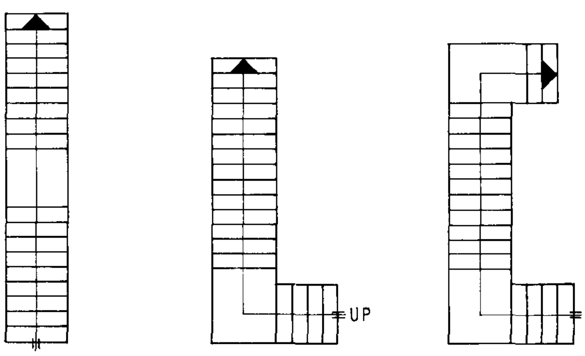
- Stairs fixed to the base of a building;
- Staircases without landing;
- Staircases with landing;
- External Staircases;
- Internal staircases.



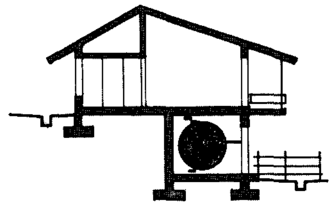
1-STAIRS FIXED TO BASE OF BUILDING : PORCH AND VERANDAH STEPS, NORMALLY NOT EXCEEDING THREE.



2-STAIRCASES WITHOUT LANDING : THESE STAIRCASES ARE USED IN DOMESTIC BUILDINGS WHITH A STOREY HEIGHT OF ABOUT 2.75m, WHERE SPACE IS LIMITED - INTERNAL



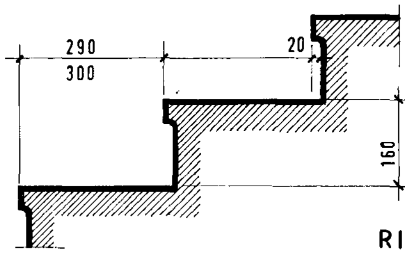
3-STAIRCASES WITH LANDING : STAIRCASES WITH LANDINGS ARE NECESSARY IN BUILDINGS WITH STOREY HEIGHTS EXCEEDING 2.75 m. THE LENGTH OF THE LANDING SHOULD BE EQUAL TO OR LONGER THAN THE WIDTH OF THE STAIRS - INTERNAL



5.4.9.1 DIMENSIONS

A normal pedestrian staircase has a rise/tread ratio of 170mm to 290mm. Where heavy traffic is expected the ratio should be 160mm (rise) to 300mm (tread). The following "thumb-rule" formula can serve as guidance:

2 x RISES + 1 x TREAD = 610 TO 650 mm (WITH 630 mm AS AVERAGE)

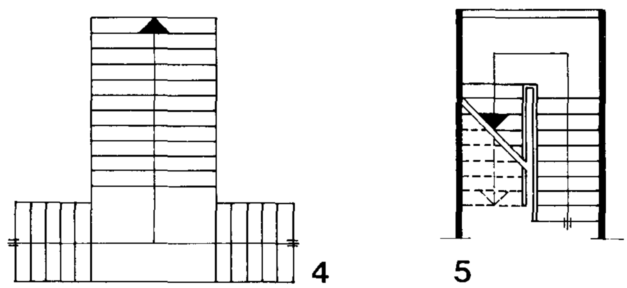


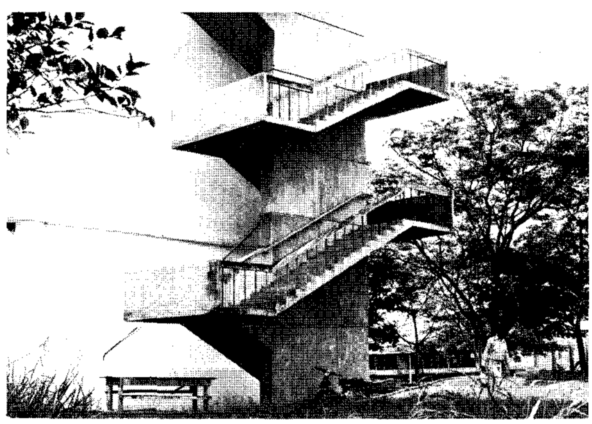
RISE-TREAD RATIO

4-INTERNAL 3-RUN-STAIRCASE : THESE ARE EXPENSIVE, BUT USED AS MONUMENTAL STAIRCASES TO UNDERLINE THE IMPORTANCE OF THE ENTRANCE.

5-INTERNAL 2-RUN-STAIRCASE ; COMMONLY USED IN MULTISTOREY STRUCTURES.

NOTE : NO SINGLE RUN SHOULD HAVE MORE THAN 18 RISES WITHOUT LANDING.





6-EXTERNAL STAIRCASES : FOR 2 OR 3-STOREY STRUCTURES AND EXTERNAL ESCAPE STAIRCASES. THE PHOTOGRAPH ABOVE SHOWS THE EXTERNAL STAIRCASE OF THE STUDIO BLOCK, FACULTY OF ARCHITECTURE, U.S.T. KUMASI. DESIGNED BY L.CHRISTIANS.

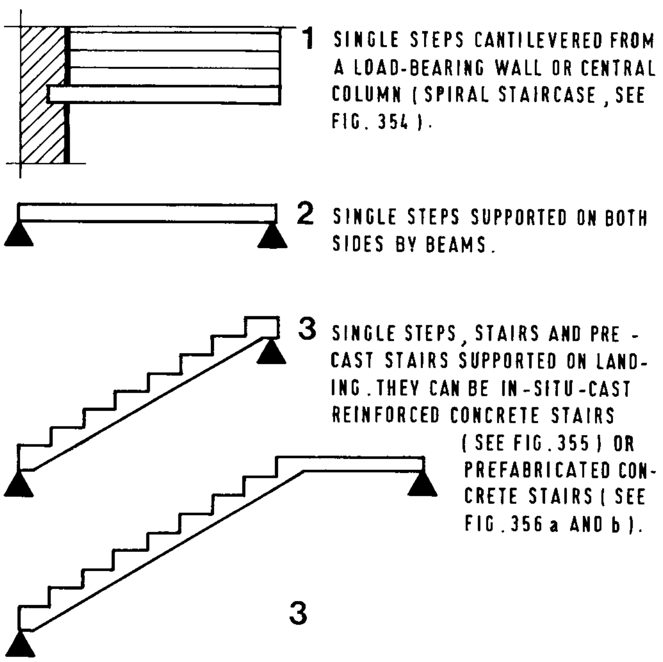


FIG. 353 : **DIFFERENT METHODS OF STAIRCASE CONSTRUCTION**

Widths of stairs are:

- For narrow or circular stairs: 700 to 800mm (with 350 to 400mm distance from railing to walking line);
- For straight stairs: 1100mm (with 550mm distance from railing to walking line); width of stairs with traffic for two persons passing up and down at the same time: 1100 to 1250mm; width of stairs with traffic for three persons: 1875mm.

5.4.9.2 CONSTRUCTION

Stairs can be constructed as:

- Single steps cantilevered from a load-bearing wall or central column (in the case of a circular or spiral staircase);
- Single steps supported at both sides;
- Staircase supported on landings (Fig. 353 *to* 355).

Materials for the construction of steps, stairs and staircases are:

- **Natural Stone:** Stones are mainly used for steps as part of external hard landscaping or as steps and stairs in areas with extremely heavy traffic.
- **Burnt Bricks:** These are very attractive and rustic for hard landscaping where they can serve as steps and stairs as part of the paving and dwarf walls from level to level;
- **Concrete:** This is the most common material for the construction of staircases nowadays, either in situ or as prefabricated steps and staircase beams (Fig. 356);
- **Steel:** Steel is mostly used for cat-walk stairs in factories, escape staircases, ship steps and ladders (Fig. 357);
- **Timber:** This is an economic material for staircase construction in domestic buildings (Fig. 358).

STAIRCASE RAILINGS

For a straight staircase not wider than 800mm only the railing is required. Wider staircases need a second hand rail along the wall.

Handrails and railings can be designed in many different ways, normally in timber with wooden balusters or mild steel tubular supports or tubular steel handrails and P.V.C. profiles over flat mild steel bars welded to tubular steel supports (Fig. 359).

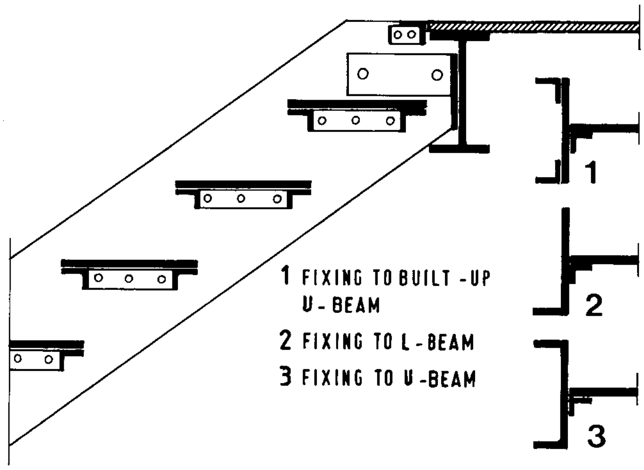
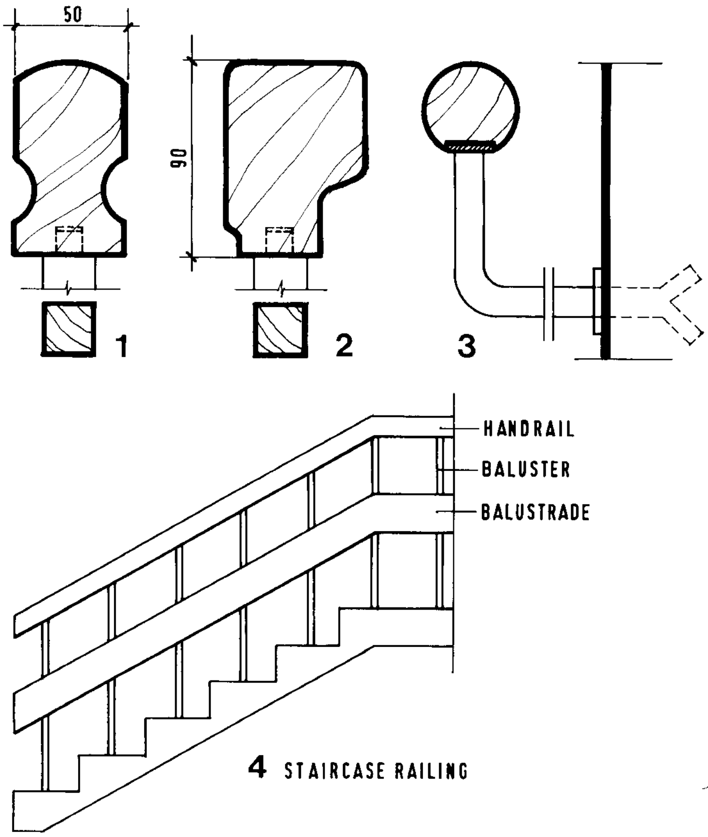


FIG. 357 : **STEEL STAIRS** : TREAD / RISE RATIO IS FROM 210 (WITH HANDRAIL) TO 250 x 150 mm (WITHOUT HANDRAIL) FOR SHIP STAIRS, LADDERS, CATWALK STAIRS AND ESCAPE STAIRS IN FACTORIES.



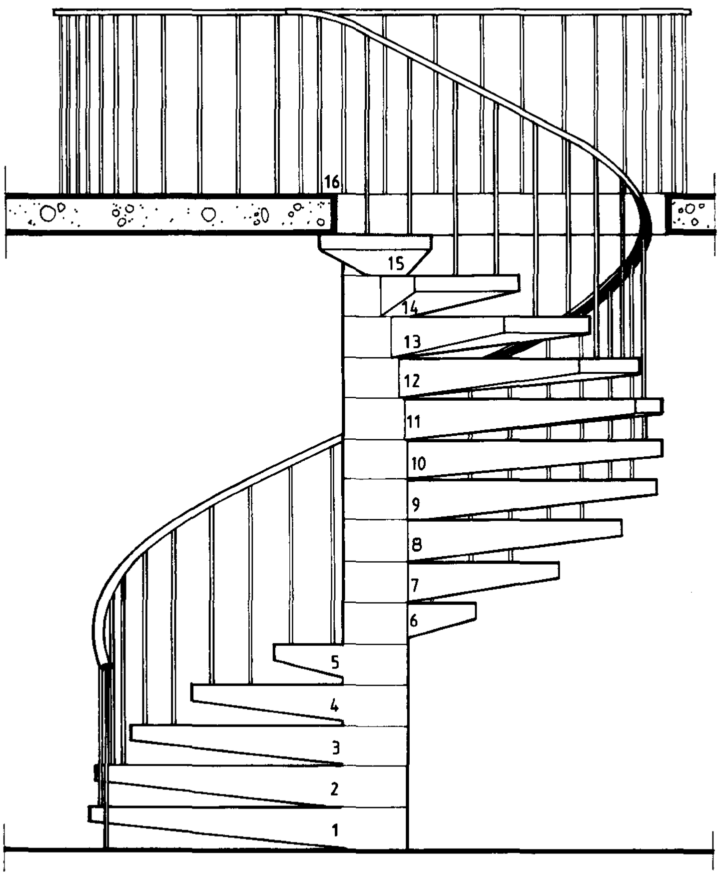
1,2 TIMBER HANDRAILS FIXED TO 25 x 25 mm WOODEN BALUSTERS.
3 45 mm DIAMETER HARDWOOD HANDRAIL FIXED TO 20 x 4 mm M.S. FLAT BAR AND WITH 15 mm DIAMETER M.S. BARS TO WALL.

HANDRAILS CAN BE DESIGNED IN DIFFERENT SHAPES FROM TIMBER, STEEL AND P.V.C. PROFILES OVER STEEL.

FIG. 359 : **STAIRCASE RAILINGS AND HANDRAILS**

5.4.9 STAIRCASES

A: 0 50 100 150 cm (mm) B: 0 50 100 150 cm

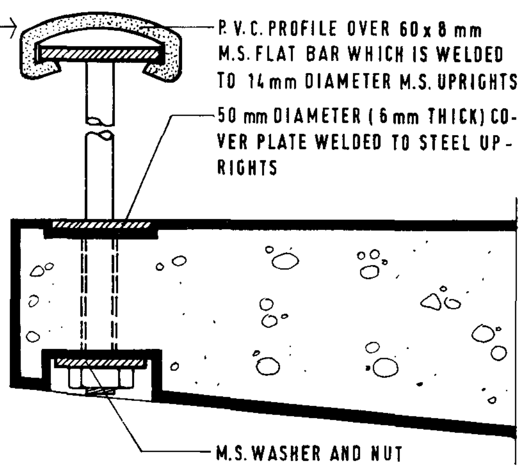


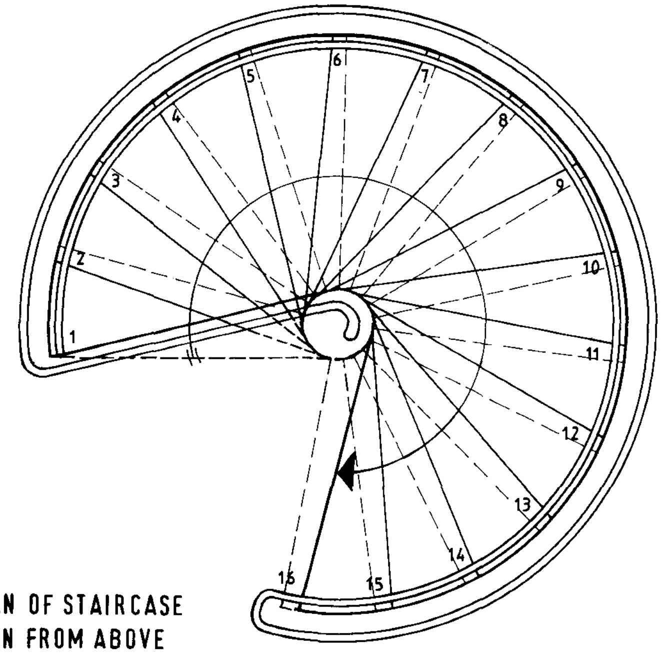
ELEVATION OF SPIRAL STAIRCASE IN THE STUDIO BLOCK OF THE FACULTY OF ARCHITECTURE, U.S.T., KUMASI.

SINGLE STEPS SUPPORTED FROM A CENTRAL LOAD-BEARING COLUMN.

THE PRECAST TERRAZZO STEPS ARE REINFORCED WITH 8 AND 10 mm DIAMETER REINFORCING RODS. THE ERECTION SEQUENCE IS TO FIX THE SPIRAL TREADS AND TO CAST THE REINFORCED CONCRETE CENTRE CORE FIRST; SECOND TO FIX THE STEEL UPRIGHTS, TWO TO EACH STEP; THIRD TO WELD THE FLAT M S BAR FOR THE RAILING TO THE UPRIGHTS AND LAST TO COVER THE BAR WITH THE P.V.C. PROFILE.

RAILING DETAIL SHOWING FIXING OF BALUSTERS TO TREADS





PLAN OF STAIRCASE SEEN FROM ABOVE

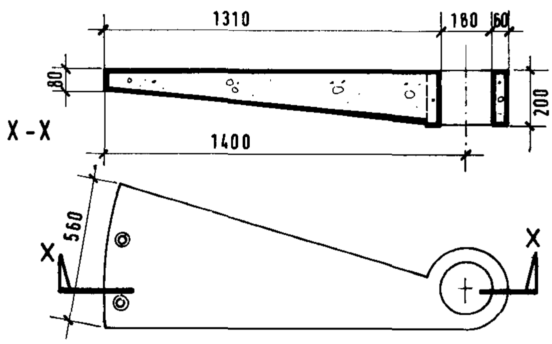
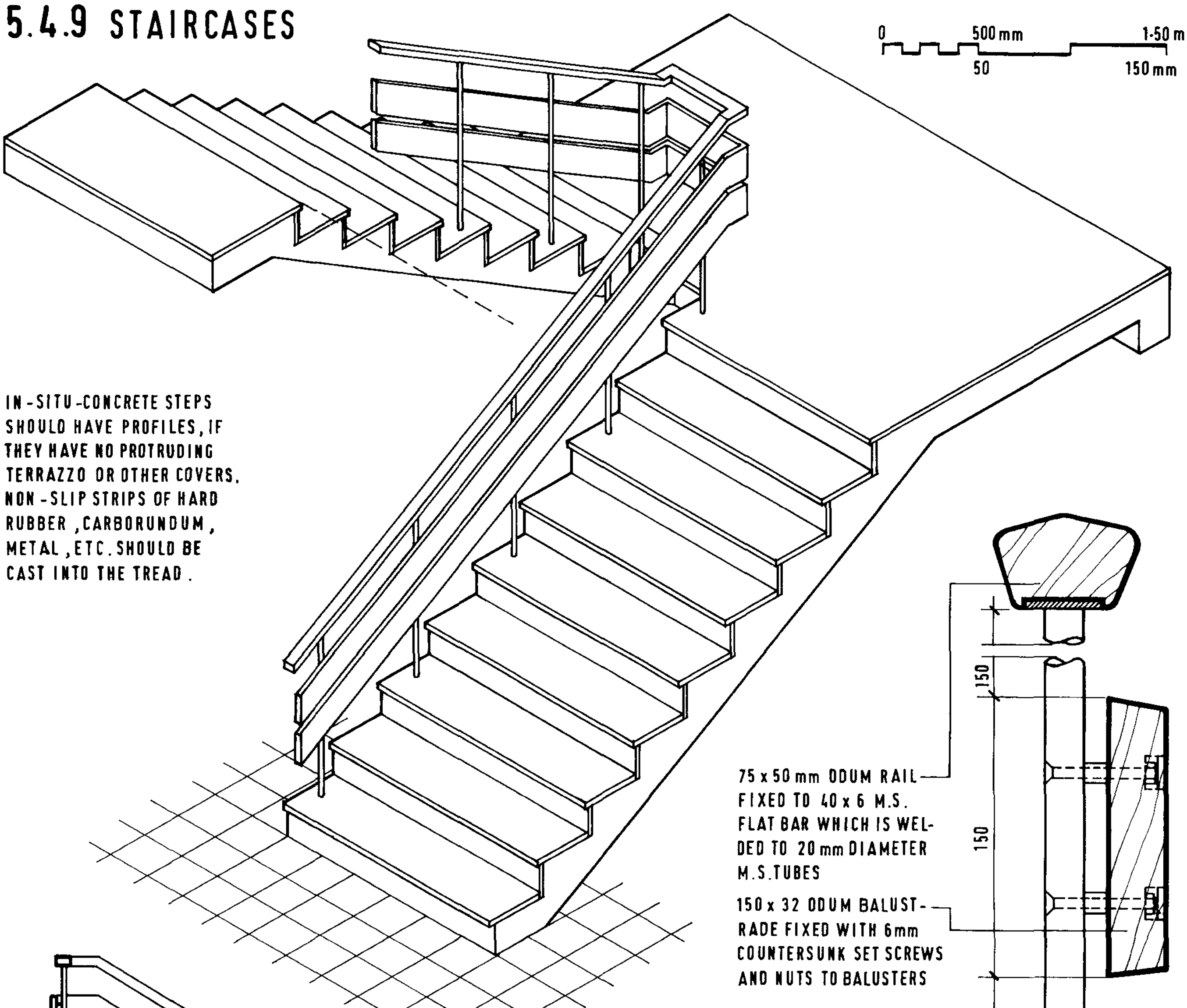


FIG: 354 SPIRAL STAIRCASE

PLAN AND SECTION OF PRECAST TREAD

5.4.9 STAIRCASES



IN-SITU-CONCRETE STEPS SHOULD HAVE PROFILES, IF THEY HAVE NO PROTRUDING TERRAZZO OR OTHER COVERS. NON-SLIP STRIPS OF HARD RUBBER, CARBORUNDUM, METAL, ETC. SHOULD BE CAST INTO THE TREAD.

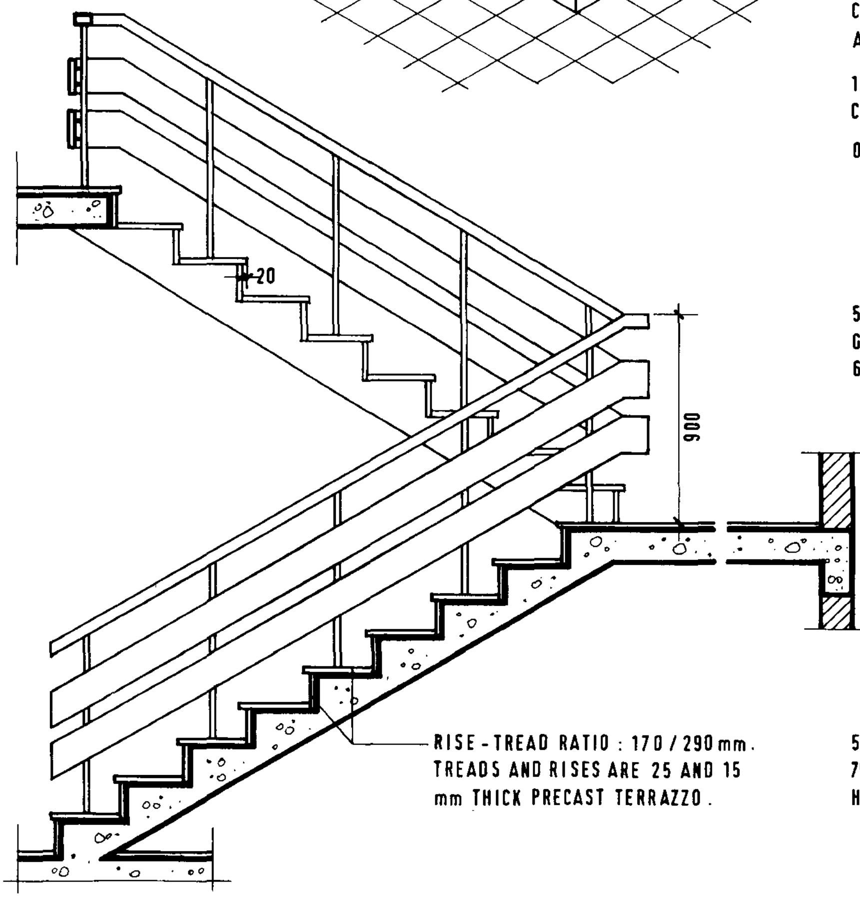
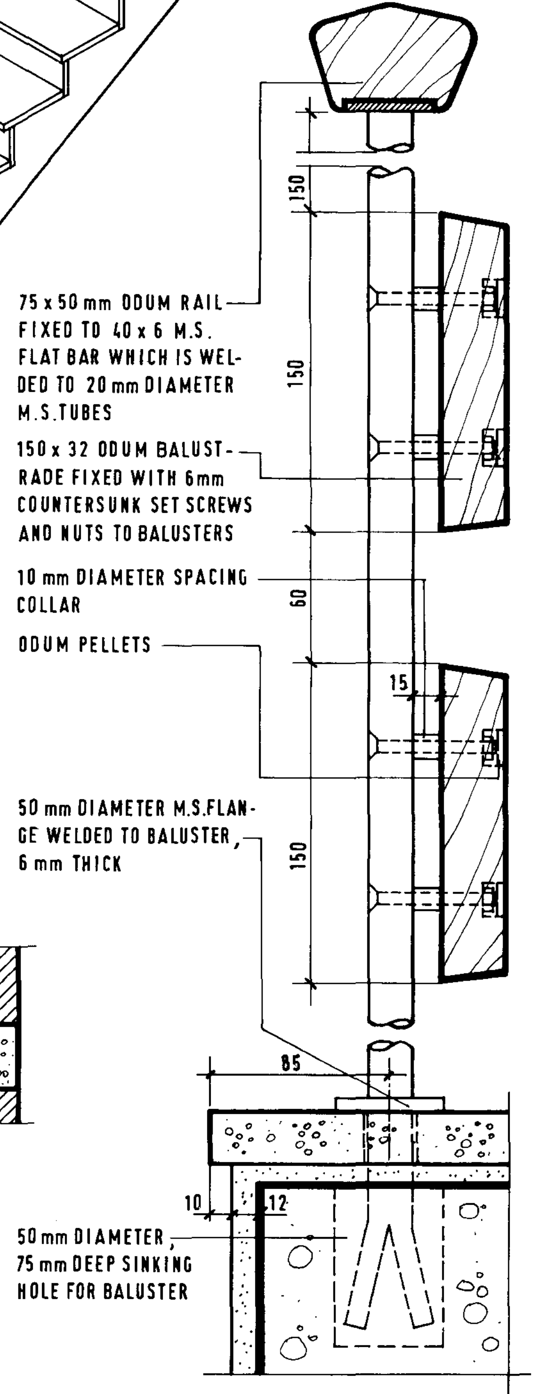
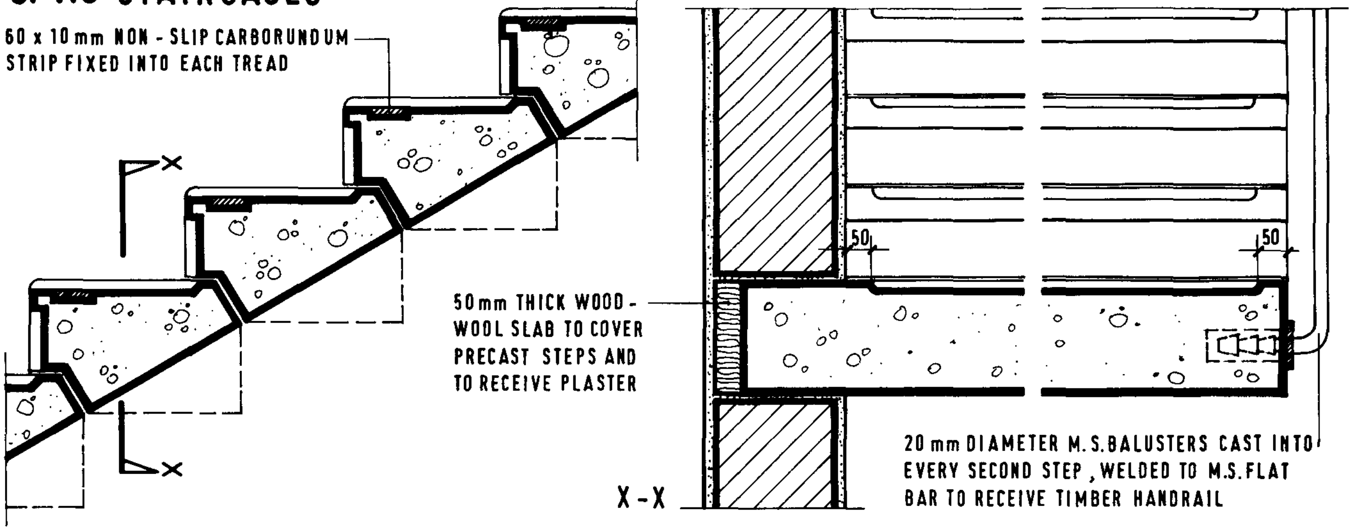


FIG.355 : **IN-SITU-REINFORCED CONCRETE STAIRCASE SUPPORTED ON LANDINGS**



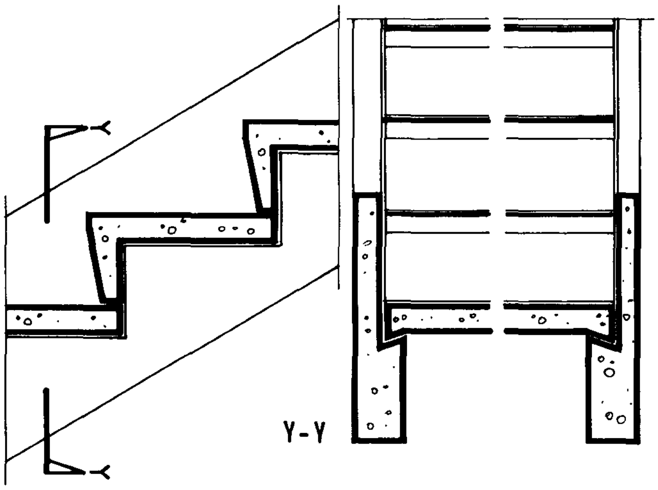
STAIRCASE RAILING DETAIL

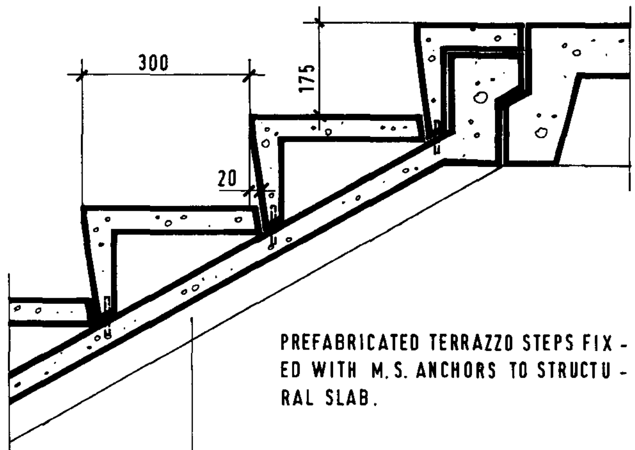
5.4.9 STAIRCASES



PREFABRICATED REINFORCED CONCRETE STEPS CANTI-LEVERED FROM LOAD-BEARING BLOCKWORK WALL **1**

0 50 100 500 mm





PREFABRICATED CONCRETE STEPS AND SUPPORTING BEAMS **2**

3 PREFABRICATED STRUCTURAL SLAB WITH PRECAST STEPS

4 PREFABRICATED STAIR FLIGHTS AND LANDING UNITS

PREFABRICATED STAIR STRUCTURES ARE JUSTIFIED IN MULTI-STOREY BUILDINGS AND IN PREFABRICATED PANEL STRUCTURES. SYSTEMS 2,3 AND 4 HAVE TO BE FIXED ON SITE WITH THE AID OF A CRANE AND REQUIRE AN ACCURATE PRODUCTION TECHNIQUE.

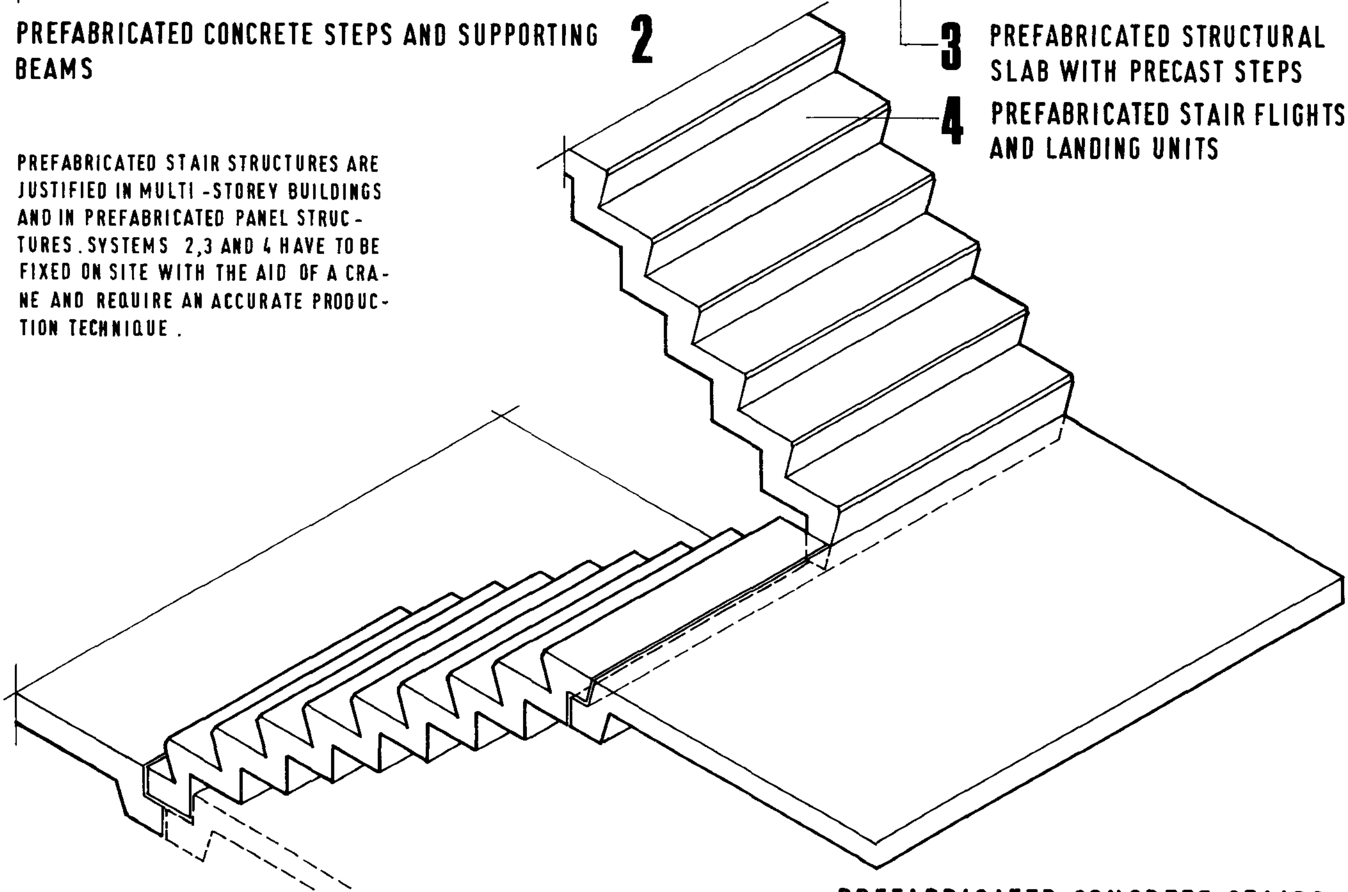
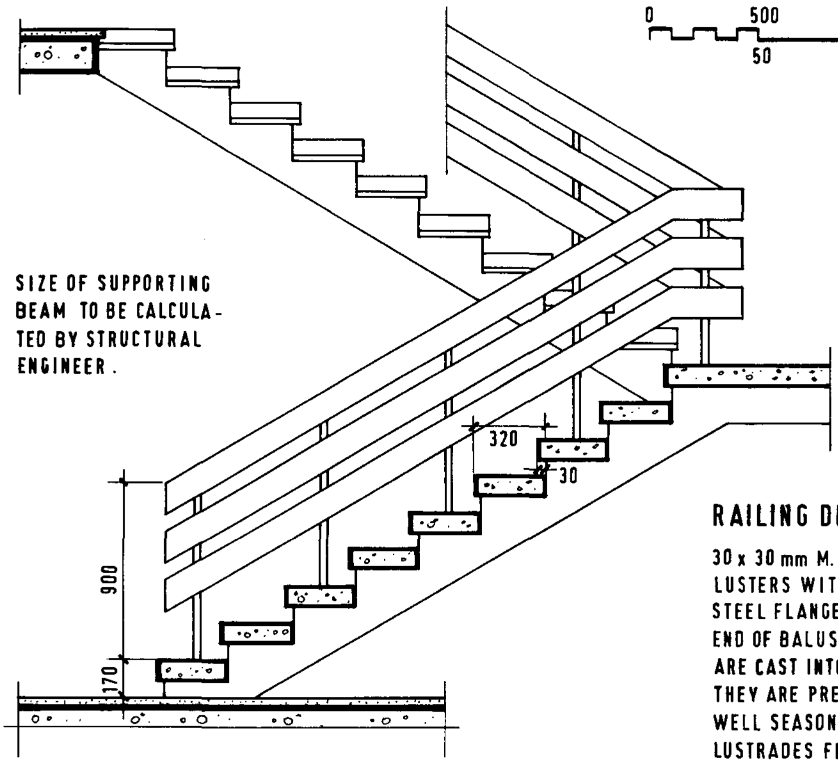


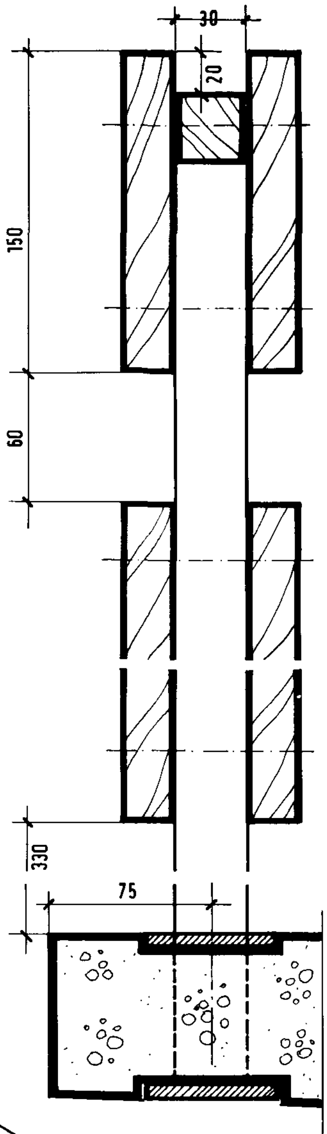
FIG. 356.a : PREFABRICATED CONCRETE STAIRS

5.4.9 STAIRCASES



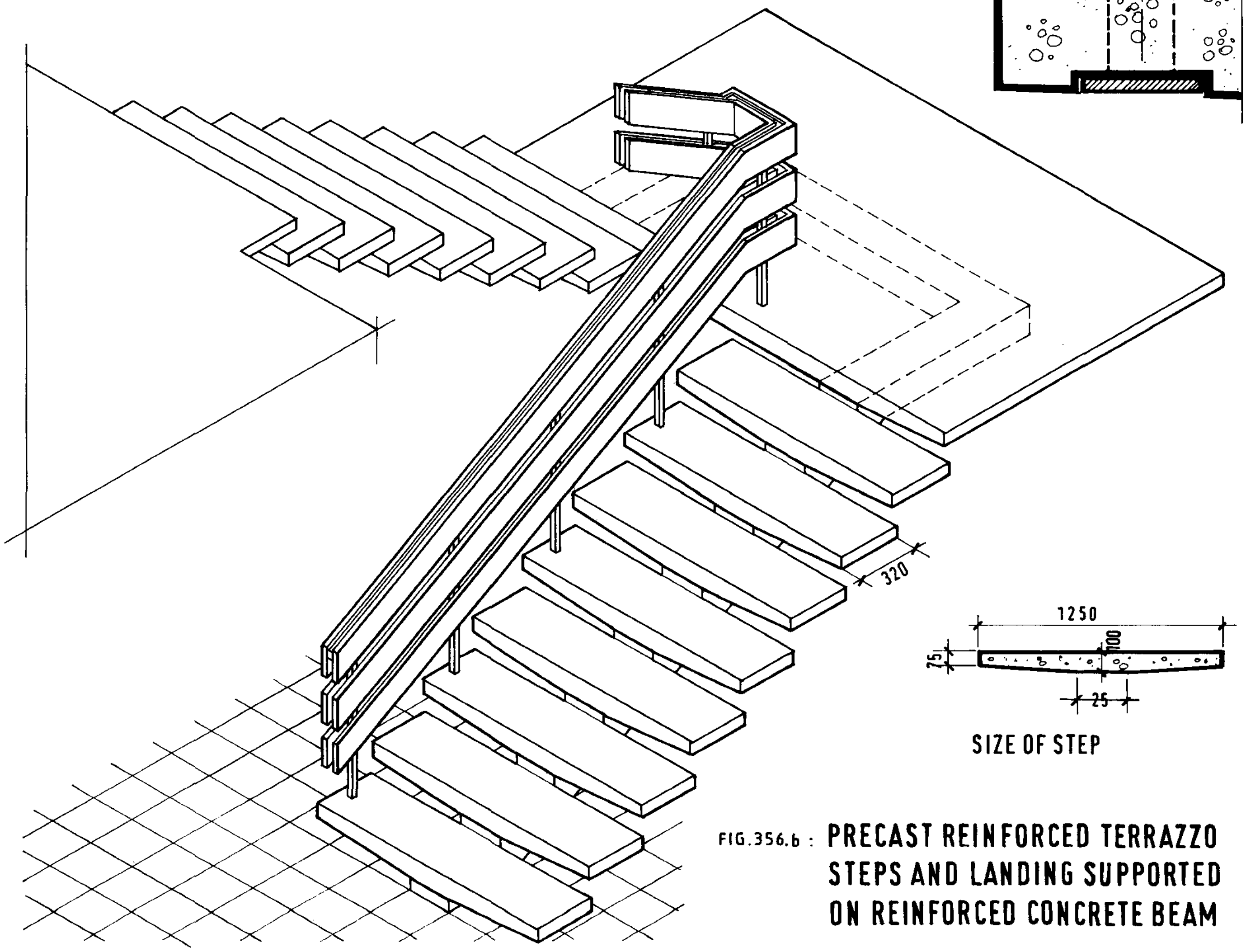
SIZE OF SUPPORTING BEAM TO BE CALCULATED BY STRUCTURAL ENGINEER.

SECTION THROUGH STAIRCASE



RAILING DETAIL :

30 x 30 mm M.S. BOX SECTION BALUSTERS WITH 60 x 60 x 6 mm STEEL FLANGES WELDED TO BOTTOM END OF BALUSTERS BEFORE THESE ARE CAST INTO THE STEPS WHEN THEY ARE PRECAST. 150 x 25 mm WELL SEASONED HARDWOOD BALUSTRADES FIXED WITH 6 mm DIAMETER COUNTERSUNK SET SCREWS AND NUTS (CLOSED WITH TIMBER PELLETS) TO M.S. BOX SECTIONS. 30 x 30 mm BLOCKING PIECE AT TOP RAIL.



SIZE OF STEP

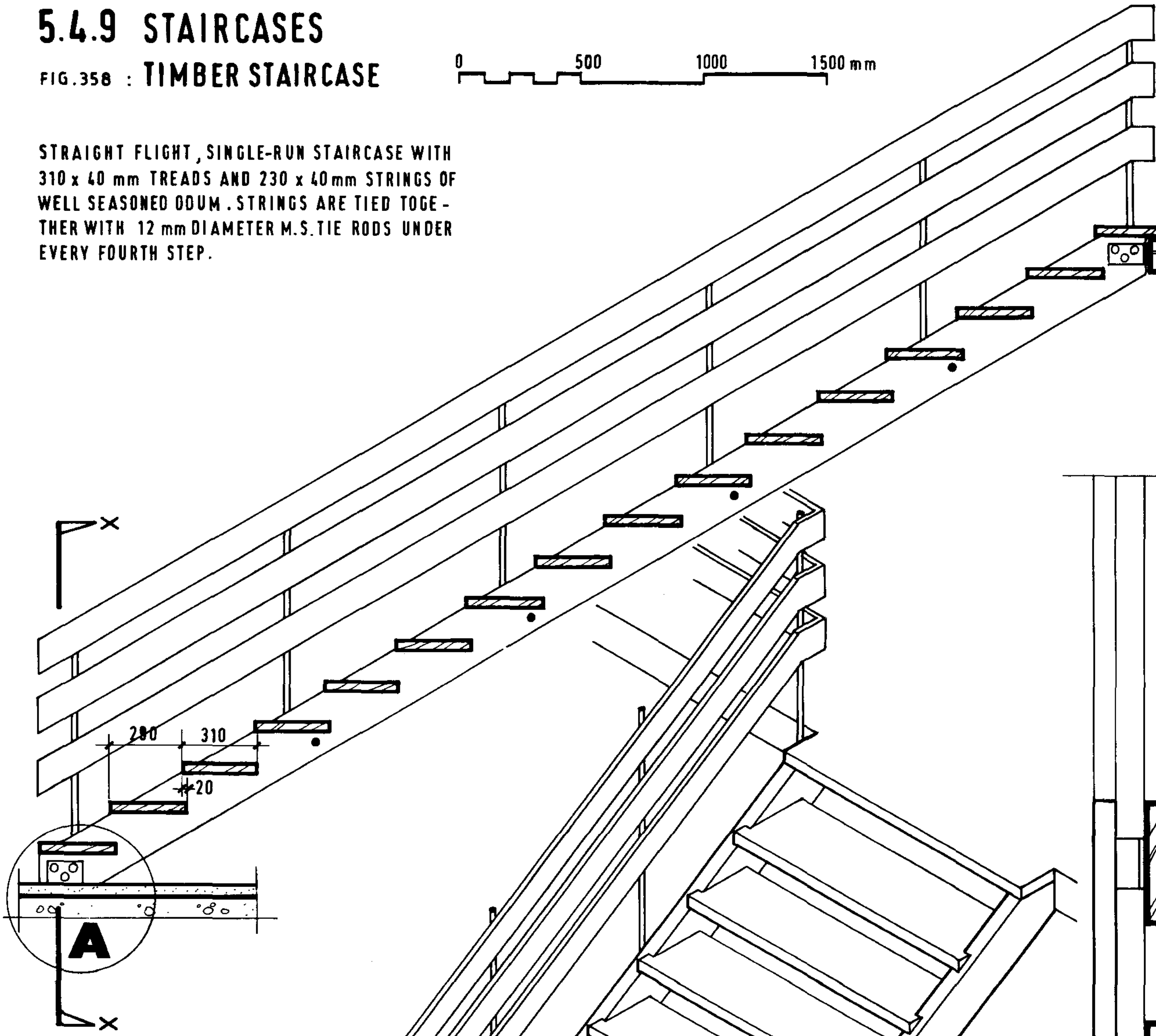
FIG.356.b : **PRECAST REINFORCED TERRAZZO STEPS AND LANDING SUPPORTED ON REINFORCED CONCRETE BEAM**

5.4.9 STAIRCASES

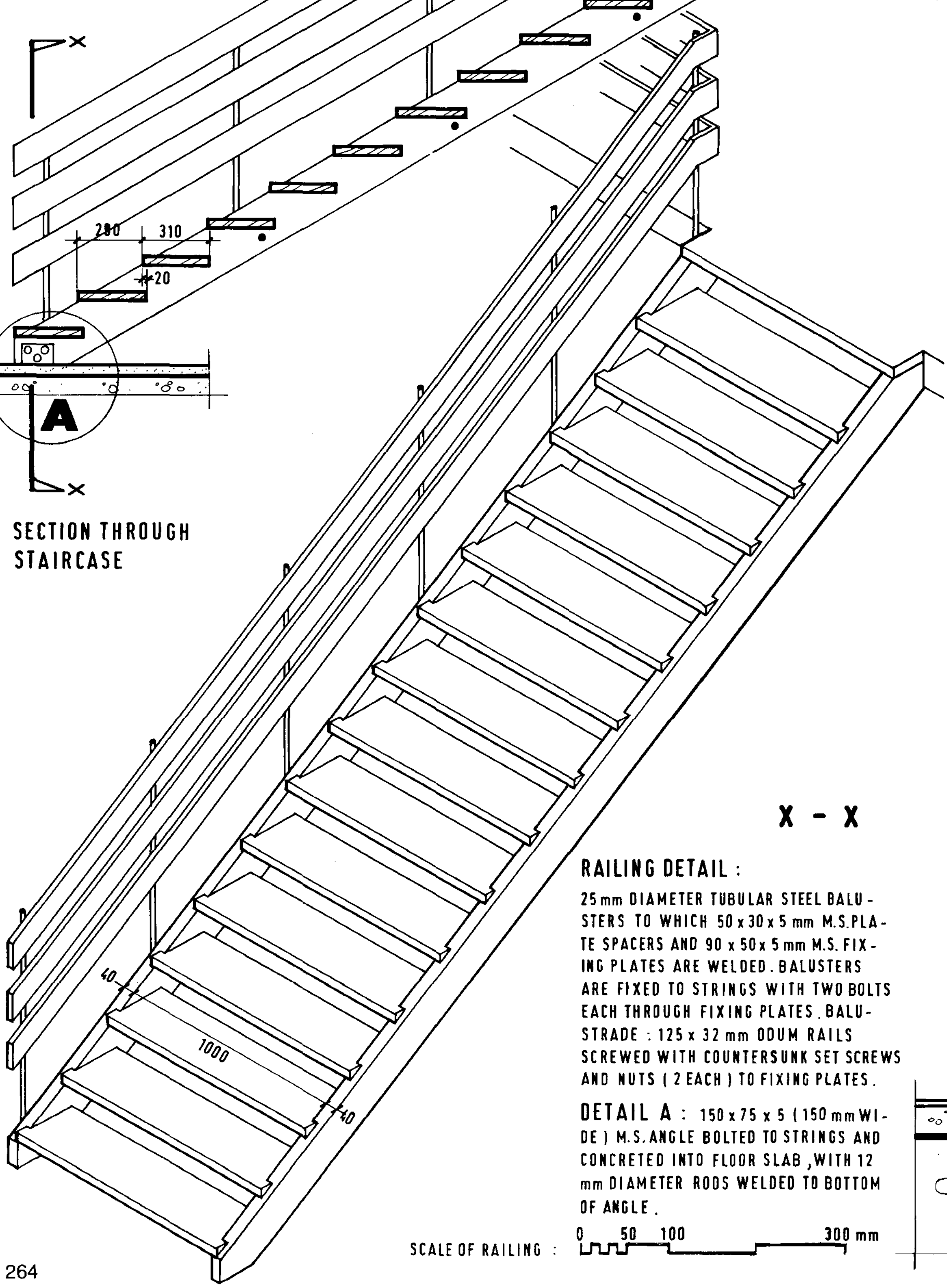
FIG.358 : TIMBER STAIRCASE

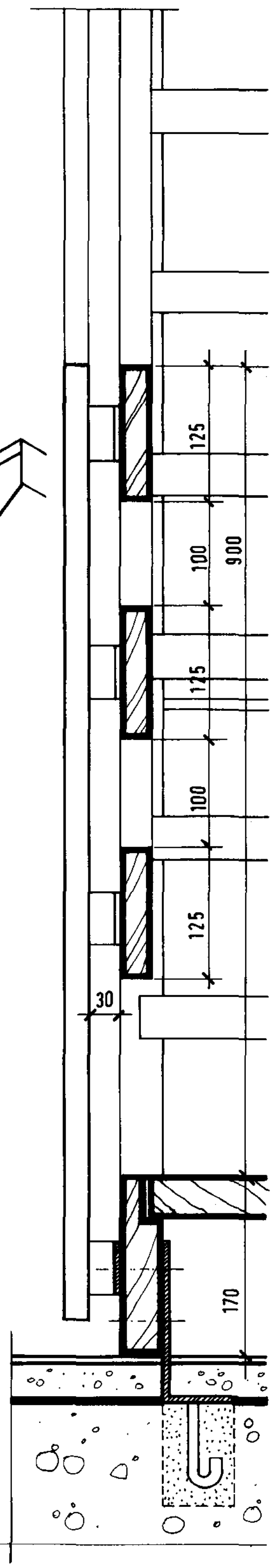
0 500 1000 1500 mm

STRAIGHT FLIGHT, SINGLE-RUN STAIRCASE WITH 310 x 40 mm TREADS AND 230 x 40mm STRINGS OF WELL SEASONED ODUM. STRINGS ARE TIED TOGETHER WITH 12 mm DIAMETER M.S. TIE RODS UNDER EVERY FOURTH STEP.



SECTION THROUGH STAIRCASE





X - X

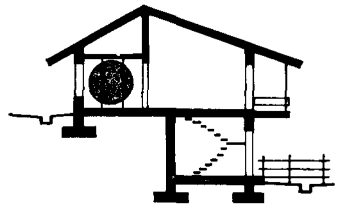
RAILING DETAIL :

25 mm DIAMETER TUBULAR STEEL BALUSTERS TO WHICH 50 x 30 x 5 mm M.S. PLATE SPACERS AND 90 x 50 x 5 mm M.S. FIXING PLATES ARE WELDED. BALUSTERS ARE FIXED TO STRINGS WITH TWO BOLTS EACH THROUGH FIXING PLATES. BALUSTRADE : 125 x 32 mm ODUM RAILS SCREWED WITH COUNTERSUNK SET SCREWS AND NUTS (2 EACH) TO FIXING PLATES.

DETAIL A : 150 x 75 x 5 (150 mm WIDE) M.S. ANGLE BOLTED TO STRINGS AND CONCRETED INTO FLOOR SLAB, WITH 12 mm DIAMETER RODS WELDED TO BOTTOM OF ANGLE.

SCALE OF RAILING : 0 50 100 300 mm

5.4.10 BUILT-IN FITTINGS



These are fittings which are workshop-manufactured and built in on the site, e.g. kitchen cupboard units, store shelves, wardrobes, room dividers, book shelves, benches, counter fittings, etc. They are produced from timber frames and plywood panels for side, bottoms, tops and shelves. For painted surfaces the timber and ordinary plywood must be fine-grained. For natural finish the veneer of the plywood and corresponding sections should have decorative timber grain. The surface can be oiled, varnished, waxed or, with a spraying gun polished matt or glossy. Timber used for built-in-fittings should be seasoned.

WORKMANSHIP

Built-in-fittings and cabinet work are the most expensive class of architectural woodwork. These fittings are almost always shop-assembled, scraped and sanded before fixing. The joints must be absolutely accurate. After installation the fittings are hand-sanded down before final finishing. Furniture belongs to a distinct class of work which is not normally related to architectural construction. It is, however, becoming quite usual for architects to design furniture for their projects, as they design the built-in-fittings, for example library shelves, church benches, assembly hall chairs, conference room furniture, hotel and restaurant furniture, furniture for schools and institutions. Utility furniture, built by small local carpenter workshop in many tropical developing countries with a history of carpenter artisanship, is nearly always produced to standard sizes (Fig. 360). Joinery fittings produced by these small workshops are complete doors, door frames, windows (louvered shutters and timber louvres) and window frames.

ASSEMBLY

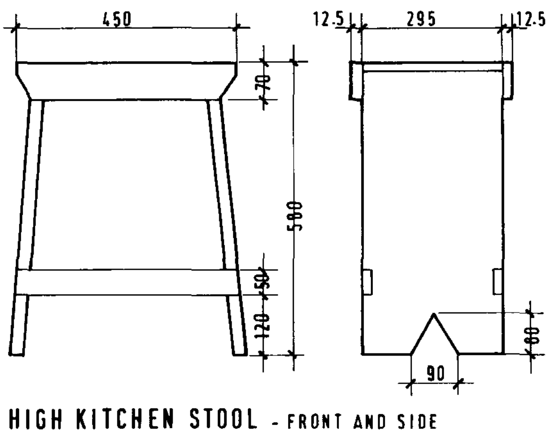
High-grade built-in-fitments are produced and as far as possible also assembled at a joinery workshop and transported from there to the site for installation. Joints are housed where the end of one panel or framing section butts against the face of another, or mitred (plain, with block, with loose tongue or lapped); they are normally glued, blocked and sometimes secured with finishing nails or screws. Screw heads should be countersunk and concealed by cover moulds, putty, plastic or wooden fillers. In order to avoid warping, no large, wide surfaces should be used without breaking the same up into smaller panels. Panels should be rigidly secured on one side only or left entirely loose in housed (unglued) joints.

INSTALLATION

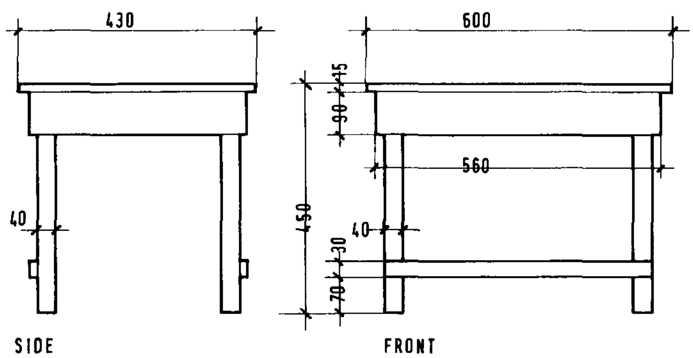
For painted surfaces all woodwork should be primed with aluminium paint or sanded before delivery to the site. If the fittings are built against unplastered walls these should at least be covered with building paper or a moisture barrier in the case of timber houses or bituminous paint in the case of blockwork. Timber blocking for large built-in-fittings must be preservative treated, accurately placed and properly secured to the wall.

DETAILS

Built-in-fittings involve framing members, shelves and panels together in three dimensions. Since the architect works on drawings which are two-dimensional it would be advisable to produce an isometric or axonometric drawing of the fittings which would prevent many of the difficulties which arise in practice if the design drawings are not quite clear. Fig. 361 to 364 show some typical fitments and built-in-fittings: Bookshelf, kitchen cupboard, built-in-wardrobe and post office counter.

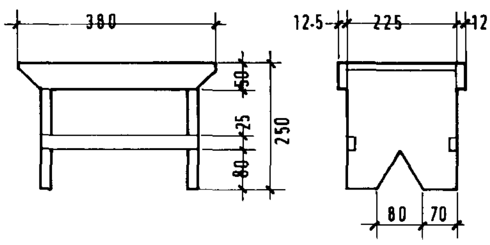


HIGH KITCHEN STOOL - FRONT AND SIDE



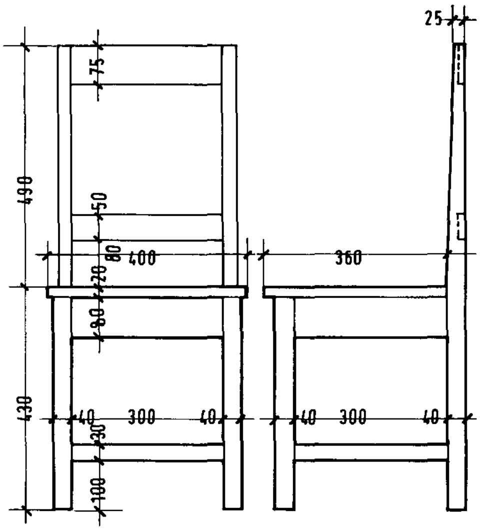
KITCHEN TABLE

TYPICAL TRADITIONAL UTILITY FURNITURE IN GHANA ARE USED IN THE KITCHENS, IN OUTDOOR COOKING AREAS AND IN DINING PLACES. FURNITURE FOR THE HALL OR LIVING ROOM IS USUALLY OF HIGHER STANDARDS. LOCAL UTILITY FURNITURE ARE DIFFERENT STOOLS, CHAIRS, BENCHES AND TABLES. TIMBER USED FOR KITCHEN FURNITURE IS MAINLY WAWA (TRIPLOCHITON SCLEROXYLON).



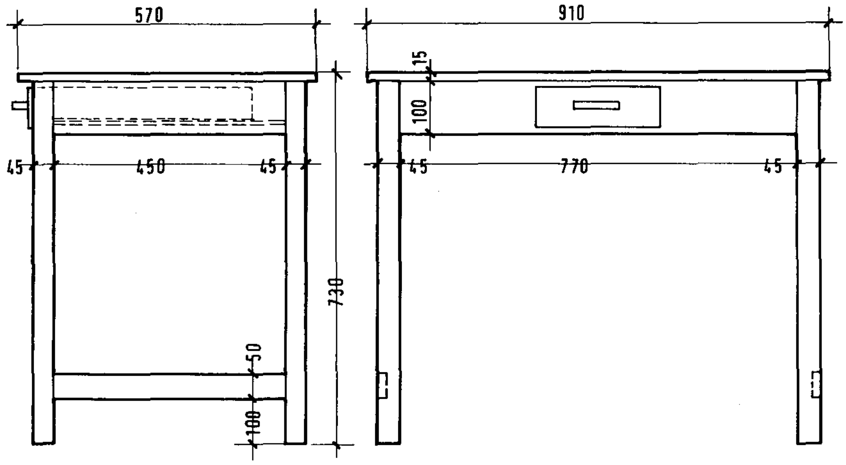
LOW KITCHEN STOOL

FIG. 360 : TRADITIONAL UTILITY FURNITURE



FRONT SIDE

DINING CHAIR



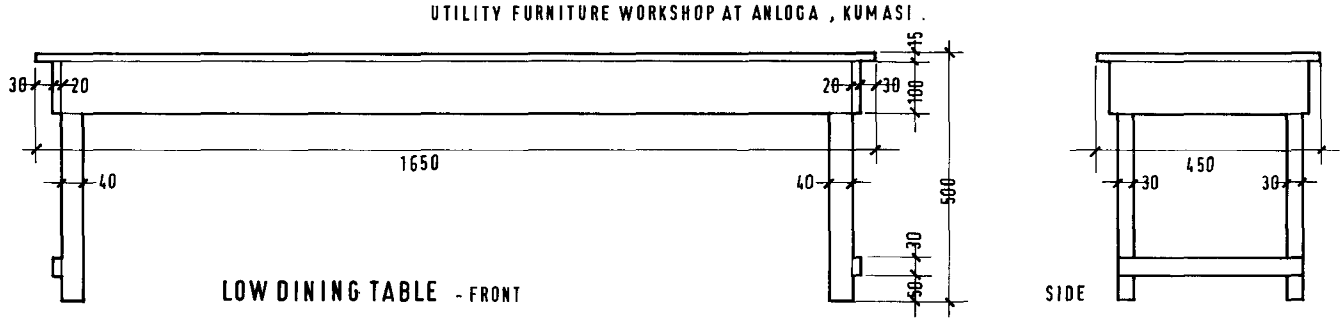
SIDE FRONT

HIGH KITCHEN TABLE WITH DRAWER

0 50 100 500 mm

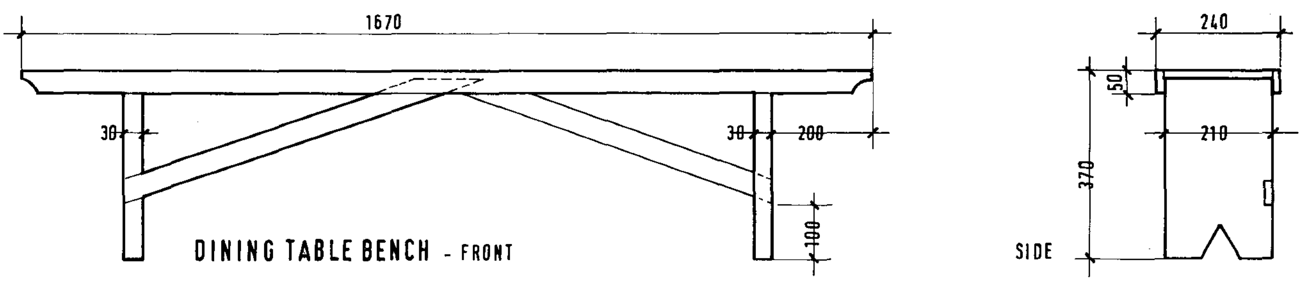
THE LOCAL CARPENTER PRODUCING UTILITY DINING ROOM FURNITURE WILL USE THE DURABLE ODUM (CHLOROPHORA EXCELSA) FOR CHAIRS AND TIMBER SPECIES, WHICH ARE LOCALLY DESCRIBED AS "REDWOOD" FOR BENCHES AND TABLES. THESE ARE RED CEDAR (UAPACA), SAPELE (ENTANDROPHRAGMA CYLINDRICUM), UTILE (ENTANDROPHRAGMA UTILE) AND AFRICAN MAHOGANY (KHAYA IVORENSIS). THE FURNITURE IS POLISHED ON COMPLETION. A COMBINATION OF ODUM AND WAWA IS USED FOR THE MANUFACTURE OF CHILDREN'S TOYS, WOODEN BOWLS AND TRADITIONAL STOOLS. THE DARK BROWN COLOUR OF THE ODUM TOGETHER WITH THE WHITISH COLOUR OF WAWA PRODUCE AN ATTRACTIVE FINISH.

UTILITY FURNITURE WORKSHOP AT ANLOGA, KUMASI.



LOW DINING TABLE - FRONT

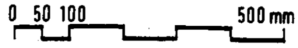
SIDE

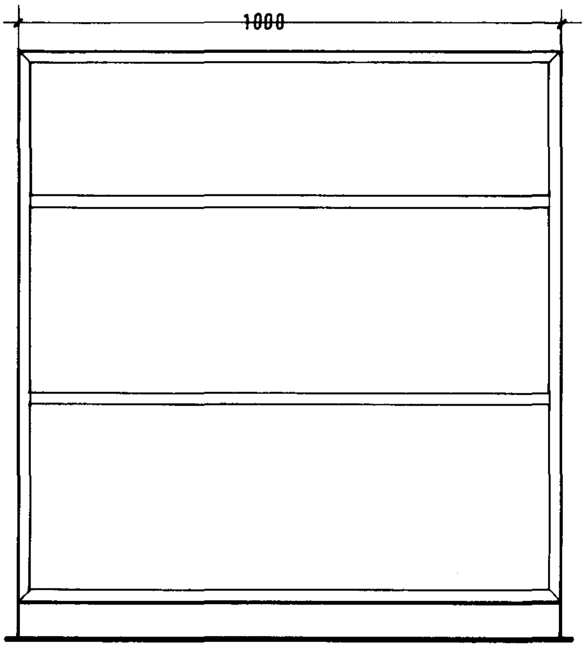


DINING TABLE BENCH - FRONT

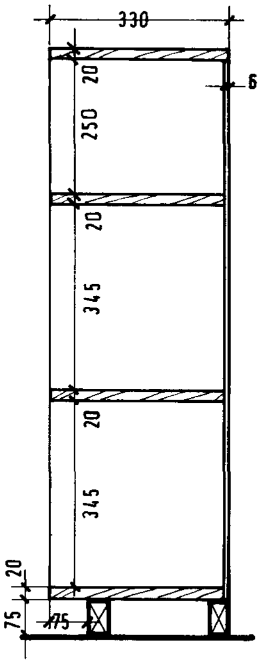
SIDE

5.4.10 BUILT-IN FITTINGS FIG.361 : BOOKSHELF

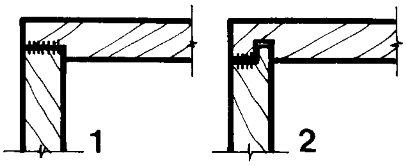




FRONT ELEVATION OF SHELF

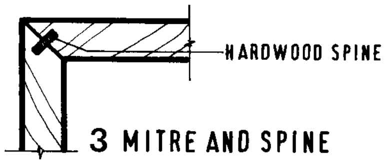


SECTION

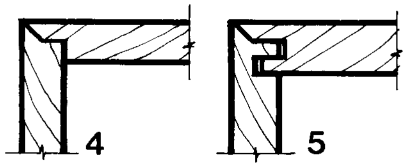


SHOULDER JOINTS

THESE JOINTS ARE USED FOR INEXPENSIVE WORK. THEY ARE GLUED; 2 IS STURDIER.



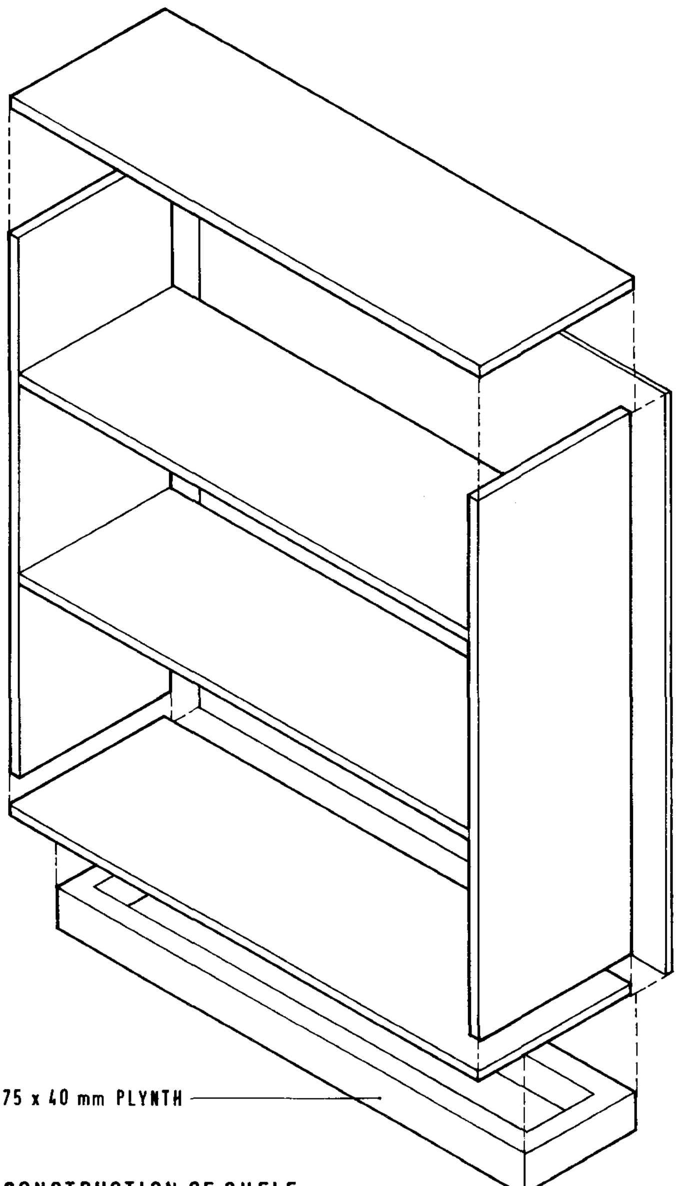
3 MITRE AND SPINE



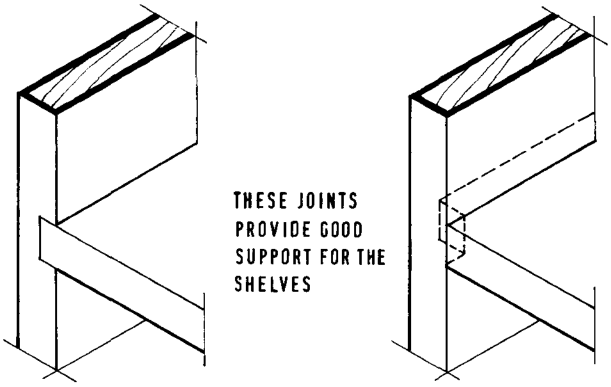
4 MITRE AND SHOULDER

5 MITRE AND T. & G.

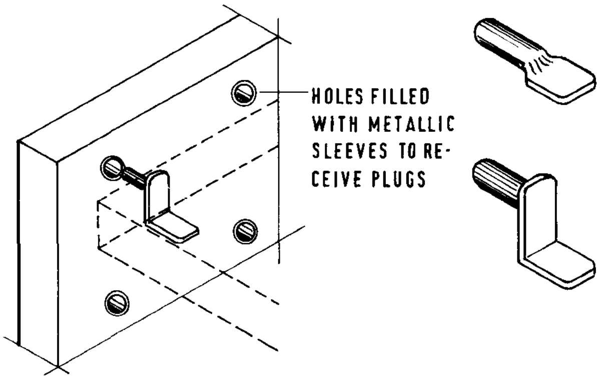
BOOKSHELVES CAN BE BUILT - IN OR MANUFACTURED FREE STANDING. THEY HAVE FIXED (6) OR ADJUSTABLE SHELVES (7). CORNER JOINTS BETWEEN THE TOP, BOTTOM AND SIDES OF A SHELF CAN BE SHOULDER JOINTS (1,2) OR MITRED JOINTS (3,4,5). THE MITRE AND SPINE JOINT IS PREFERABLE FOR EXTERNAL CORNERS. THESE JOINTS ARE GLUED. THEY CAN ALSO BE FACE - SCREWED OR NAILED. WHEN VENEERED PLYWOOD IS USED FOR SHELF CONSTRUCTION JOINTS MUST BE GLUED.



CONSTRUCTION OF SHELF



6 FIXED SHELVES : EXPOSED JOINT (LEFT) AND CONCEALED MORTISE

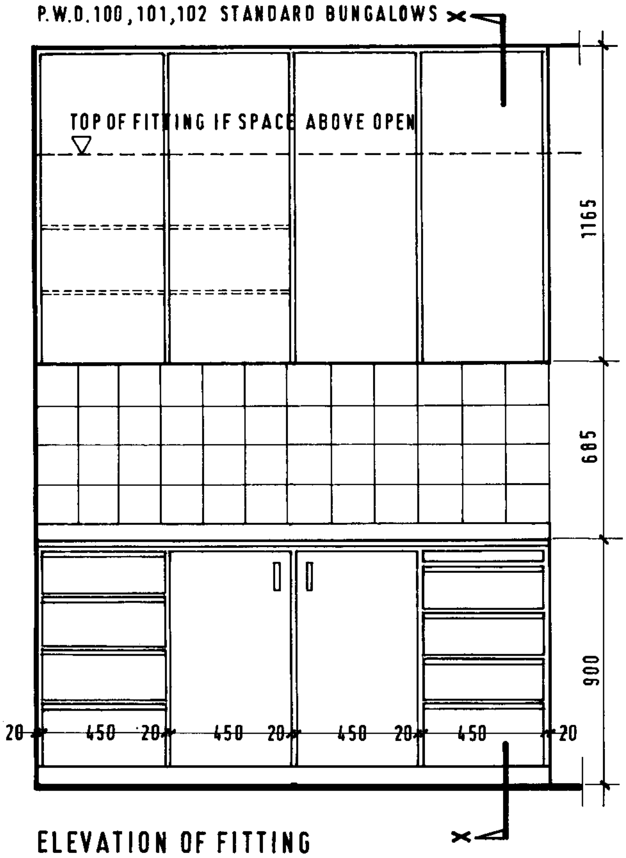


7 ADJUSTABLE SHELVES

5.4.10 BUILT-IN FITTINGS

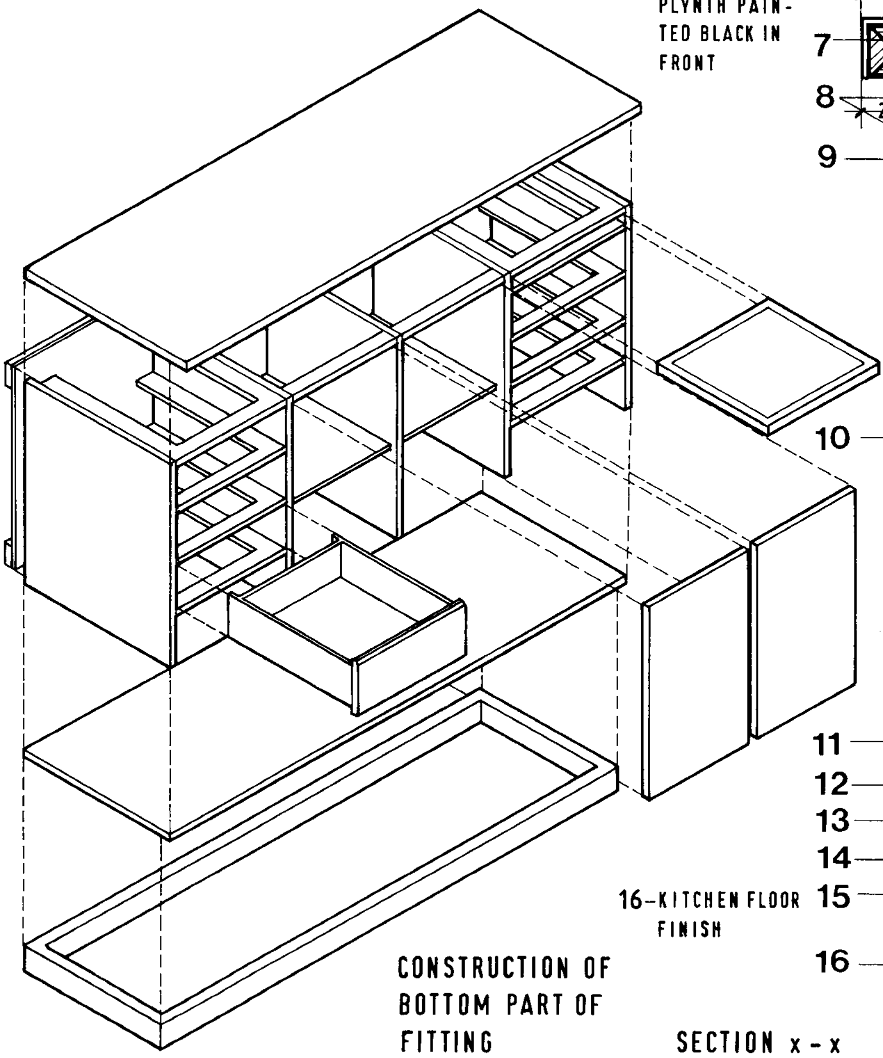
FIG.362 : KITCHEN FITTING (PART OF)

DESIGNED BY HANNAH SCHRECKENBACH FOR
P.W.D.100, 101, 102 STANDARD BUNGALOWS

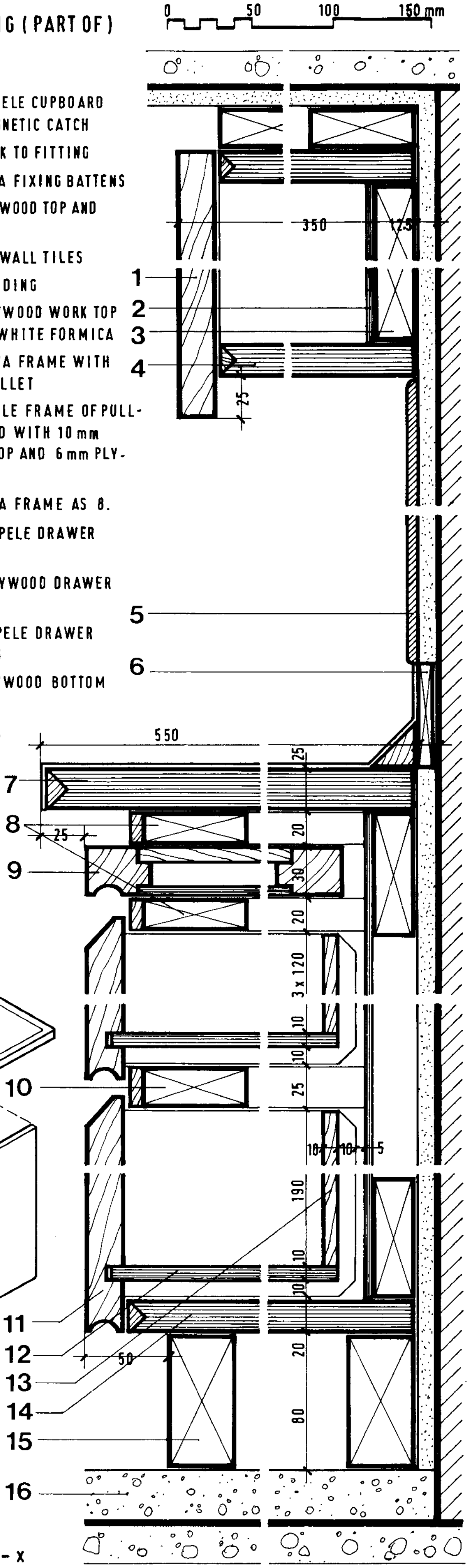


ELEVATION OF FITTING

1-25 mm THICK SAPELE CUPBOARD DOOR WITH MAGNETIC CATCH
2-HARDBOARD BACK TO FITTING
3-75 x 25 mm WAWA FIXING BATTENS
4-20 mm THICK PLYWOOD TOP AND BOTTOM
5-WHITE GLAZED WALL TILES
6-65 x 12.5 GROUNDING
7-25 mm THICK PLYWOOD WORK TOP COVERED WITH WHITE FORMICA
8-65 x 20 mm WAWA FRAME WITH SAPELE FACE FILLET
9-40 x 30 mm SAPELE FRAME OF PULL-OUT CHOP BOARD WITH 10 mm THICK SAPELE TOP AND 6 mm PLYWOOD BOTTOM
10-65 x 25 mm WAWA FRAME AS 8.
11-25 mm THICK SAPELE DRAWER FRONT
12-10 mm THICK PLYWOOD DRAWER BOTTOM
13-10 mm THICK SAPELE DRAWER BACK AND SIDES
14-20 mm THICK PLYWOOD BOTTOM TO CUPBOARD
15-80 x 40 mm WAWA PLYNTH PAINTED BLACK IN FRONT
16-KITCHEN FLOOR FINISH

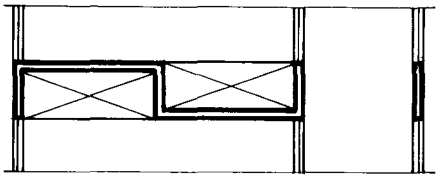


CONSTRUCTION OF BOTTOM PART OF FITTING



SECTION X - X

5.4.10 BUILT-IN FITTINGS



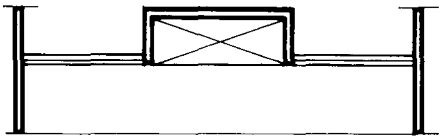
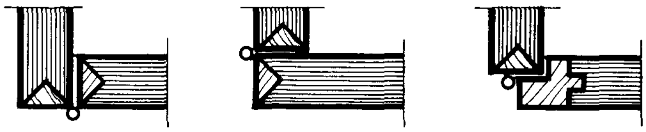


FIG. 363 **BUILT-IN WARDROBE**

DESIGNED FOR P.W.D. STANDARD BUNGALOW TYPES 100, 102, 103 BY HANNAH SCHRECKENBACH.

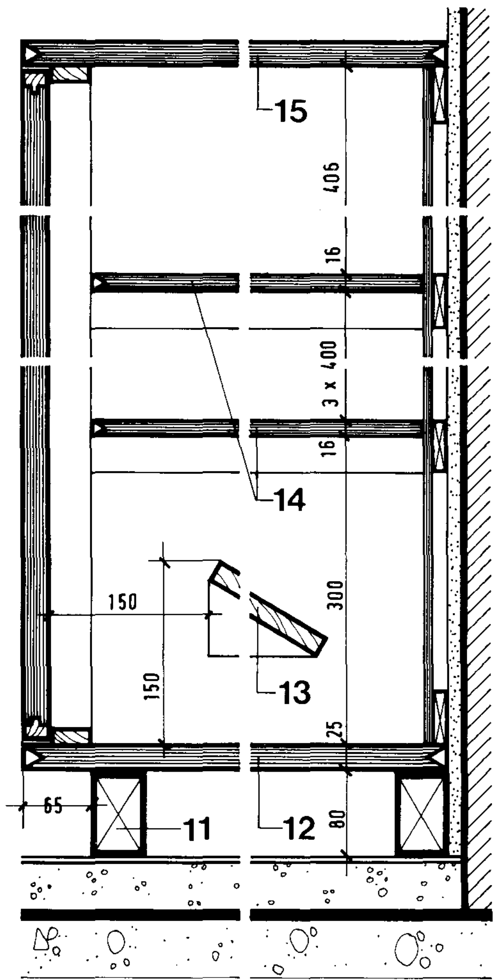
THE WARDROBE CAN BE BUILT TO BE PART OF A PARTITION WALL AS SHOWN IN 1 OR TO BE PART OF THE EXTERNAL WALL AS SHOWN IN 2 AND BELOW.



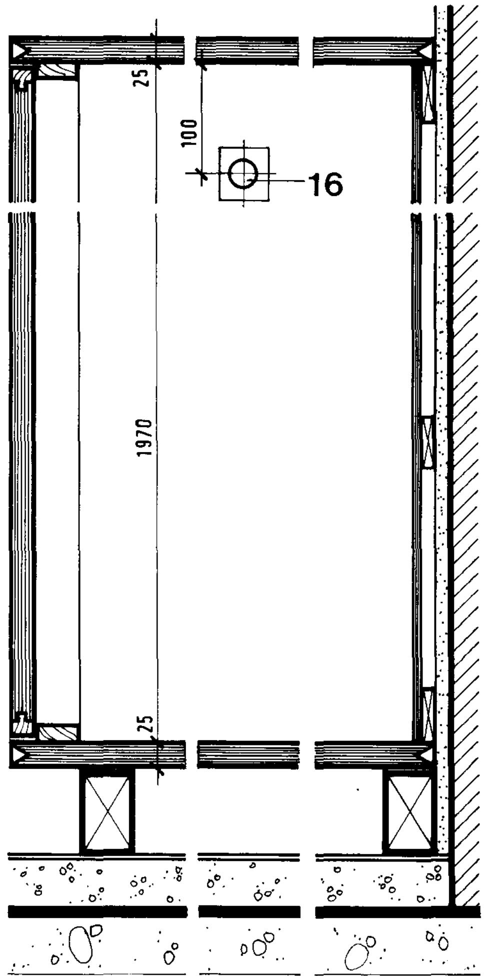
EDGES CONCEALED: LEAST EXPENSIVE. PLYWOOD FLUSH DOOR WITH EDGE TRIMMINGS.

EDGES EXPOSED: SIMPLE EFFECT, TO BE USED ONLY IF CORNERS OF WARDROBE ARE EXPOSED.

LIP DOOR: THIS PRODUCES A RAISED PANEL EFFECT.



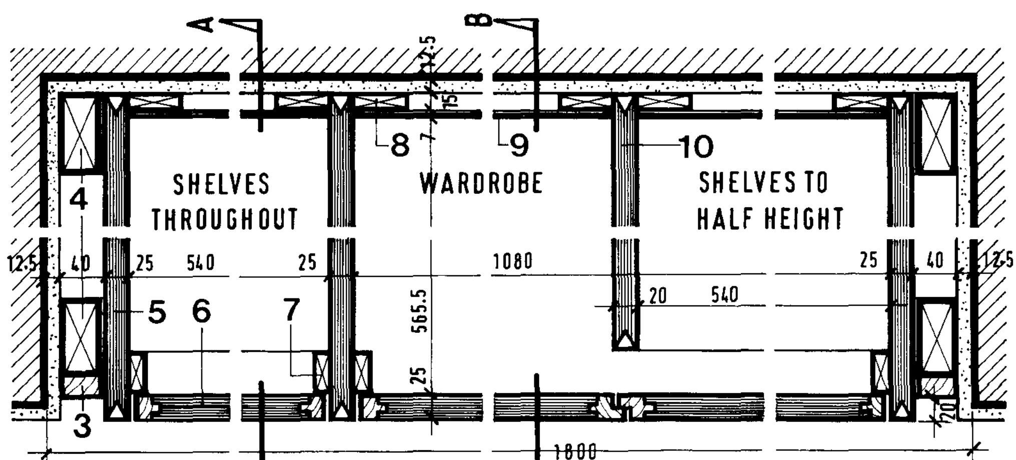
SECTION A - A



SECTION B - B

3 — 40 x 20 mm EDINAM FILLET
4 — 75 x 40 mm WAWA BLOCKING
5 — 25 mm THICK PLYWOOD SIDES OF WARDROBE WITH EDINAM EDGE TRIMMING
6 — 25 mm THICK PLYWOOD WARDROBE DOOR VENEERED ON THE OUTSIDE WITH EDINAM
7 — 40 x 15 mm PLANTED DOOR STOP
8 — 50 x 15 mm GROUNDING
9 — 7 mm THICK PLYWOOD BACK TO UNIT
10 — 20 mm THICK PLYWOOD SHELF SIDE
11 — 80 x 50 mm WAWA PLYNTH, PAINTED BLACK
12 — 25 mm THICK PLYWOOD BOTTOM OF WARDROBE WITH EDINAM EDGE TRIMMING
13 — 20 mm THICK HARDWOOD SHOE SHELF ON 20 mm THICK BEARERS
14 — 16 mm THICK PLYWOOD SHELVES ON 40 x 15 mm HARDWOOD BEARERS
15 — 25 mm THICK VENEERED PLYWOOD WARDROBE TOP WITH EDINAM EDGE TRIMMING
16 — 25 mm DIAMETER METALLIC OR HARDWOOD HANGING RAIL FIXED WITH A SLEEVE AND M.S. PLATE TO WARDROBE SIDES

HEATED WARDROBES IN HUMID CONDITIONS SHOULD BE PROVIDED WITH SMALL VENT OPENINGS IN THE WARDROBE DOORS TO INDUCE AIR MOVEMENTS.

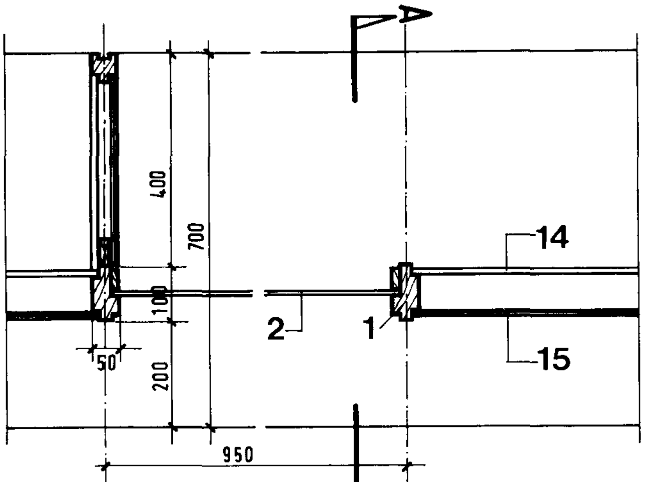


PLAN OF WARDROBE

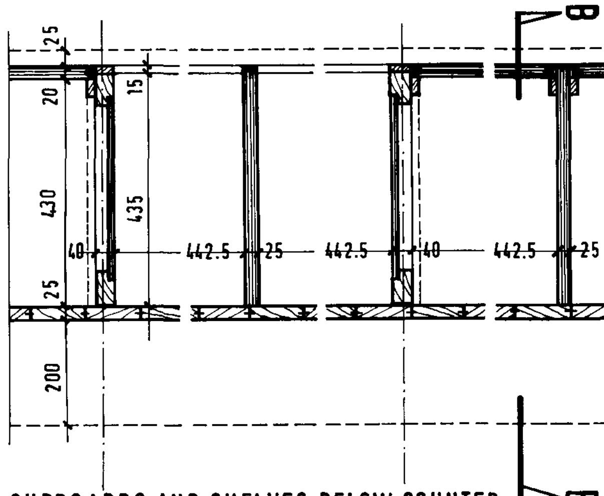
5.4.10 BUILT-IN FITTINGS

FIG. 364 : POST OFFICE COUNTER, PARLIAMENT HOUSE, ACCRA

ARCHITECT : HANNAH SCHRECKENBACH, 1970.



PART OF COUNTER PLAN



CUPBOARDS AND SHELVES BELOW COUNTER

1—100 x 50 SAPELE FRAME

2—6 mm THICK CLEAR GLASS FIXED TO FRAME

3—25 mm THICK PLYWOOD TOP, FRONT AND BACK TO COUNTER COVERED WITH BLACK FORMICA

4—120 x 40 FRAMING

5—65 x 40 mm FRAMING FACED IN FRONT WITH SAPELE FILLET

6—25 mm THICK SAPELE DRAWER FRONT WITH 65 mm WIDE BLACK PLASTIC STRIP FIXED TO WIDTH OF DRAWER

7—12.5 mm THICK SAPELE BACK AND SIDES OF DRAW-

8—ER AND 12.5 m THICK PLYWOOD BOTTOM

9—25 mm THICK T. & G. SAPELE STRIPS, 100mm WIDE

10—20 mm THICK SAPELE FACED PLYWOOD DOOR

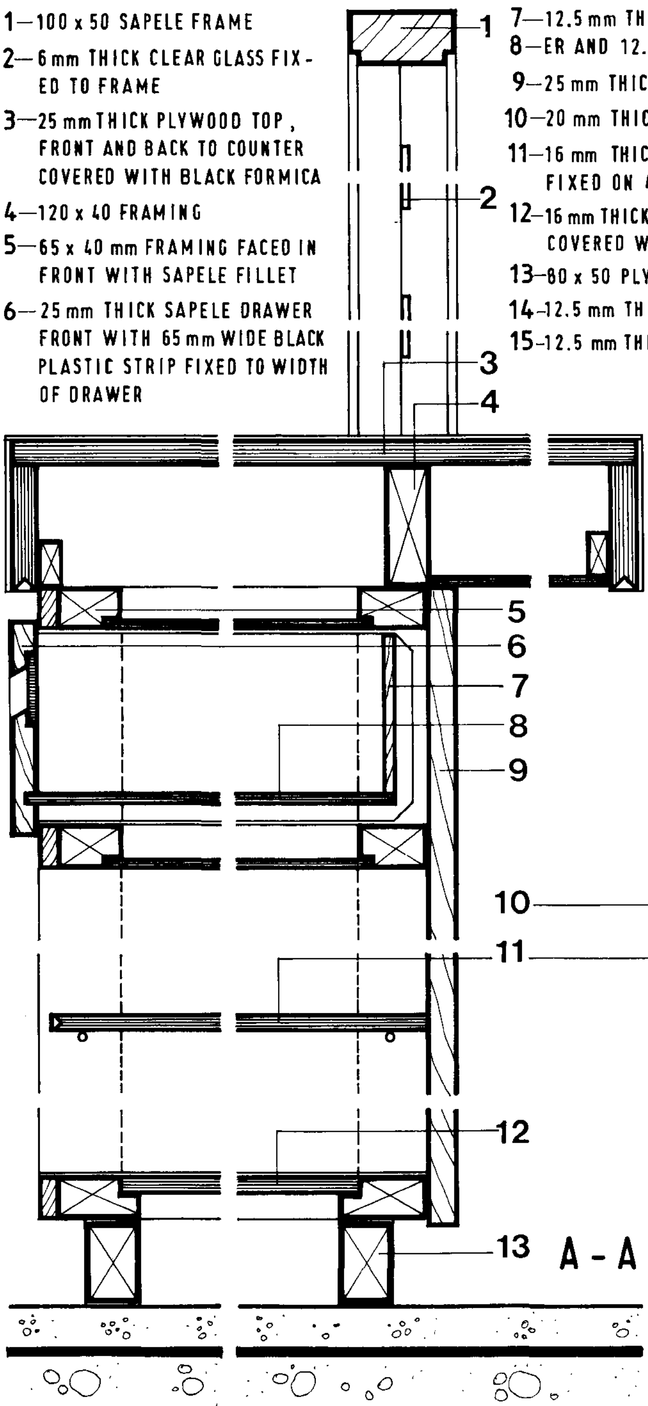
11—16 mm THICK PLYWOOD SHELVES ADJUSTABLE OR FIXED ON 40 x 15 BEARERS

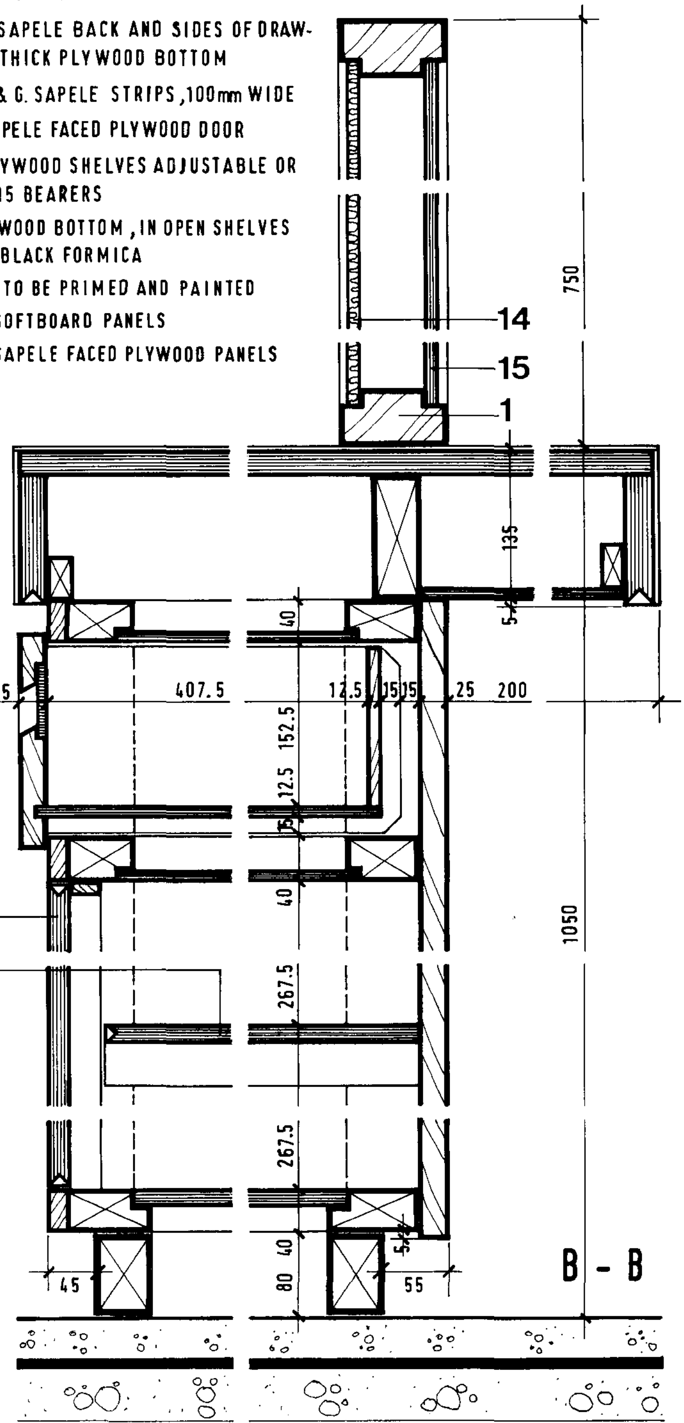
12—16 mm THICK PLYWOOD BOTTOM, IN OPEN SHELVES COVERED WITH BLACK FORMICA

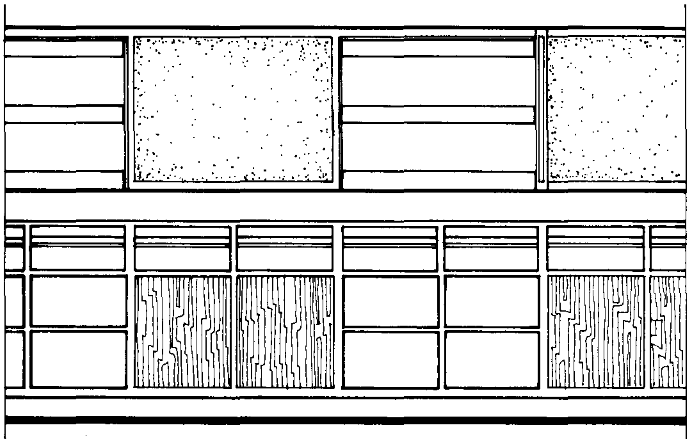
13—80 x 50 PLYNTH TO BE PRIMED AND PAINTED

14—12.5 mm THICK SOFTBOARD PANELS

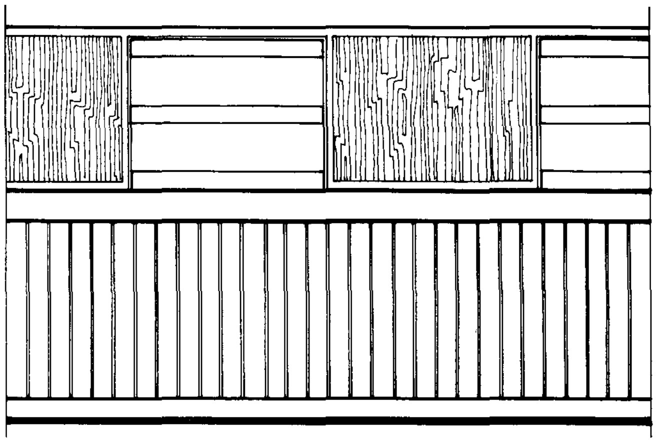
15—12.5 mm THICK SAPELE FACED PLYWOOD PANELS







ELEVATION FROM SERVICE SIDE OF COUNTER



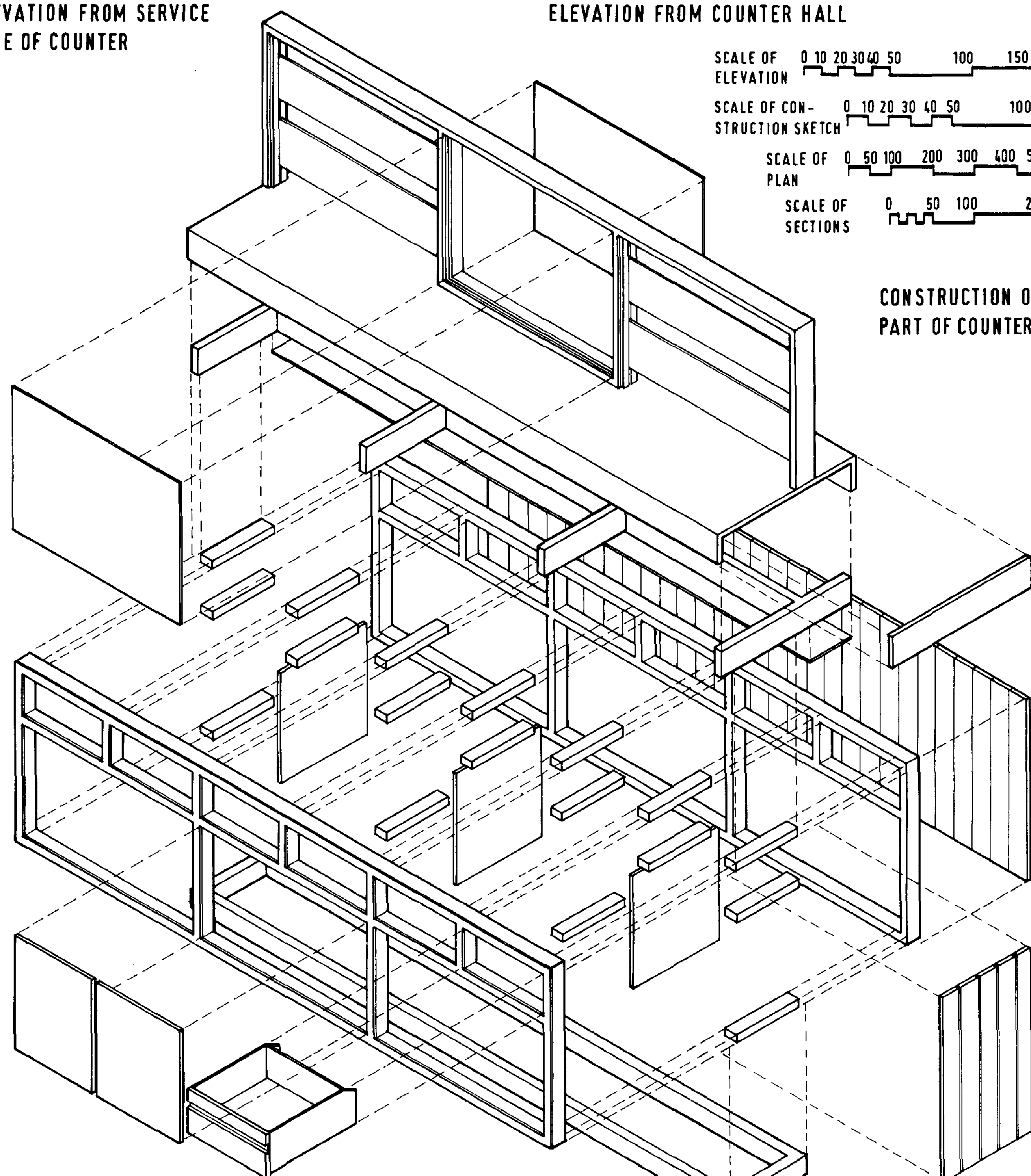
ELEVATION FROM COUNTER HALL

SCALE OF ELEVATION 0 10 20 30 40 50 100 150 cm

SCALE OF CONSTRUCTION SKETCH 0 10 20 30 40 50 100 cm

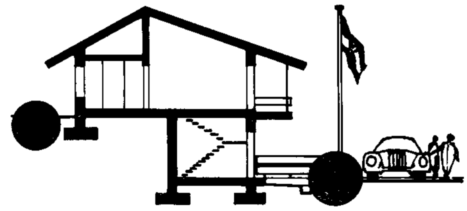
SCALE OF PLAN 0 50 100 200 300 400 500 mm

SCALE OF SECTIONS 0 50 100 200 mm



CONSTRUCTION OF PART OF COUNTER

5.5 EXTERNAL WORKS



In this part the basic external works will be listed and detailed including some aspects of hard landscaping which should be familiar to an architect when he is designing for an urban environment.

The most important external work is drainage. In this section only drainage above ground will be discussed. Drainage below ground will be explained in part 6 of this book (**"Basic Services"**).

5.5.1 DRAINAGE

"Drainage" means the removal of any liquid by a system which is specifically constructed for this purpose. Whereas a **Foul Water Drain** is a drain conveying foul water (water contaminated by soil waste, waste or trade effluent) normally underground (and which will be described under "Sewage Disposal" in "Basic Services"), a **Surface Water Drain** is a drain conveying surface water (run-off of natural water from the ground surface, paved areas, roofs and unpaved land). In certain conditions a **Subsoil Water Drain** may be necessary, which is a drain conveying subsoil water, that is water occuring naturally below the surface of the ground, e.g. on large areas of flat ground, like a football pitch or other playing fields.

DESIGN PRINCIPLES

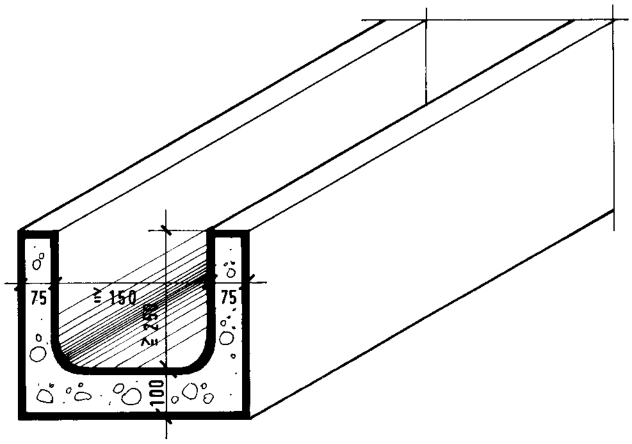
Any drainage installation should be self cleaning. It should function with a minimum of maintenance while collecting and discharging surface water without causing a nuisance or any danger to health. The design of any drainage system should be as simple and direct as circumstances of any site permit. Any future development on a site or adjacent sites (new development, extensions) should be considered when determining sizes, runs and falls of drains. References should always be made to the requirements and planning proposals of the local authorities and to their bye-laws.

5.5.1.1 SURFACE DRAINS

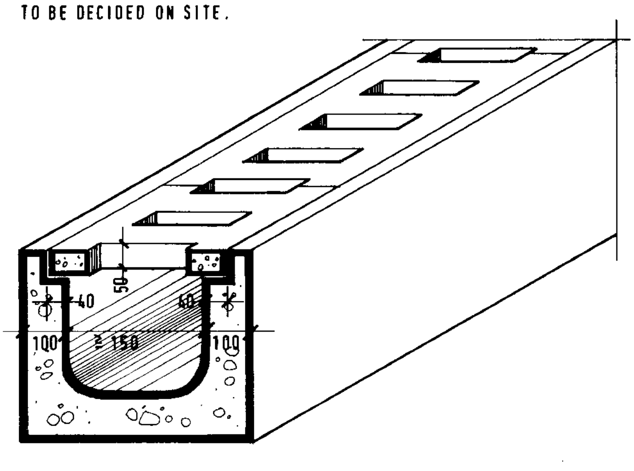
Drains carrying off surface water can be constructed as open and covered drains.

– **Open Drains:** A tropical rainstorm can produce, over a short period, very heavy rainfall, so that it is important to design a sufficiently large surface drainage system which can cope with the flood but which can also easily be cleaned when clogged up with debris (leaves, sticks, slick etc.). Data on average and peak levels of rainfall can be obtained from the local meteorological services to enable the designer to design the correct size of drain. An architect normally designs only the drains which collect the surface water from the site of his project. This drain will discharge into a common or storm water drain, the design of which is the responsibility of the local authorities. The on-site open drains are usually precast or in situ cast concrete drains (Fig. 365).

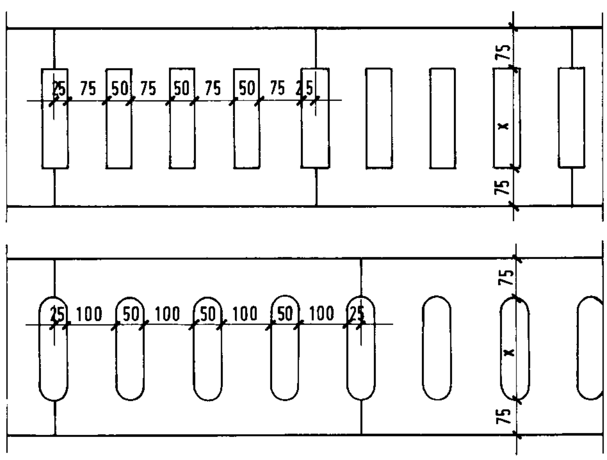
– **Covered Drains:** Concrete drains can be covered where it is so required with concrete covers, cast iron or steel grilles. Care must be taken to sufficiently reinforce concrete covers, especially in areas where drains cross driveways and parking areas.



OPEN IN-SITU CAST CONCRETE DRAIN
DEPTH AND WIDTH OF DRAIN
TO BE DECIDED ON SITE.

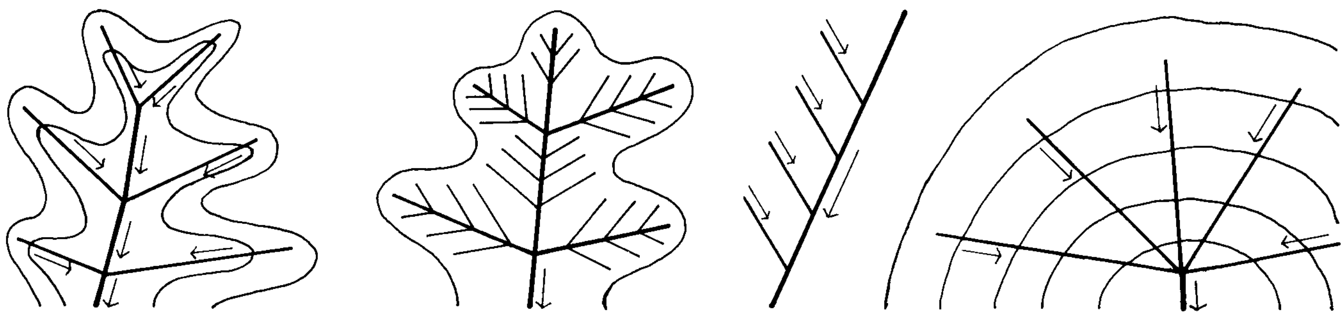


COVERED CONCRETE DRAIN : THE CONCRETE COVERS ARE REINFORCED AND CAN BE CAST IN LENGTHS FROM 500 TO 600 mm AND 50mm THICK.



DRAIN COVERS CAN BE CAST WITH NARROW OPENINGS AS SHOWN ABOVE OR SOLID WITH GRIP OPENINGS AT BOTH ENDS OF THE COVER SLAB. WIDTH OF OPENING 'x' DEPENDS ON WIDTH OF DRAIN.

FIG.365 : OPEN AND COVERED CONCRETE DRAINS

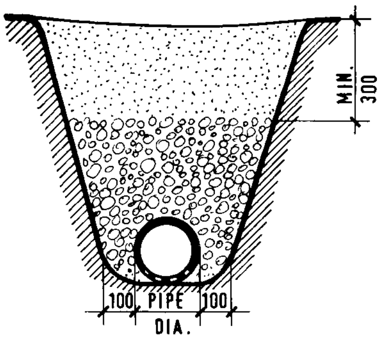


NATURAL : PIPES ARE LAID TO FOLLOW THE NATURAL VALLEYS AND DEPRESSIONS ON SITE. BRANCHES DISCHARGE INTO THE MAIN DRAIN. THIS DISCHARGES INTO A RIVER.

HERRINGBONE : SMALLER SUBSIDIARY BRANCHES (PARALLEL TO EACH OTHER) DISCHARGE FROM BOTH SIDES AT AN ANGLE INTO MAIN BRANCHES. SUBSIDIARIES SHOULD NOT EXCEED 30 m IN LENGTH.

GRID : THIS IS A MAIN NEAR THE BOUNDARIES OF A SITE, INTO WHICH BRANCHES DISCHARGE FROM ONE SIDE ONLY.

FAN SHAPE : THE DRAINS ARE LAID ON THE SITE SO THAT THEY CONVERGE TO A SINGLE OUTLET INTO THE MAIN DRAIN AT ONE POINT ON THE BOUNDARY.

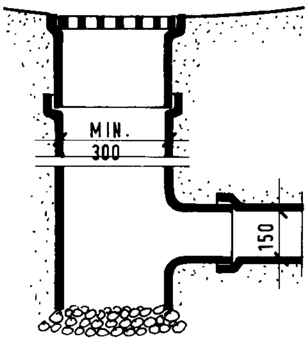


SANDY PERMEABLE SOIL

10 mm TO 20 mm DIAMETER COARSE SAND AND GRAVEL MIXTURE.

PERFORATED DRAIN PIPE LAID WITH PERFORATIONS FACING DOWN.

DRAIN PIPE DETAIL



CONCRETE OR VITRIFIED CLAY PIPES WITH UNDERGROUND CONNECTIONS TO A MAIN DRAIN ARE USED, WITH CAST IRON GRATES.

TYPICAL LAWN DRAIN

FIG.366 : **SUBSOIL DRAINAGE**

5.5.1.2 SUBSOIL DRAINS

Subsoil water or land drainage may be necessary for a number of reasons:

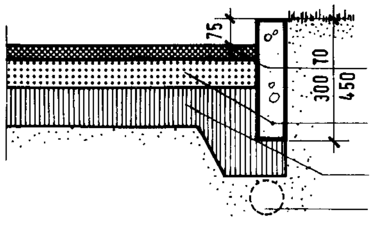
- To avoid surface flooding;
- To increase surface stability;
- To reduce dampness of the ground below buildings.

Fig. 366 explains the different systems of subsoil drains. Subsoil drains must discharge into a natural ditch or water course. Where this is not possible they may, on the approval of the local authorities, discharge into a surface drainage via an intercepting trap. The following materials are used for subsoil drains:

- **Clayware;**
- **Slotted P.V.C. Pipes;**
- **Porous Concrete** (if the subsoil water carries sulphates or is acid, this is not suitable);
- **Perforated Galvanized Steel Pipes.**

5.5.2 DRIVEWAYS

Driveways are entrances and exits to sites. It may not be necessary to construct them in the same way as roads, but as they form part of the external works an architect must be familiar with some details. Surface water drainage normally runs along on one side of the driveway. The driveways must be constructed so that water drains off easily from their surfaces. Bases of driveways must be well compacted. In most tropical developing countries driveways are constructed with a 25mm thick gravel (of 10mm diameter crushed stone) layer on top of 150mm compacted sub-grade. In places with a fair amount of traffic an asphaltic seal coat is used on top of a 65mm thick layer of crushed stone on 150mm thick compacted base course. Where heavy traffic is expected a 50mm thick layer of bituminous concrete on top of compacted sub-grade is suggested. For large car-parking areas with heavy traffic it may be advisable to use a 150mm thick concrete layer on 150mm thick compacted sub-grade (Fig. 367).



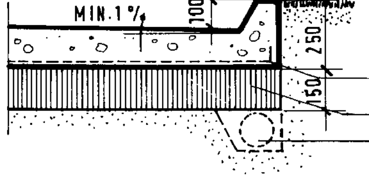
FOR HEAVY TRAFFIC :

50 mm THICK BITUMINOUS CONCRETE

100 mm THICK LAYER WELL COMPACTED CRUSHED STONES

BASE, COMPACTED SUB-GRADE

DRAIN, IF NECESSARY



FOR LARGE PARKING AREAS :

MESH REINFORCEMENT

COMPACTED SUB-GRADE

DRAIN

FIG.367 : **DRIVE WAYS AND CAR PARKING AREAS**

MINIMUM LONGITUDINAL PITCH FOR PROPER DRAINAGE OF DRIVE WAYS AND CAR PARKING AREAS IS 1%. IF GUTTERS ARE USED RUN-OFFS OR CATCH BASINS SHOULD BE PROVIDED AT SUITABLE INTERVALLS OR UNDERGROUND DRAINAGE, DEPENDING ON SOIL CONDITIONS.

CONCRETE SLABS OF PARKING AREAS MAY BE COVERED WITH A 25 mm TO 50mm THICK LAYER OF ASPHALT. EXPANSION JOINTS MUST BE PROVIDED IN THE CONCRETE SLAB EVERY 10 m. CURBS AT THE EDGE OF DRIVE WAYS AND PARKING AREAS CAN BE OF CONCRETE, 100mm THICK, OR NATURAL STONE (GRANITE).

5.5.3 PAVING AND HARD LANDSCAPING

In the urban context not only the buildings but equally so the connective webs of open spaces between the buildings play an important part. It is these spaces which link buildings and penetrate into their interiors with which the urban designer works when designing an "urban landscape". This complex network of urban space found in medieval European towns and many traditional settlements all over the world is both functionally sensible and aesthetically immensely satisfying. Urban spaces are created of paths and places.

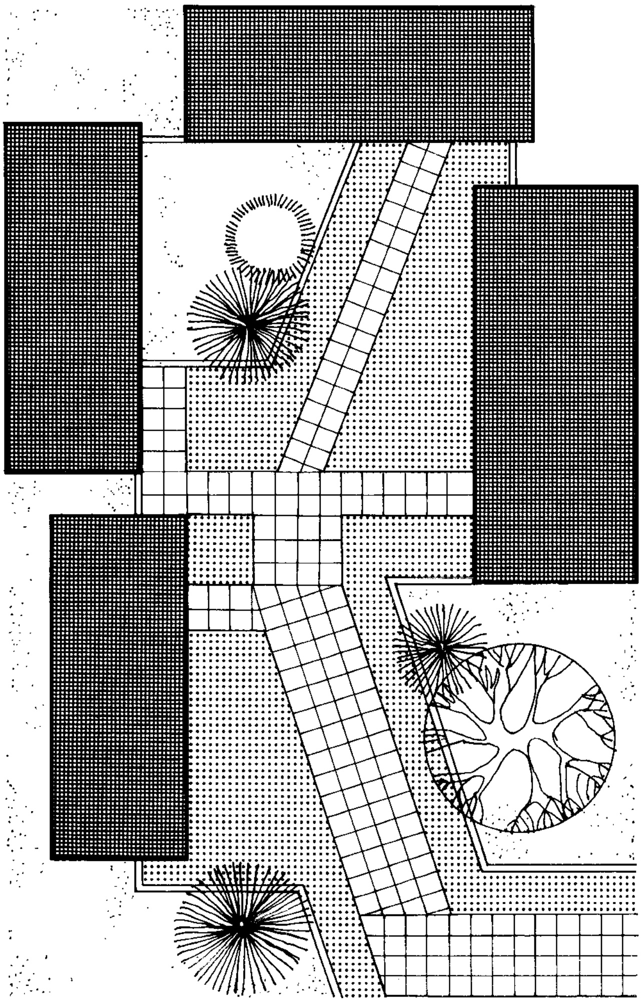
Paths: These cater for movement. They must not only facilitate physical movement but also help us to orientate ourselves; in short they should enable us to get from where we are to where we want to go. Paths are: Roads, pavements, alleys, lanes, footways, steps, ramps.

Places: These are the nodes where movement comes to a stop. They can be in-between paths, or at the end of paths. They are: Parks, courtyards, squares, gardens, playgrounds and outdoor sitting areas. A place, square, courtyard, etc. can turn into a path through pathways encircling or crossing them.

5.5.3.1 LANDSCAPE DESIGN

The design concept for hard and soft landscaping is dictated by:

- **The Site**: Wheter the site is level, steep, concave or convex contoured;
- **The Site in Relation to Adjacent Sites**: Wheter there is a pronounced relation, e.g. raised above or sunk below the adjacent sites;
- **The Views from the Site**: When sitting at different points on the site or when moving;
- **The Surroundings of the Site**: Whether the site is inside a city where the townscape is dominated by high-rise buildings (and where hard landscaping is obviously more dominant) or whether the site is in the outer town ring or suburban area (where a smaller scale hard landscaping with more soft landscaping is appropriate) or whether the site is in a rural setting (where essentially soft and natural landscaping dominates).



Hard landscaping design is a matter of manipulating spaces, masses, textures and colours in such a way as to produce aesthetic satisfaction and delight for the pedestrian.

5.5.3.2 PAVING

This serves to relate and unify buildings at different levels together with planting. It provides at the same time a hard, durable and nonslip surface which should also be suitable for limited vehicular traffic (service vehicles to shops and markets in pedestrian only or traffic-free areas). Paving can be arranged in such a layout or pattern or by using different colours that it imparts a sense of direction to the pedestrian. By using rough or heavily profiled surfaces which are uncomfortable to walk on pedestrians can be prevented from using areas which should not be used for walking on. The design of a paved area can encourage people to follow certain paths, not in a rigid way but considering natural movements and circulation patterns (Fig. 368). Most paving slabs are precast concrete slabs with different surface finishes. Burnt brick paving of different patterns is also common, as well as paving with natural stone flags. All are bedded in sand-cement or sand-lime mortar on a compacted gravel or laterite bed (Fig. 369). In situ concrete paving is economic in large areas, but must incorporate dividing strips to form panels and include suitable slabs or manhole covers at places where inspection chambers, ducts or manholes are to be incorporated later. Large paved areas must be provided with sufficient fall to drain-off as quick as possible.

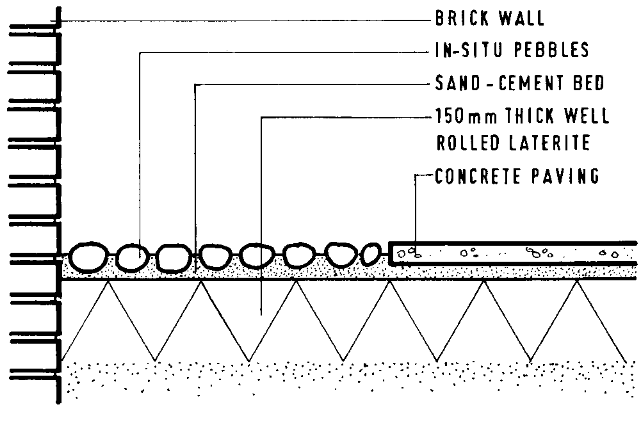
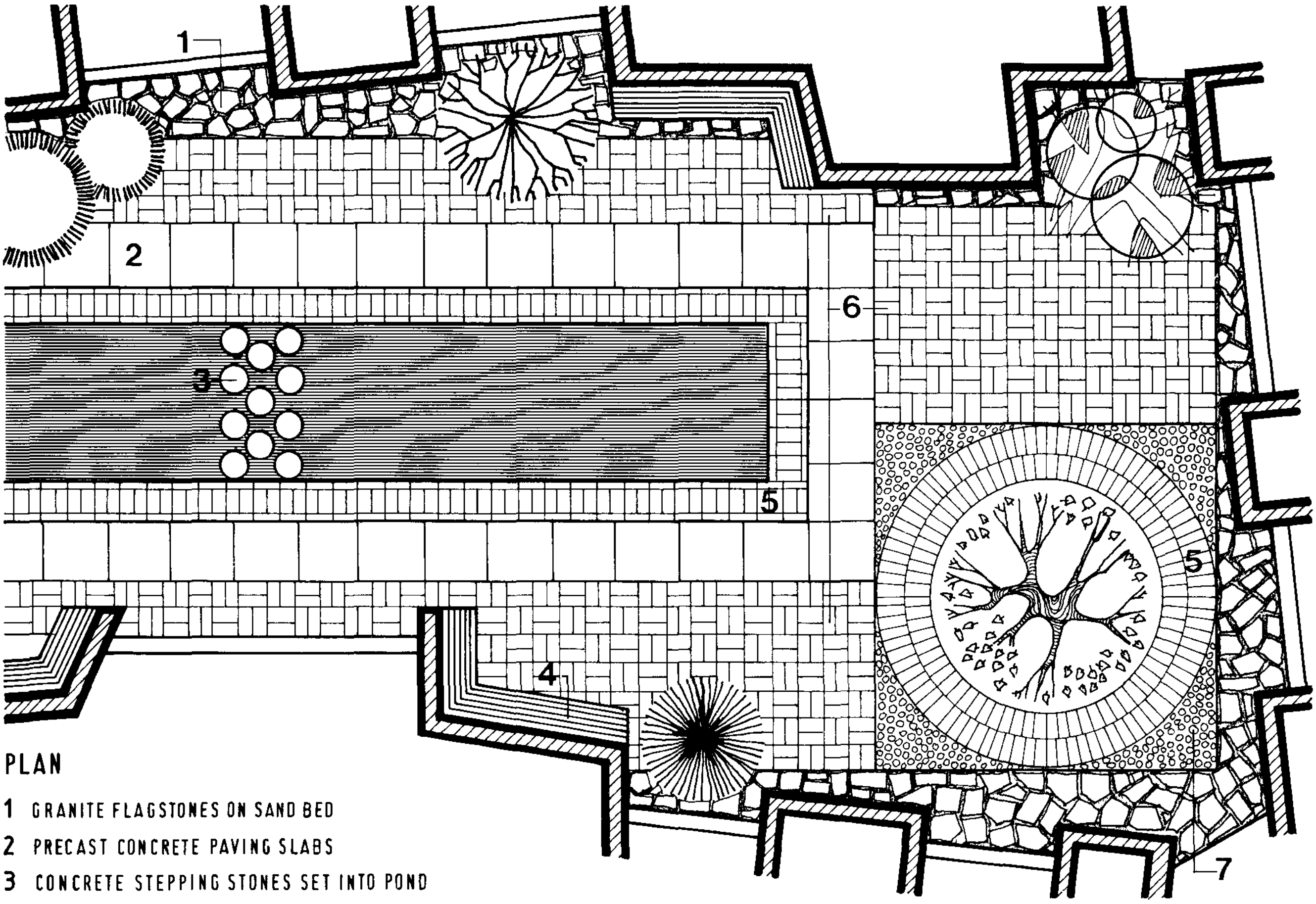


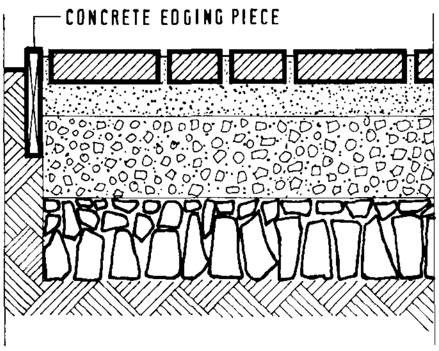
FIG.368 : **SENSE OF DIRECTION THROUGH PAVING**

PAVING SLABS CAN BE EXPLOITED TO PROVIDE A COMFORTABLE, NON-SLIP, TRAFFIC BEARING SURFACE AND TO GIVE A SENSE OF DIRECTION. IN-SITU COBBLES AND LARGE PEBBLES DISCOURAGE WALKING ON. THESE AREAS COULD BE USED FOR PARKING BICYCLES, PRAMS ETC. AND COULD ALSO FORM SURFACE DRAINAGE CHANNELS ALONGSIDE THE PATHS.



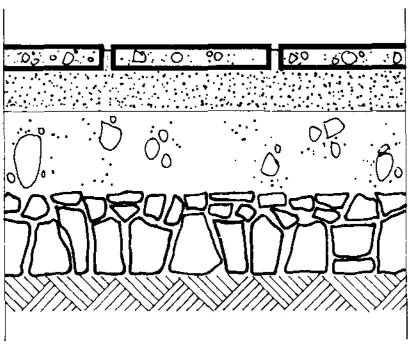
PLAN

1 GRANITE FLAGSTONES ON SAND BED
2 PRECAST CONCRETE PAVING SLABS
3 CONCRETE STEPPING STONES SET INTO POND
4 PERMANENT BENCH OF BRICKS AND 75 x 50 mm HARDWOOD SECTIONS
5 BRICK PAVING OF DIFFERENT PATTERNS
6 BRICK PAVING IN BASKET WEAVE PATTERN
7 IN-SITU LARGE PEBBLES SET INTO CEMENT - SAND SCREED



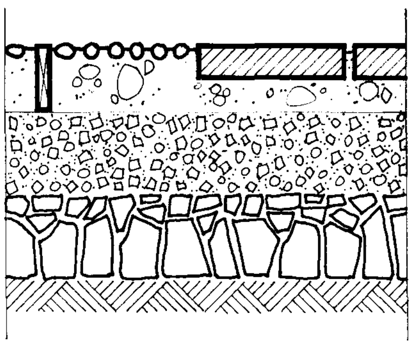
BRICK PAVING

BRICK PAVERS SET INTO 50 mm THICK COARSE SAND BED OVER 100 mm WELL COMPACTED GRAVEL LAYER AND BROKEN STONE BASE.



CONCRETE PAVING SLABS

PRECAST PAVING SLABS ON MIN. 25 mm THICK CEMENT-SAND BED OVER 100 mm GRAVEL LAYER AND STONE BASE.

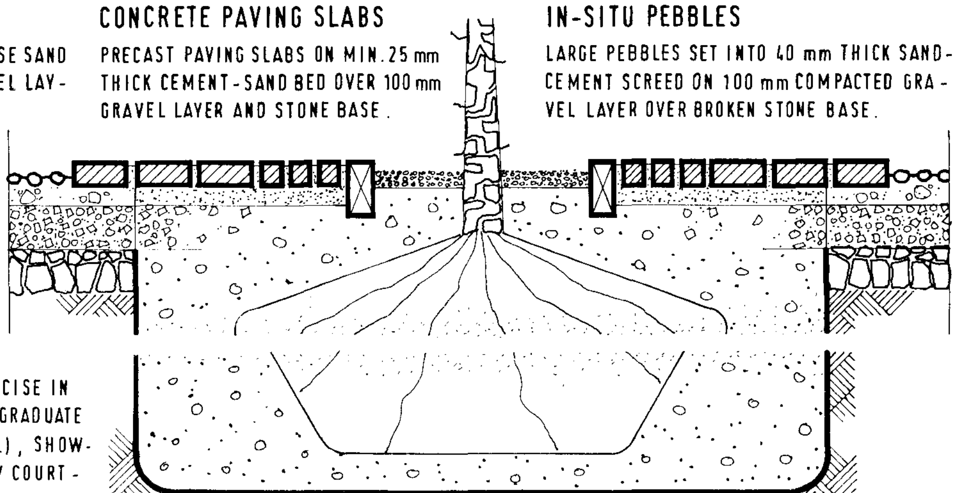


IN-SITU PEBBLES

LARGE PEBBLES SET INTO 40 mm THICK SAND-CEMENT SCREED ON 100 mm COMPACTED GRAVEL LAYER OVER BROKEN STONE BASE.

TREE SET INTO PAVEMENT

ROOTS OF TREE SET INTO SANDY, POROUS SOIL MIXED WITH COMPOST TO RETAIN MOISTURE. 100 x 50 mm CONCRETE EDGING PIECES TO BRICK PAVING.

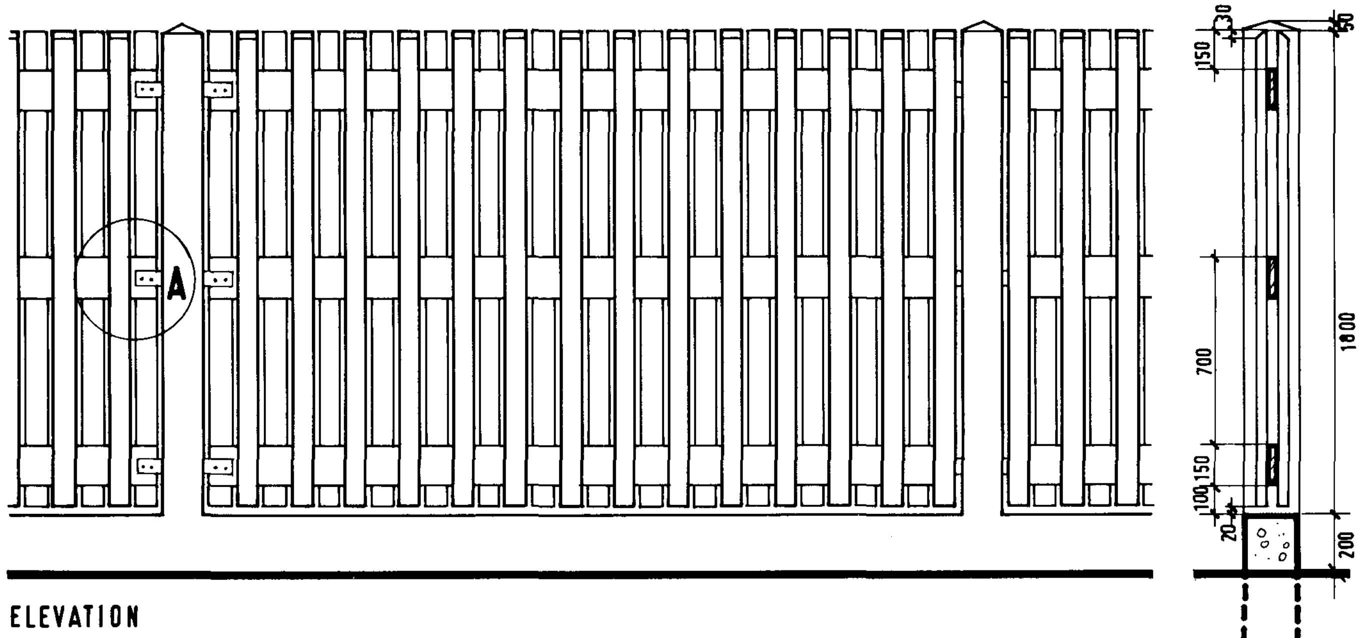


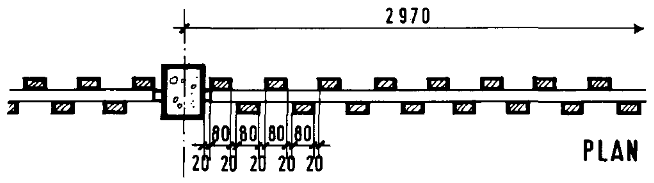
FROM A CONSTRUCTION TECHNOLOGY EXERCISE IN THE FIFTH YEAR (FIRST YEAR OF THE POSTGRADUATE DIPLOMA COURSE IN ARCHITECTURE, U.S.T.), SHOWING PART PLAN OF A UNIVERSITY LIBRARY COURTYARD, PRESENTED BY JACKSON G.K.ABANKWA.

FIG.369 : DIFFERENT PAVING PATTERNS

THE ABOVE EXERCISE WAS BASED ON THE DESIGN "CAMPUS CONNECTION", A REDESIGN OF THE ACADEMIC AREA OF U.S.T., KUMASI, BY W.F. HILL, SENIOR LECTURER, DEPT. OF ARCHITECTURE.

5.5.4 FENCING AND MISCELLANEOUS





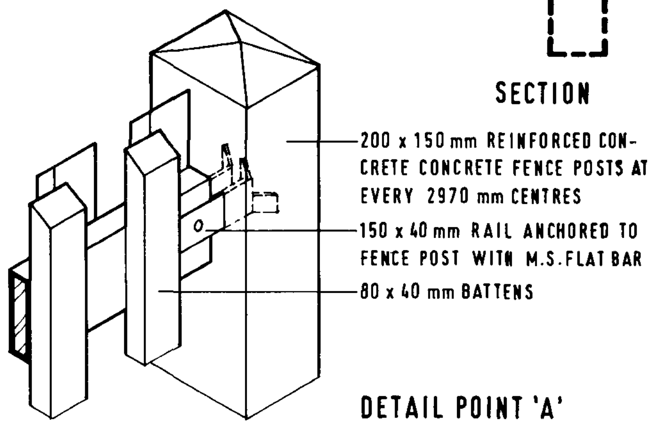


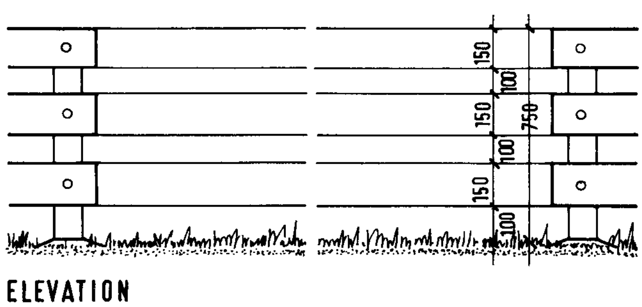
FIG. 370 : **TWO-SIDED TIMBER FENCE**

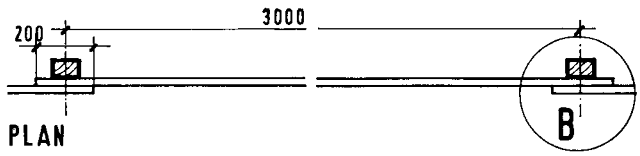
HEIGHT OF FENCE FROM 1.50 m TO 1.80 m. THE HEIGHT OF THE CONCRETE BASE WALL DEPENDS ON THE SITE CONTOURS. THE BASE WALL CAN BE STAGGERED FOR SLOPING SITES. WOOD FOR THE FENCE MUST BE WELL SEASONED AND PRESERVATIVE TREATED.

5.5.4.1 FENCES

The most common fencing material, galvanized or P.V.C. coated chain link and barbed wire fixed to concrete posts is very expensive. Moreover it is in most cases an imported building material which involves scarce foreign currency in many developing countries. As a simple and also beautiful substitute, a timber fence fulfills the same functions (Fig. 370 *and* 371). Other fencing material:

- **Hedges**: For shelter and cover, hedges, which bend with the wind, are more successful than rigid screens or solid fences. There are a number of fast growing thorny types of hedges for fencing in tropical countries, for example *Caesalpinia Pulcherrima* (Pride of Barbados or Flower Fence) and Jerusalem Thorn. Both are normally grown together.
- **Concrete**: Concrete can form a complete fence wall in form of prefabricated decorative perforated blocks or is normally used for fence posts in conjunction with other materials.
- **Steel**: Galvanized steel bars (round, square, flat) or hollow tubes are used in areas where unclimbable fencing is required. These rigid steel barriers can incorporate panels of different materials, P.V.C. coated wiremesh or barbed wire.





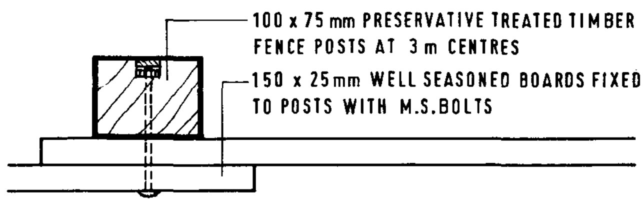


FIG. 371 : **LOW TIMBER BOARD FENCE (PAINTED WHITE)**

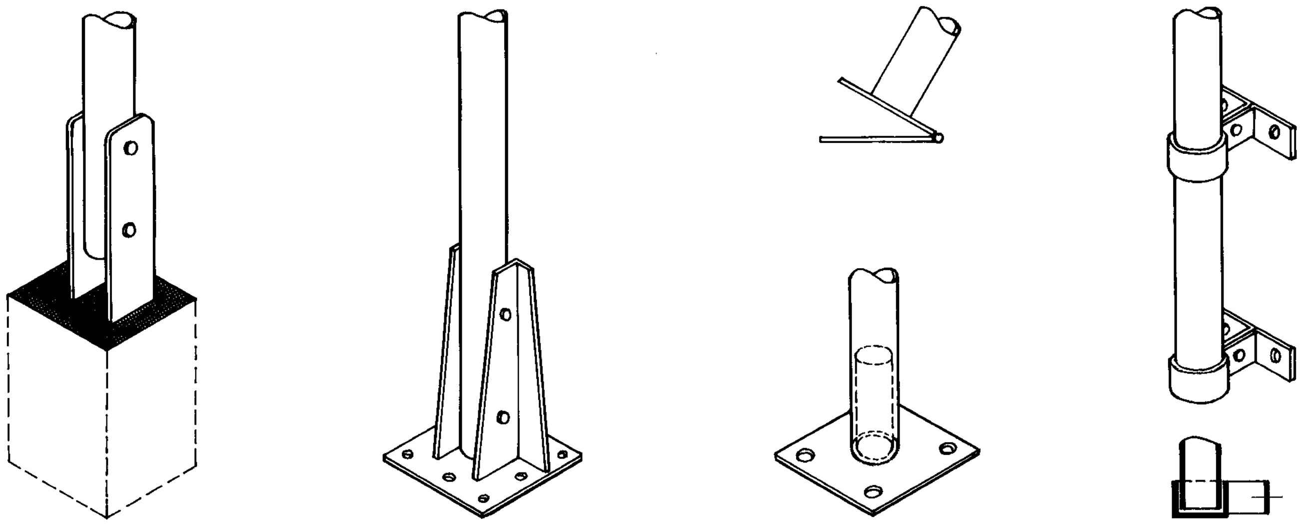
5.5.4.2 FLAGPOLES

Flagpoles and flagstaffs are equipped with a cap at the top, fixing hooks for the halyard line for raising and lowering of the flag, a pulley at the top through which the halyard line runs and a cleat at the lower end for securing the line.

MATERIALS

- **Timber**: Top-graded, well seasoned and preservative treated hardwood is necessary which is also elastic enough to withstand the stresses to which a flagpole is exposed.
- **Mild Steel:** Poles from galvanized mild steel can be put together by overlapping a number of tubular sections over each other.
- **Aluminium Alloy**: This is an expensive but very durable material for flagpoles. It does not need any surface treatment, except lacquering in very exposed conditions close to the seaside. The alloy can also be anodized.
- **Glass Fibre Flagstaffs**: These are very expensive but have become very popular, especially in Europe and the U.S.A. They are light in weight, corrosion-free, do not rot or weather and do not need any maintenance. Their standard of surface finish is unequalled by most of the other materials.

Fig. 372 shows different methods of fixing of flagpoles to supports on the ground or against a wall.



TRADITIONAL TABERNACLE FITTING

NORMALLY OF STEEL, SET INTO A CONCRETE BASE. LENGTH OF TABERNACLE AND DEPTH OF CONCRETE BASE DEPEND ON HEIGHT OF FLAG STAFF AND DYNAMIC LOAD. SUITABLE FOR TIMBER FLAG POLES OR TUBULAR FLAG STAFFS.

PLATE TABERNACLE

THIS TYPE OF FITTING IS SUITABLE FOR ROOF MOUNTING. THE FLAG STAFF IS FIXED TO TABERNACLE FITTINGS BY BOLTS PASSING AT TOP AND BOTTOM OF THE TABERNACLE THROUGH THE CENTRE OF THE FLAG STAFF.

FLANGE MOUNTING

FOR TUBULAR FLAG STAFFS. CAN BE ARRANGED TO HINGE AS SHOWN AT TOP.

WALL BRACKETS

USED FOR MOUNTING FLAG POLES ON THE FACE OF A BUILDING OR WALL. WALLS MUST HAVE ADEQUATE STRENGTH. THE BOTTOM BRACKET SHOULD HAVE A PLATE FIXED UNDER.

FIG. 372 : FIXING OF FLAG POLES

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(b) A. A. K. GBECKOR-KOVE – The Improved Mud Building (The Atakpame Building).

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(c) R. FISHER – Walls
(d) G. HALE – Floors
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(b) Security – No. 135, November, 1970.
(c) Problems of Concrete Production in Arid Climates – No. 139, August, 1971.
(d) Windows – Design and Function under Tropical Conditions (by C.G.H. PLANT) – No. 142, February, 1972.
(e) Building in Earthquake Areas – No. 143, April, 1972.
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(a) J.T. SINNAMON & G.A. VAN'T LOO – Cyclone Resistant Rural Primary School Construction – a Design Guide (Educational Building Report No. 7, 1977).

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(b) How to Build a House Using Self-help Housing Techniques – May, 1974.
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(a) B. G. WHITE – Aids to the Design of Shading Devices for Lattitudes 4°N to 12°N (Note No. 6, June, 1962).
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6 BASIC SERVICES

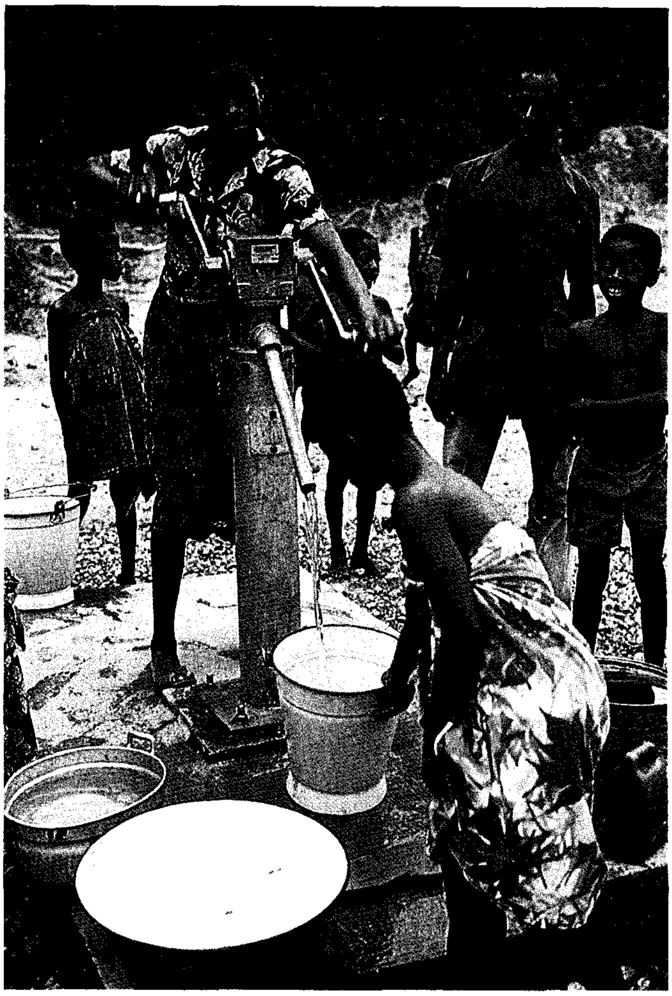


Fig. 374: Pumping water from a deep well in an Ashanti village, 1982.

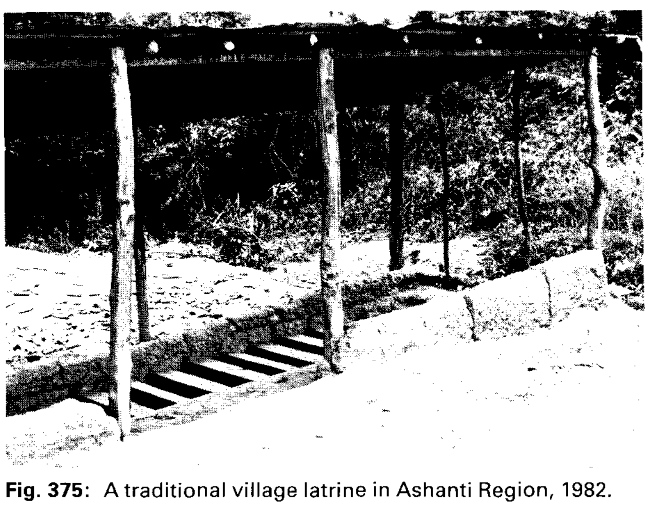


Fig. 375: A traditional village latrine in Ashanti Region, 1982.

Overleaf: Water, prescious water. The first clean water from a deep well drilled by Messrs. Prakla Seismos (Hannover) in an Ewe village in the Volta Region, 1982.

This part of the book describes and details services which are supplied to the community and to buildings, and which, in a wider sense, constitute basic needs of the people of developing countries. As can be seen further on, over half of the Third World population has inadequate or no access to some of these services, a fact which is adversely affecting the general socio-economic development of their countries.

Basic services, therefore, in the context of this book, are:

- Supply of safe water to the community and to individual dwellings;
- Sanitation (waste water and sewage disposal) for individual dwellings;
- Electricity supply to buildings and to individual households;
- Refuse collection.

6.1 INTRODUCTION

The provision of clean water and adequate sanitation is one of the basic needs of the people of the Third World. The 1981–1990 decade has been declared the "International Drinking Water Supply and Sanitation Decade" by the United Nations, following comprehensive reports prepared in the sixties and seventies by the World Health Organization for the UN, covering nearly the entire Third World. From these reports the following picture emerges:

- Over half of the Third World population has no safe water to drink;
- Over three-quarters have no kind of sanitation.

The World Health Organization further reports that by 1975 about 77% of the urban population of Third World countries were adequately served with some form of water supply (Fig. 374) but only 22% of the Third World's rural population had "reasonable" access to safe water. "Reasonable" access to safe water in the rural context was defined by the WHO as a situation where "the housewife or members of the household (mostly children – the author) do not have to spend a disproportionate part of the day in fetching the family's water needs". As far as sanitation is concerned only 25% of the urban population in the Third World had house connections to a public sewage disposal system in 1975 and only 50% of the people in the urban areas were served with some other form of excreta disposal facilities, e.g. bucket latrines and pit privies (Fig. 375). The WHO-survey shows a drop of these facilities in 1980. Also here there is a considerable difference between available facilities for the urban and the rural population. In 1980 only 13% of the rural people had adequate excreta disposal facilities.

In addition to these figures one must consider that with the steadily growing population in Third World countries the number of people without access to safe water and without sanitation also grows. This applies equally to the

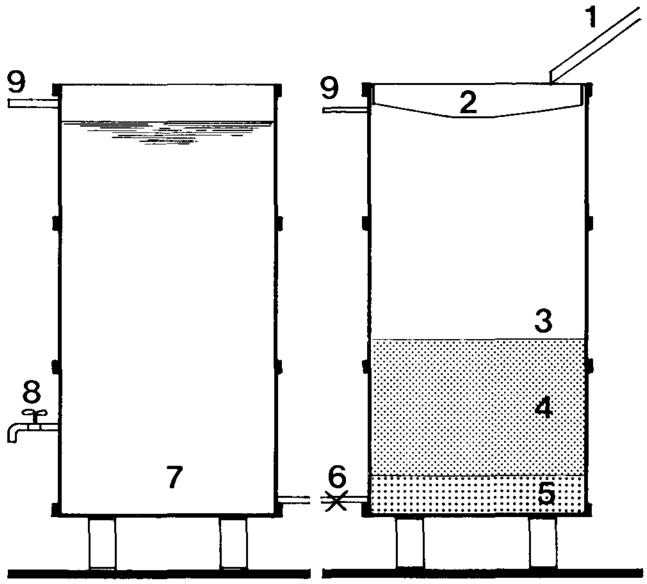
provision of electricity. In addition the tendency in developing countries is to supply electricity, if it is available in the form of hydro-power, thermal power or from generating plants, to urban areas first, where any industrial establishments are normally found. Electrical energy can be put to many uses and constitutes the basic factor for industrial, social and economic development in these countries. So, the urban population benefits first from this energy source.

In order to achieve the aim which some Third World countries are now setting themselves as a priority, namely, to develop agriculture for self-sufficiency in food and for export and with this to create the bulk of employment opportunities in agriculture, these countries will have to redistribute resources from urban to rural areas. That includes the basic services. Emphasis should therefore be laid on urgently needed indigenous technical development which adapts known technologies to local conditions, especially in the supply and maintenance of basic services.

6.2 WATER SUPPLY

Water can be supplied to a community or to individuals in many different ways and with the help of different technologies. These are:

– **Rainwater Harvesting**: This is an ancient practice, especially in arid regions, where hillsides are smoothened, rainwater run-off directed into canals and from there collected in underground cisterns or used straightaway for irrigating lower-lying fields. In Gibraltar and Jamaica, as well as on Sifnos, a Greek island, where the ground and rocks of the hills and mountains are permeable, the "runoffs" are covered with concrete or asphalt layers or with polythene sheeting to ensure maximum and unlimited rainwater harvesting. The water thus collected is (in addition to individual rainwater collection from roofs) in most cases the only major public water supply in these places today.



1—RAINWATER INLET
2—BUILT-IN SCREEN
3—"SCHMUTZDECKE", CONGEALED SURFACE, TO BE REMOVED REGULARLY AND RE-SANDED.
4—SAND FILTER BED
5—SUPPORTING GRAVEL
6—REGULATING VALVE
7—DRINKING WATER RESERVOIR
8—DRAW-OFF TAP
9—OVERFLOW. WATER TO BE COLLECTED FOR WASHING, GARDENING ETC.

FIG. 376 : **SIMPLE RAINWATER COLLECTION THROUGH SLOW SAND FILTER** - USING EMPTY DRUMS.

– **Rainwater Collection from Roofs**: With an appropriate roof design and suitable finishes, rainwater can be collected from the roofslope through gutters into cisterns or tanks. In some tropical developing countries the old colonial types of bungalows or governmental resthouses had an underground tank under the raised verandah. Water was pumped with a simple hand pump into an overhead reservoir or high level water tank. The buried tank often had an overflow into an open excavated reservoir from which water could be used for washing or watering the garden. Corrugated iron, aluminium and asbestos-cement sheeting, tiles (burnt clay, concrete), slates, shingles, concrete, bituminous felt are all suitable catchment finishes. Rainwater collected from thatched roofs tends to discolour. This can be improved by covering catchment areas on thatched roofs with polythene sheets. Roofs from which rainwater is collected should have a comparatively steep pitch to effect a quick run-off.
Rainwater running off a roof contains impurities which form a sediment that settles in the tank. The location of the draw-off tap should be well above the level of possible settlement. The best solution would, however, be to filter the water before use. This has been succesfully tried at the Department of Civil Engineering, Environmental Quality Division, U.S.T., Kumasi. Two empty oil drums were used for this purpose (Fig. 376). The first received the rainwater which passed through a slow sand filter via a valve-fitted pipe (for controlling the rate of flow) into the second, sealed draw-off drum. A simple closing or overflow mechanism could be installed in the first drum to block off or dispose of excess water. The top of the sand filter (or other suitable material, e.g. coconut fibre – burnt rice husk filter) has to be checked from time to time and cleaned by scraping off the thickness of conjealed surface. This simple system ensures the storage of uncontaminated water. The storage tanks, reservoirs or cisterns should be cleaned regularly.

– **Quanat Construction**: A quanat is an underground tunnel that taps water from a natural aquifer by exploiting the natural gradient of the land. The tunnel slopes gently so that water, which collects through the surface soil in the aquifer until it is stopped by an impermeable layer, runs through the quanat by gravity into an open canal or a well at the foot of the mountain. A quanat is, in fact, an artificial spring. This ancient Persian practice of quanat construction dates thousands of years back. The Persians built great quanats which are partly still in use in Iran today.

– **Well Sinking**: This is another ancient craft, thousands of years old, which still provides the cheapest supply of safe water in areas with shallow groundwater sources. Hand-dug wells and well construction will be explained in detail further on.

– **Deep-Well Sinking** (Fig. 377): Here mechanically drilled deep wells are provided with hand pumps. The boreholes are normally lined with steel tubing. In many developing countries well-drilling projects are under way or have already been completed. It has been found in many countries that water supply technology was transferred from the "donor-country" which financed such a project, without consideration of its appropriateness to local conditions. This resulted in serious maintenance problems, especially of the pumps which in most cases were supplied as part of the project. The tendency, however, should be to design hand pumps for local conditions which could be produced at village-craftsman-level and could therefore easily be maintained and repaired whenever something goes wrong. A number of hand pumps have been designed in developing countries in specialized workshops where villagers are involved in the maintenance, e.g. the Sholapur pump of India or the improved version of it known as the India Mark II hand pump (Fig. 378).

Fig. 377: Well drilling in the Volta Region, 1982. (Prakla Seismos Well Drilling Project).

– **Pipe-borne Water Supply:** This is the supply of water from surface sources (rivers). These are normally dammed and the water is then passed through a treatment and purifying system before it is piped through water-mains and tributary pipes to individual households and communal standpipes. Such a supply system involves sophisticated technologies for the treatment and purifying plants, the waterworks, pump stations, pipelines and water meters in the distribution system. Supply pipes and installations will be explained in **6.4 "Plumbing Installations"**.

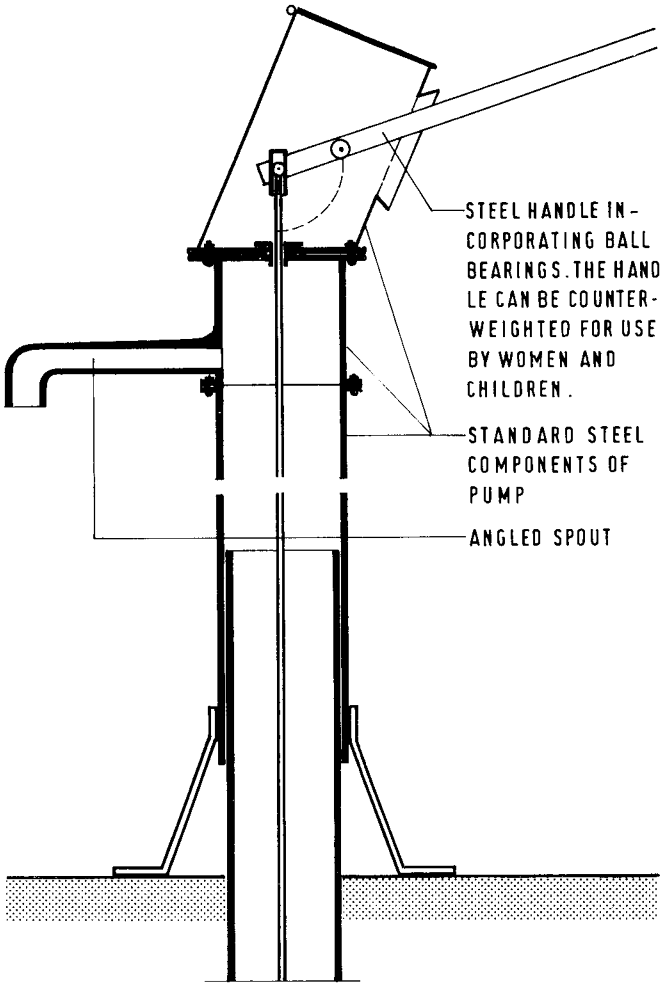


FIG. 378 : THE INDIA MARK II. HAND PUMP

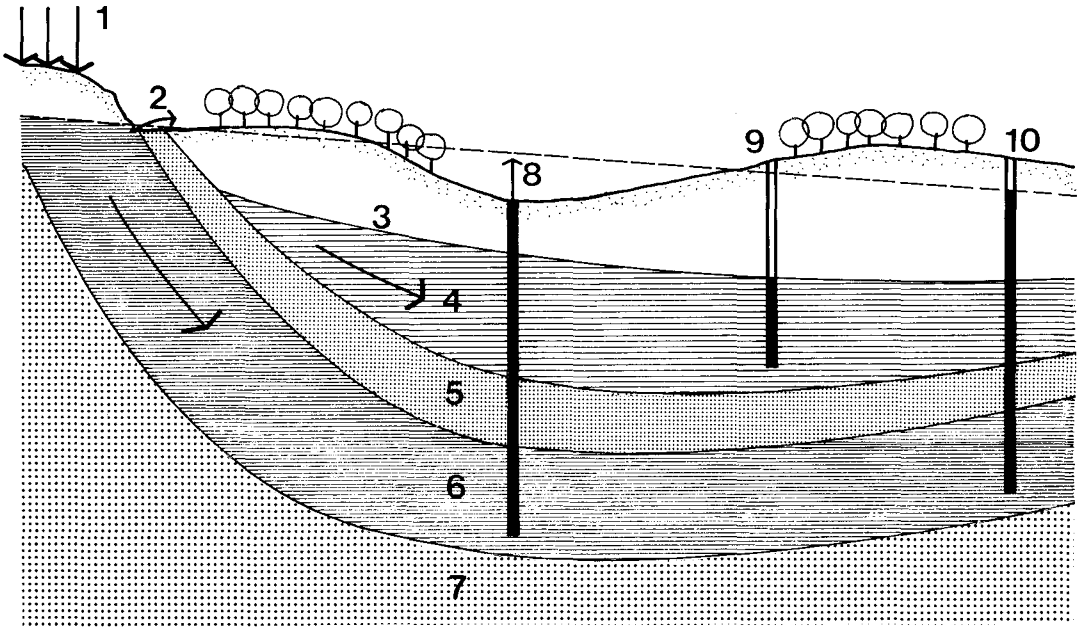
NOTE : PUMPS FOR SMALL WATER SUPPLIES ARE NORMALLY PLUNGER (RECIPROCATING) PUMPS. THE COMMON TYPES ARE SUCTION PUMPS (FOR SHALLOW WELLS), LIFT PUMPS (E.G. INDIA MARK II, FOR DEEP WELLS), FORCE PUMPS (FOR PUMPING WATER INTO A HIGHER LEVEL RESERVOIR). DIAPHRAGM PUMPS (USING THE DIAPHRAGM PRINCIPLE) ARE BEING FIELD TESTED AS FOOT-OPERATED PUMPS FOR USE IN RURAL AREAS.

For rural communities which have access to small dams, drinking water could be pumped through piping to a storage tank and from there through a simple filter system to the clean water supply tank with draw-off tap. The simple filter system could be a slow sand filtration or coconut fibre – burnt rice husk filter; the latter has been produced by the Asian Institute of Technology in Bangkok and successfully used in the Philippines.

6.2.1 HAND-SUNK WELLS

Well construction explained and detailed in this part is that of domestic wells. Irrigation and livestock watering wells do not need the same health precautions and require quite different equipment for extracting the required quantities of water.

Before a well is dug it is necessary to investigate the ground in order to find the saturated soil layer containing the groundwater. This soil layer is called "aquifer". Hand-dug wells normally tap an "open aquifer", that is the layer which contains the upper surface of the groundwater called the water table. Deep-sunk wells on the other hand are drilled through an impermeable layer of soil or rock



1—INFILTRATION AREA AT OUT-CROPPING OF FORMATION TO SUPPLY ARTESIAN FORMATION
2—SPRING
3—GROUND-WATER TABLE
4—UNCONFINED (NON-ARTESIAN) OPEN AQUIFER
5—IMPERMEABLE LAYER
6—CONFINED (ARTESIAN) AQUIFER
7—BED ROCK
8—DEEP-SUNK, FLOWING ARTESIAN WELL
9—HAND-DUG OPEN AQUIFER WELL
10—DEEP-SUNK SUB-ARTESIAN WELL (NON-FLOWING)

FIG.379 : TYPES OF AQUIFER WITH CORRESPONDING WELLS

overlying a "confined aquifer". If the water contained in this aquifer is under pressure (as often is the case) it will rise to the surface of the well ("artesian well") or partly to the surface ("subartesian" well, Fig. 379).

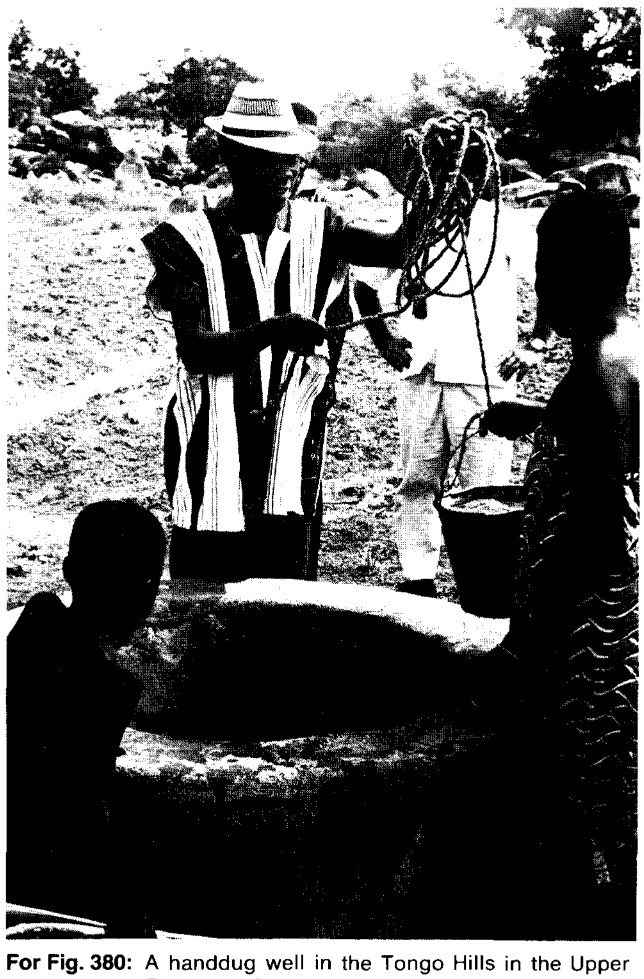
6.2.1.1 DIMENSIONS:

Wells dug by self-help methods are normally minimum 1000mm in diameter, if one man is excavating, or minimum 1300mm in diamter with two men working. Hand-dug wells studied during field investigations for this book included some built under the supervision of local well committees and with the help of Church Missions by farmers in the North of Ghana and some constructed under the auspices of local councils in the Ashanti and Volta Regions. Their depths varied between 15 and 30 metres. Wells have been sunk in other countries to larger depths, but for practical sinking a depth of up to 40 metres should be considered the limit, with an unlined „working" diameter of 1500mm.

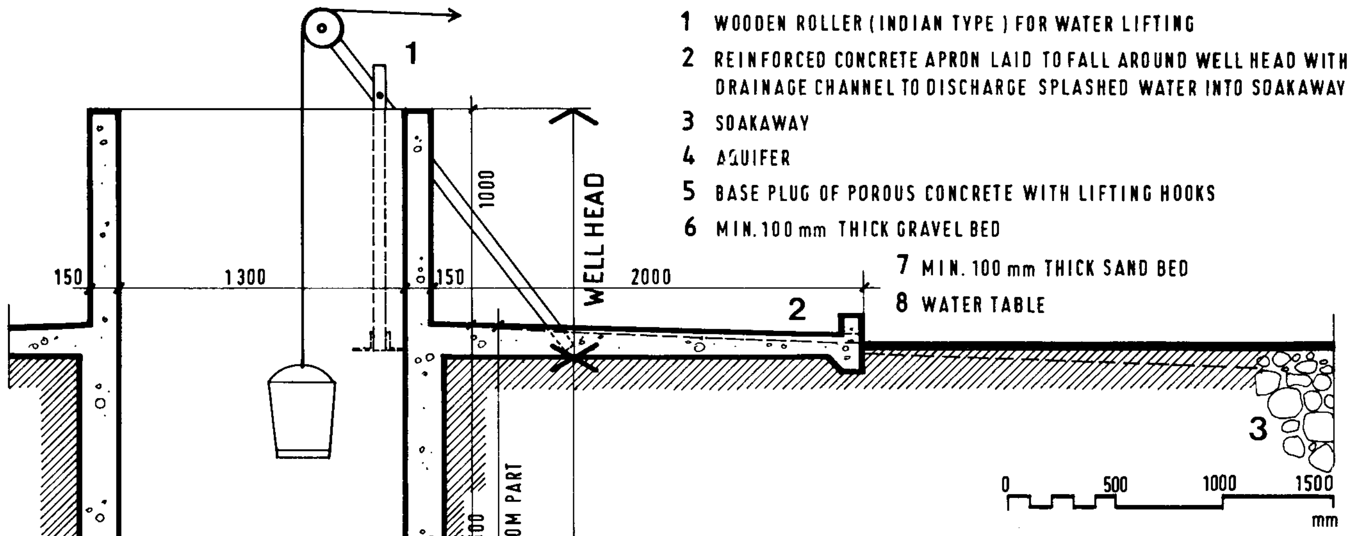
6.2.1.2 METHODS OF CONSTRUCTION:

Considering the stresses to which a well will be exposed at varying depths the common material used for well construction is reinforced concrete cast in situ about 150mm thick in the well, with precast concrete sections for the intake. A well consists of three parts (Fig. 380):

- **The Intake:** The lowest section of the well which lies within the aquifer and which must be built so that it permits the water to flow into the well.
- **The Shaft**: The access to the well. This must be lined with a suitable material to prevent it from caving in and also from contamination through water ingress from the surface.
- **The Wellhead**: The top of the well above ground level. The design of the wellhead depends on what method of extraction of water is to be used (e.g. buckets or pump). Ideally the wellhead should be sealed so that no dust, insects etc. can enter the shaft. In this case a pump is needed for extraction of water. If this is financially not possible a movable (sliding) cover from timber would be advisable for the periods when water is not extracted. In addition a simple shelter structure could be considered, which provides cover for the wellhead and the immediate surroundings. In order to prevent wellhead pollution, a solid apron of concrete approximately 2 metres wide with a screed should be laid to fall around the well head to enable splashed-over water to drain off through a drain into a soakaway.



For Fig. 380: A handdug well in the Tongo Hills in the Upper Region of Ghana, 1968.



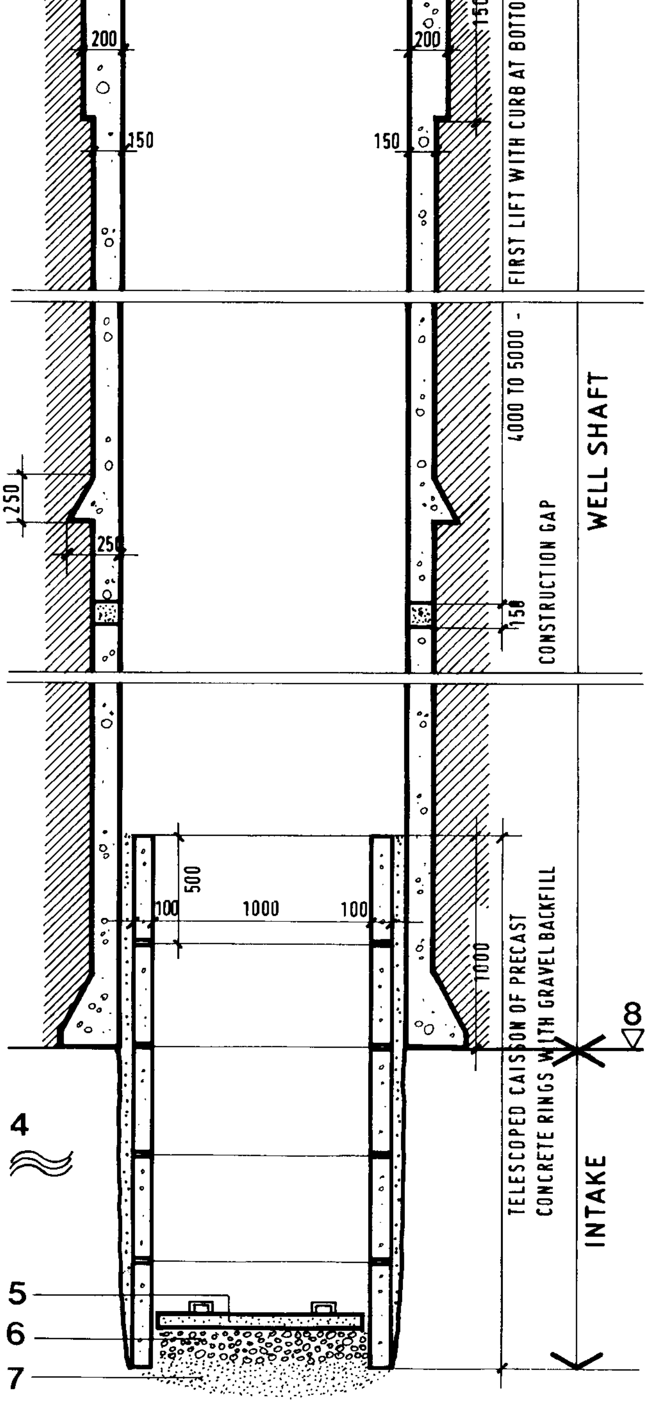


FIG. 380: **SECTION THROUGH A HAND DUG WELL**

SEQUENCE OF CONSTRUCTION (Fig. 381):

The shaft is excavated and trimmed to the required size in "lifts" of approximately 4 to 5 metres height. It is advisable to provide a temporary lining (the steel shutters used for casting can be used for this) at the well mouth. Each "lift" is then reinforced and cast in-situ. Excavation and lining continue until water is reached. Collapse normally occurs from weak soil in the top layers. If the soil becomes more stable further down it is possible to excavate and line the shaft in a continuous lift until water is reached. Curbs should be built into the concrete at every 5 metres with a thicker one at the bottom of the last lift.

To continue the well sinking into the aquifer requires a different technique because the shaft will contain water from this level onwards (this does not apply to aquifers of hard laterite or porous rock where **"caissoning"** may not be needed). The intake caisson is normally constructed of pre-cast concrete rings (with small holes to allow sufficient water seepage) of a smaller diameter than the internal shaft lining. Rings are about 500 mm high. One ring at a time is lowered into the shaft where it will sink under its own weight by excavating under the lower end of the ring. This construction method requires a headframe which is capable of carrying the precast caisson-ring's weight. Caissoning can also be done in situ, which is a more tedious method since the smaller diameter of approximately 1000 mm of the intake allows only one man to work at the bottom of the well.

The base of the well should be "plugged", that is levelled and closed with a bed of sand and gravel or with a precast porous concrete plug laid on a sand bed. Lifting hooks should be embedded into the concrete to enable the plug to be moved in case of necessary well deepening.

Other traditional materials used for well lining are brickwork, masonry blocks or, as has been successfully tried in the North of Ghana, laterite stones hewn to segmental blocks and set in cement mortar. Such wells, however, are not suitable for great depths. Where aquifers are of loose sand, timber plank piling (of 1500 to 2000 mm lengths) is used for caissoning so that the brickwork or blockwork wall can be built up inside of the cylinder. The wellhead should be 1 metre high, its reinforced concrete wall or cement-sand blockwork wall 150 mm thick and smoothly plastered in and outside. Simple water lifting devices can be fixed with an axle to galvanized steel angles, or the wellhead is covered with a reinforced concrete cover to which a hand pump is fixed. A hatch for access to the well must be provided in this case.

Before a new well is used it should be thoroughly cleaned and disinfected with a chlorine solution. If good care is taken of the extraction equipment, buckets, ropes etc., water from a well should be free of contamination. Normally water extracted from a well is used straightaway. When it is stored in buckets in kitchens etc. for a longer period before use, the danger of contamination is great. A simple way out is to use a storage arrangement similar to that already described in "Rainwater Collection from Roofs" in the form of two drums, one for filtration and the second for clean water storage.

Depending on the different climatic seasons in tropical developing countries the best time to construct a well is when the water table is lowest. This will ensure that the well contains adequate water throughout the year.

6.2.1.3 LOCATION OF HAND-DUG WELLS:

In order to have a contamination-free well it is important to place it correctly, especially in relation to any pit latrines and animal pens nearby which constitute potential sources of pollution. As a thumb-rule a well reaching down to an open aquifer should be located about 30 to 50 metres away from such sources and if possible on higher ground (Fig. 382).

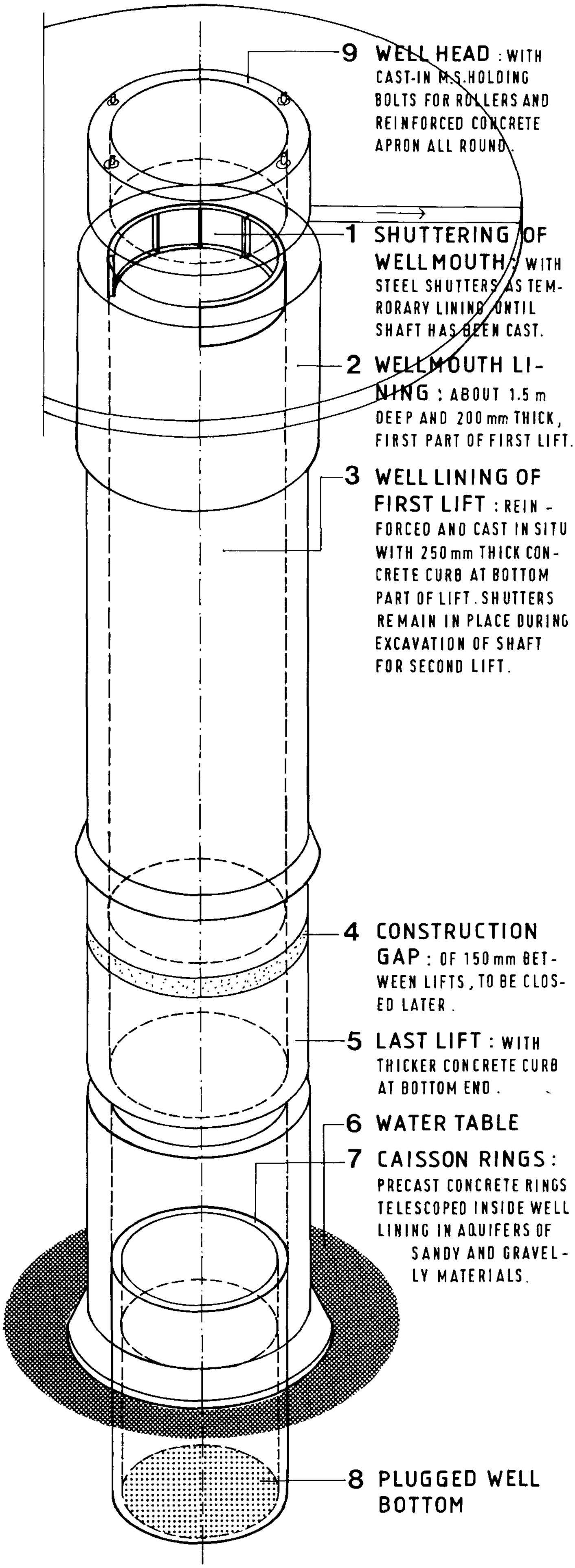


FIG.381 : SEQUENCE OF CONSTRUCTION OF HAND DUG WELLS WITH CAISSON

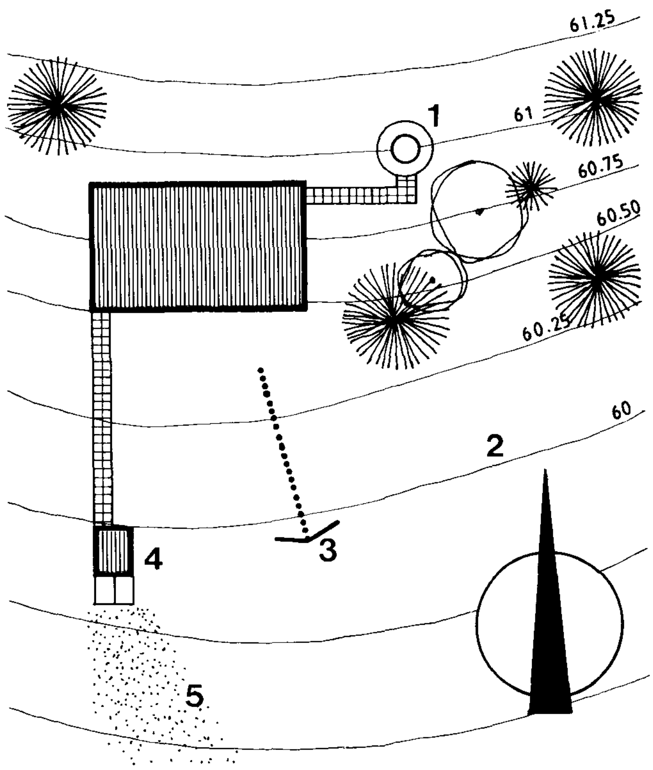


FIG.382 : LOCATION OF WELL

1 HAND-DUG WELL
2 CONTOUR LINES
3 DIRECTION OF GROUND WATER FLOW
4 COMPOST LATRINE
5 CONTAMINATED GROUND. CONTAMINATION TO ABOUT 3 m BELOW BOTTOM OF PIT AND MOVING IN THE DIRECTION OF THE GROUND WATER FLOW.

6.3 SANITATION

There are many factors which have contributed to the fact that in many developing countries rural and urban sanitation programmes have so far been unsuccessful. Excreta disposal cannot be dealt with in the same way in each country. Social, cultural and religious traditions, especially those concerning personal hygiene, are different in each country; they may differ again from ethnic group to ethnic group in one country alone. Rural people are often not aware of the significance of sanitation. Many people are, moreover, ignorant of the fact that the most widespread diseases, especially in tropical developing countries, are those transmitted by human excreta and contaminated water. These diseases, cholera, typhoid fever, amoebic dysenteries, diarrhoeal diseases, infectious hepatitis, hookworm, in addition to water-based diseases like schistosomiasis and guinea worm, are the biggest "killers" in Third World countries. An estimated 10 to 25 million people die every year from these diseases (that is 30,000 to 70,000 a day; WHO-report 1977). With effective sanitation which takes into account social, religious and cultural traditions of the people and which is based on different available and appropriate technological options, it should be possible to control these diseases.

6.3.1 RURAL SEWAGE DISPOSAL

In July, 1977 a Technical Advisory Group meeting on "Rural latrines" took place in Kumasi, organized by the Environmental Quality Division of the Civil Engineering Department, U.S.T. and sponsored by the International Development Research Centre, Canada. Participants from Ghana, Nigeria, Tanzania, Botswana, India and Canada considered a large number and variety of different rural latrine types. Fig. 383 shows sketches and explains some of the known existing and tested rural latrines and excreta disposal systems. Only those latrines which have been found to work successfully and are of low cost, either as water-independent or water-dependent systems, which have a well-proven technology, which have been accepted in different rural areas of tropical developing countries and which can also be adapted to serve as communal latrines, are described and detailed further on. These latrines are suitable for rural areas as well as for sub-urban settlements where piped sewage disposal or septic tanks are not yet available. There are some general rules which should strictly be followed for the construction of pit latrines:

- They should be located a minimum of 30 metres away from shallow wells in the direction of the ground-water flow.
- They should be placed a minimum of 10 metres away from habitable rooms.
- They should only be built in suitable, pervious soil. In sandy soil the pit must be lined.
- They are suitable only in areas with a population density of not more than 150 peoples per hectare. In denser areas vault-systems and septic tanks are preferable or piped sewage disposal systems.

6.3.1.1 OFF-SET VENTED DRY PIT LATRINE

This is a dry pit latrine which was first patented in South Africa in 1944 as Reid's Odourless Earth Closet (R.O.E.C.) and has many advantages over the direct pit latrine. Instead of being located directly below the seat or squatting platform, it is built adjacent to it so that the near face of the pit is in line with the outer wall of the latrine building (Fig. 384 and 385). The pit is connected to the latrine with a straight pipe to the squatting hole, set at an angle between 50° to 60°. The pit is vented with a 150 mm diameter PVC vent pipe which is covered at the top with netting, and must reach above the highest part of the latrine building to induce a suction of air from the squatting pipe through the pit. The pit, when full, can be emptied without disturbing the latrine structure.

6.3.1.2 OFF-SET COMPOST PIT LATRINE:

This latrine (Fig. 386) combines some features of the off-set vented dry pit latrine and the **"Multrum"** latrine (see Fig. 382), a compost latrine. The composting chamber is located outside the latrine structure. Whereas the Multrum latrine has air inlets in the chamber and the composting is achieved through oxidation, in the off-set compost pit latrine composting is effected by anaerobic (oxygen-free) digestion, although it is vented, and has a slower composting rate.

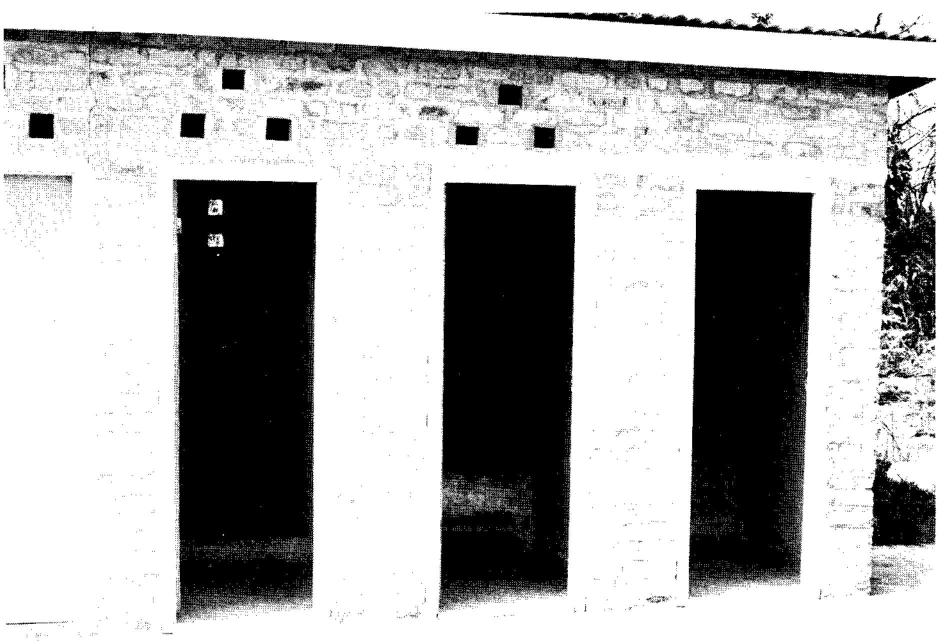
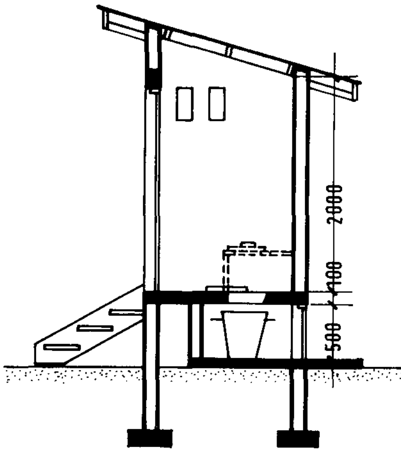
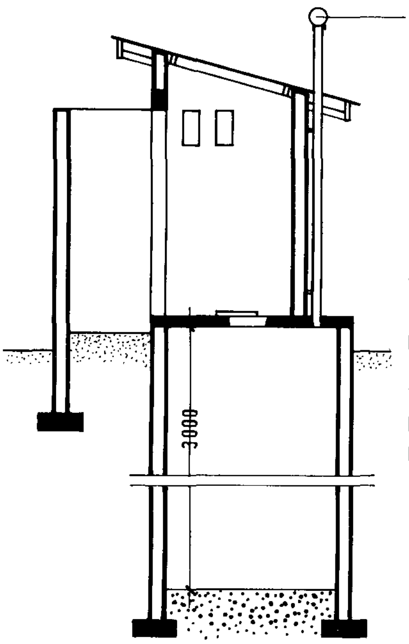


Fig. 385: Off-set vented improved pit latrine, Faculty of Engineering, U.S.T., Kumasi, 1982.



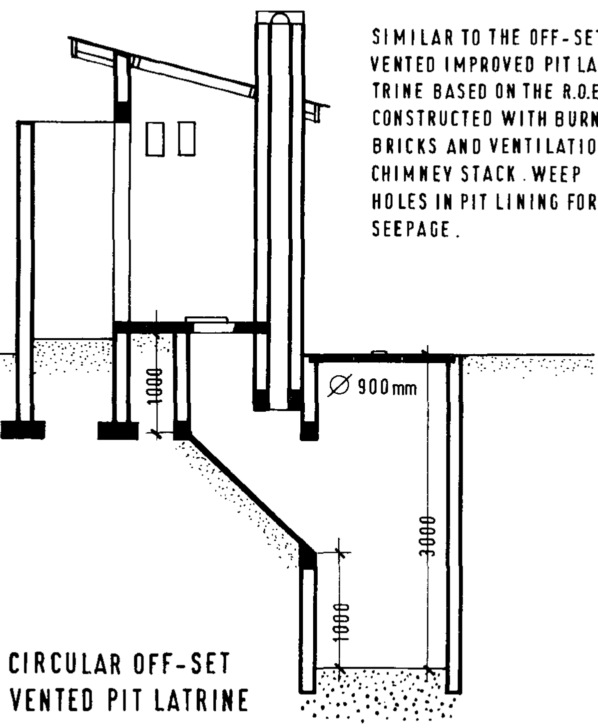
COLLECTION OF EXCRETA IN BUCKET PLACED UNDER THE SQUATTING PLATFORM OR SEAT. REGULAR COLLECTION TO CENTRAL DISPOSAL POINTS NECESSARY. FLY AND ODOUR NUISANCE.

1 BUCKET LATRINE



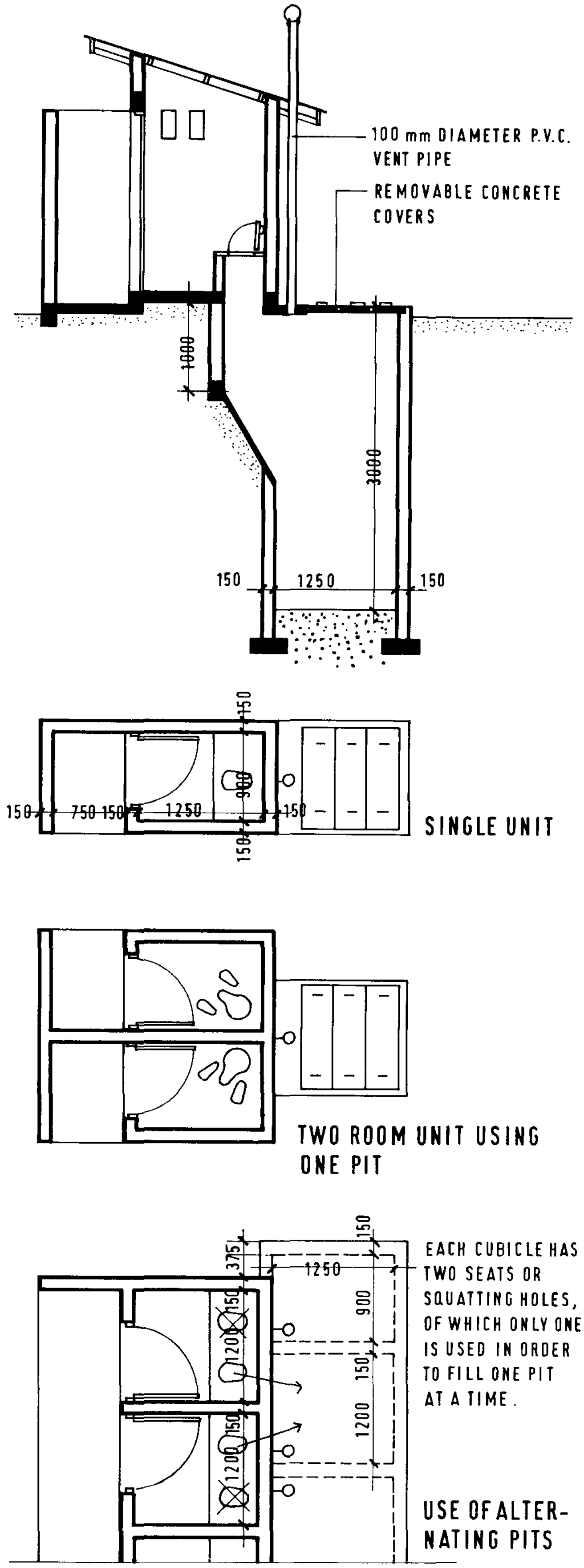
EXRETA FALLS STRAIGHT INTO PIT BELOW SQUATTING PLATFORM OR SEAT. PITSIZE UP TO 1500 x 900 x 3000 mm DEEP RECTANGULAR OR 900 mm DIAMETER CIRCULAR. IF PIT IS LINED WEEP HOLES MUST BE PROVIDED FOR SEEPAGE. FAECES AND ABLUTION UNDERGO ANAEROBIC DIGESTION AND VOLUME REDUCTION.

2 DIRECT PIT LATRINE (UNVENTED OR VENTED)



SIMILAR TO THE OFF-SET VENTED IMPROVED PIT LATRINE BASED ON THE R.O.E.C., CONSTRUCTED WITH BURNT BRICKS AND VENTILATION CHIMNEY STACK. WEEP HOLES IN PIT LINING FOR SEEPAGE.

3 CIRCULAR OFF-SET VENTED PIT LATRINE

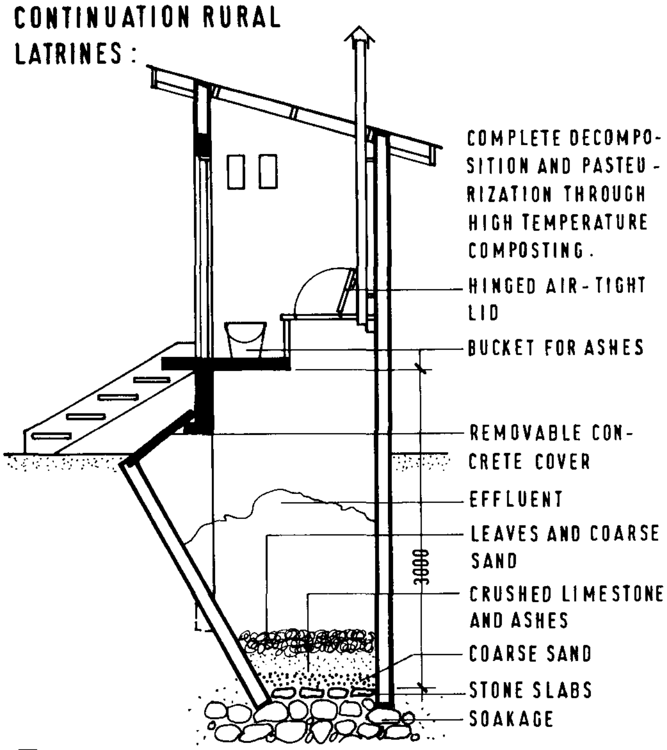


4 RECTANGULAR OFF-SET VENTED IMPROVED PIT LATRINE

BASED ON THE R.O.E.C. THE PIT IS LINED, LEAVING WEEP HOLES FOR SEEPAGE. THE LATRINE CAN BE USED AS SINGLE UNIT OR AS TWO ROOMS USING ONE PIT, OR AS A COMMUNAL LATRINE WITH ALTERNATING PITS.

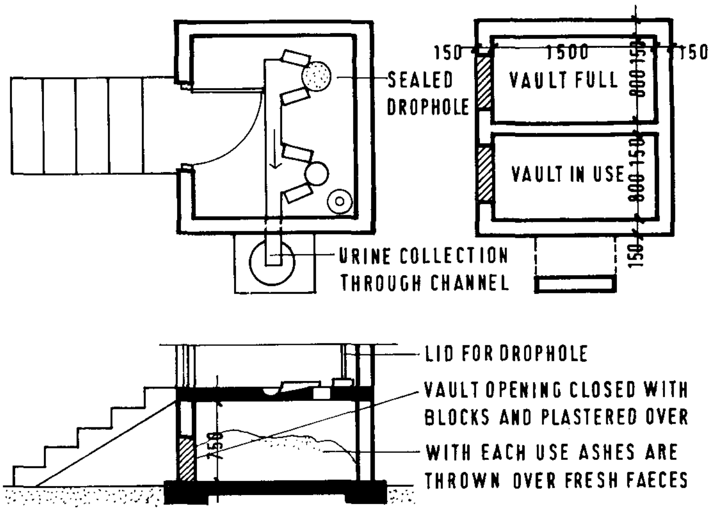
FIG.383 : **RURAL LATRINE CATALOGUE**

CONTINUATION RURAL LATRINES:



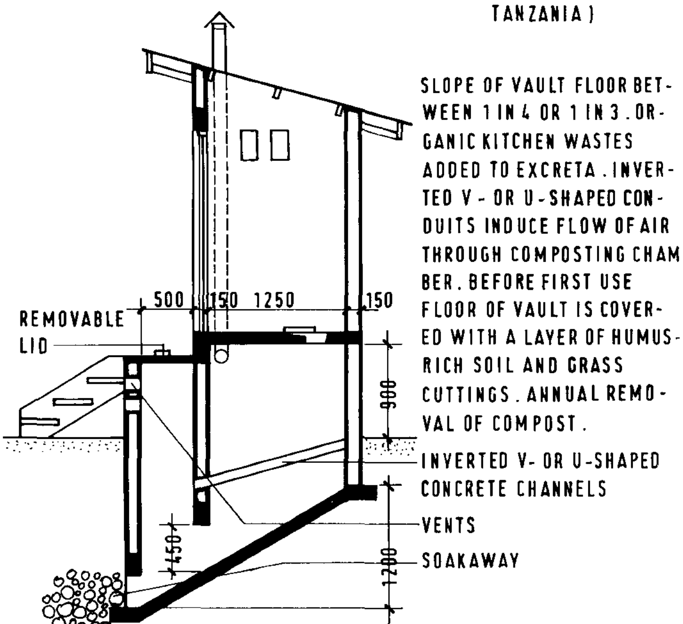
COMPLETE DECOMPOSITION AND PASTEURIZATION THROUGH HIGH TEMPERATURE COMPOSTING.

5 BIO-POT (SOURCE: MINISTRY OF NATIONAL EDUCATION, TANZANIA)



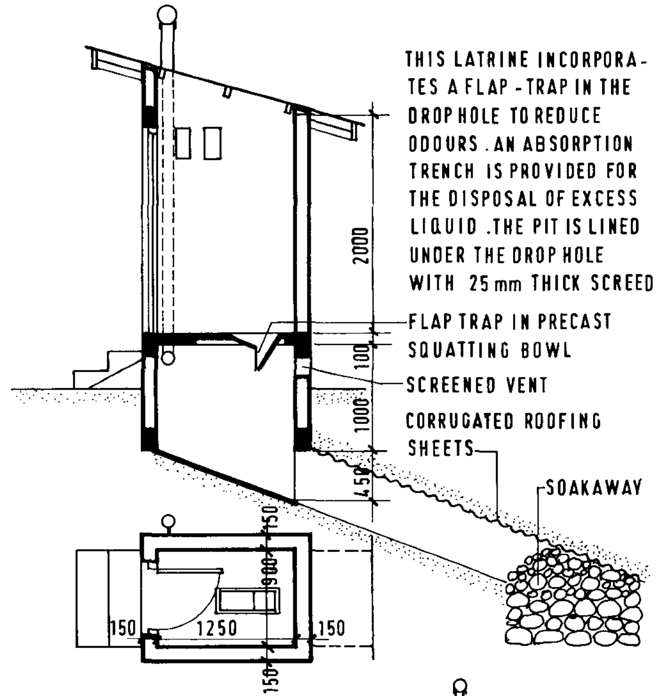
6 VIETNAMESE DOUBLE VAULT COMPOST LATRINE:

SEPERATION OF URINE AND FAECES. ANAEROBIC COMPOSTING TAKES PLACE IN SEALED TANK. COMPOST IS READY FOR USE AS FERTILIZER AFTER 5 MONTHS. ONLY ONE VAULT IS USED UNTIL IT IS FULL.



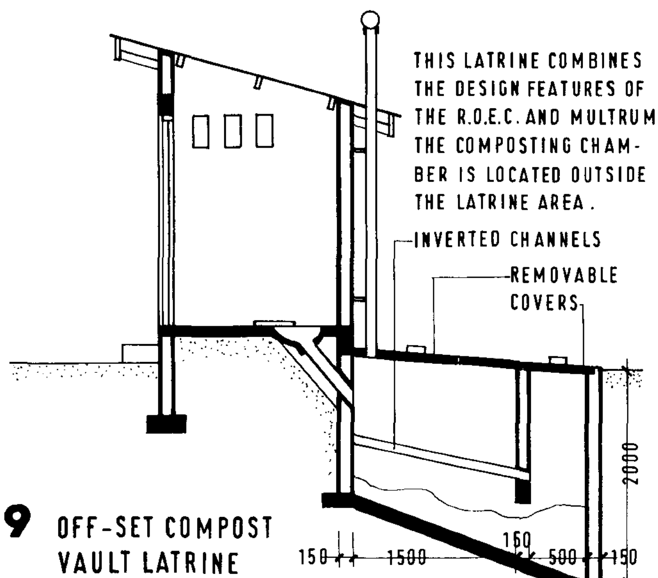
SLOPE OF VAULT FLOOR BETWEEN 1 IN 4 OR 1 IN 3. ORGANIC KITCHEN WASTES ADDED TO EXCRETA. INVERTED V- OR U-SHAPED CONDUITS INDUCE FLOW OF AIR THROUGH COMPOSTING CHAMBER. BEFORE FIRST USE FLOOR OF VAULT IS COVERED WITH A LAYER OF HUMUS-RICH SOIL AND GRASS CUTTINGS. ANNUAL REMOVAL OF COMPOST.

7 MULTRUM (CLIVUS) COMPOST LATRINE



THIS LATRINE INCORPORATES A FLAP-TRAP IN THE DROP HOLE TO REDUCE ODOURS. AN ABSORPTION TRENCH IS PROVIDED FOR THE DISPOSAL OF EXCESS LIQUID. THE PIT IS LINED UNDER THE DROP HOLE WITH 25 mm THICK SCREED.

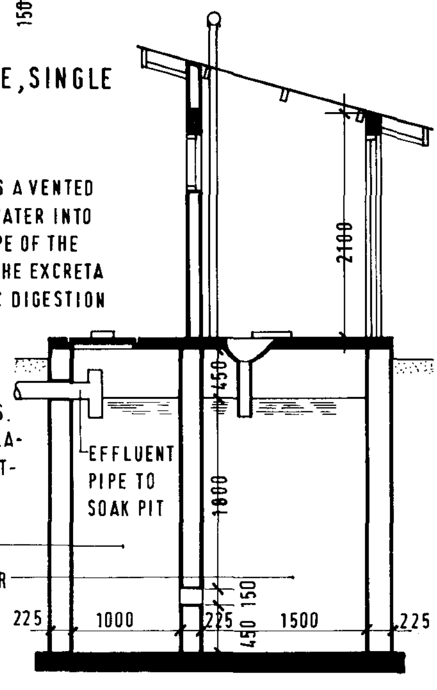
8 UTAFITI LATRINE, SINGLE COMPARTMENT



THIS LATRINE COMBINES THE DESIGN FEATURES OF THE R.O.E.C. AND MULTRUM. THE COMPOSTING CHAMBER IS LOCATED OUTSIDE THE LATRINE AREA.

9 OFF-SET COMPOST VAULT LATRINE

THE AQUA PRIVY HAS A VENTED TANK CONTAINING WATER INTO WHICH DIPS THE PIPE OF THE SQUATTING BOWL. THE EXCRETA UNDERGO ANAEROBIC DIGESTION IN THE DIGESTION TANK. THE SLUDGE MUST BE REMOVED EVERY 5 TO 10 YEARS. TANK WALLS TO BE PLASTERED WITH CEMENT-SAND PLASTER.



10 AQUA PRIVY

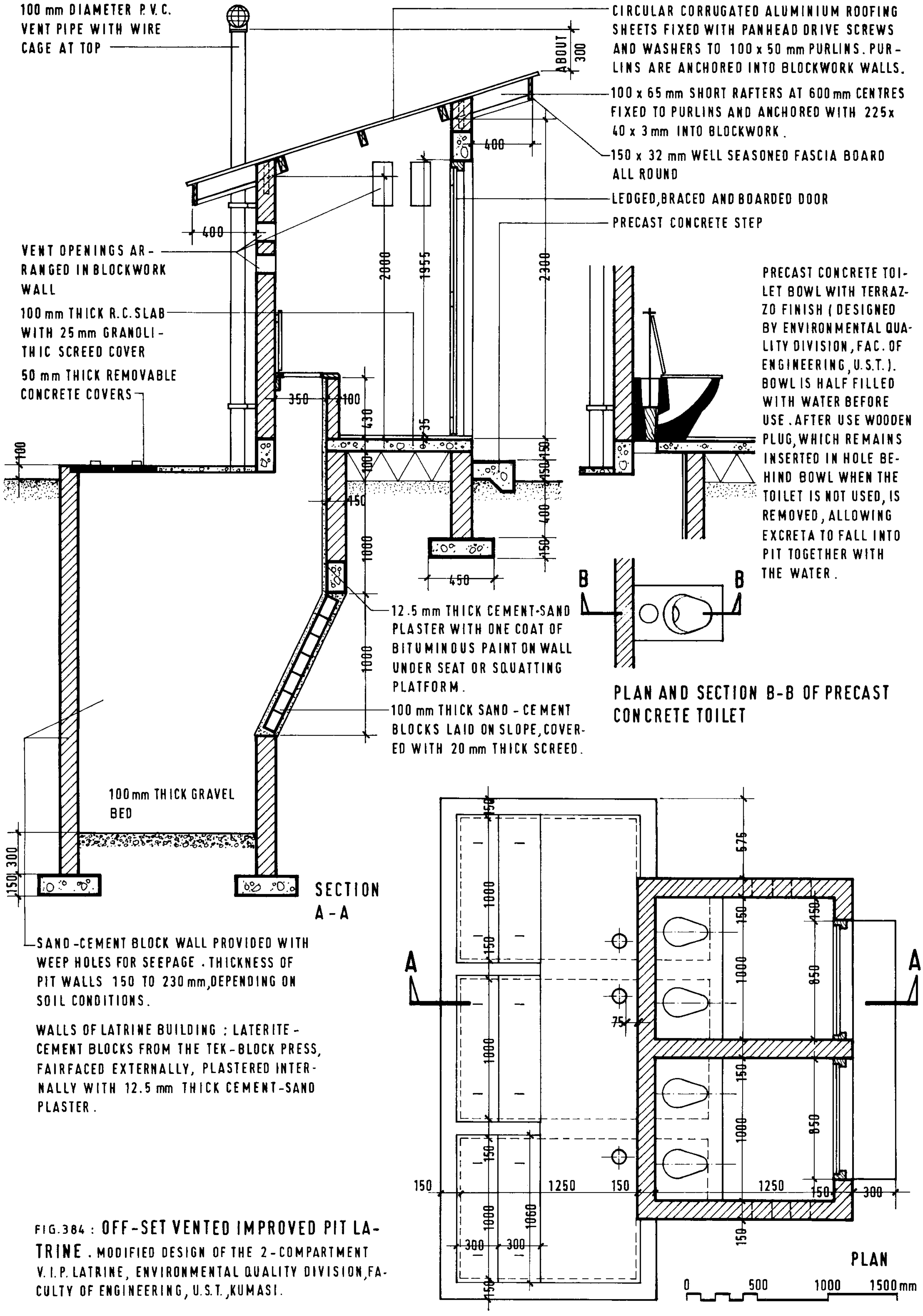
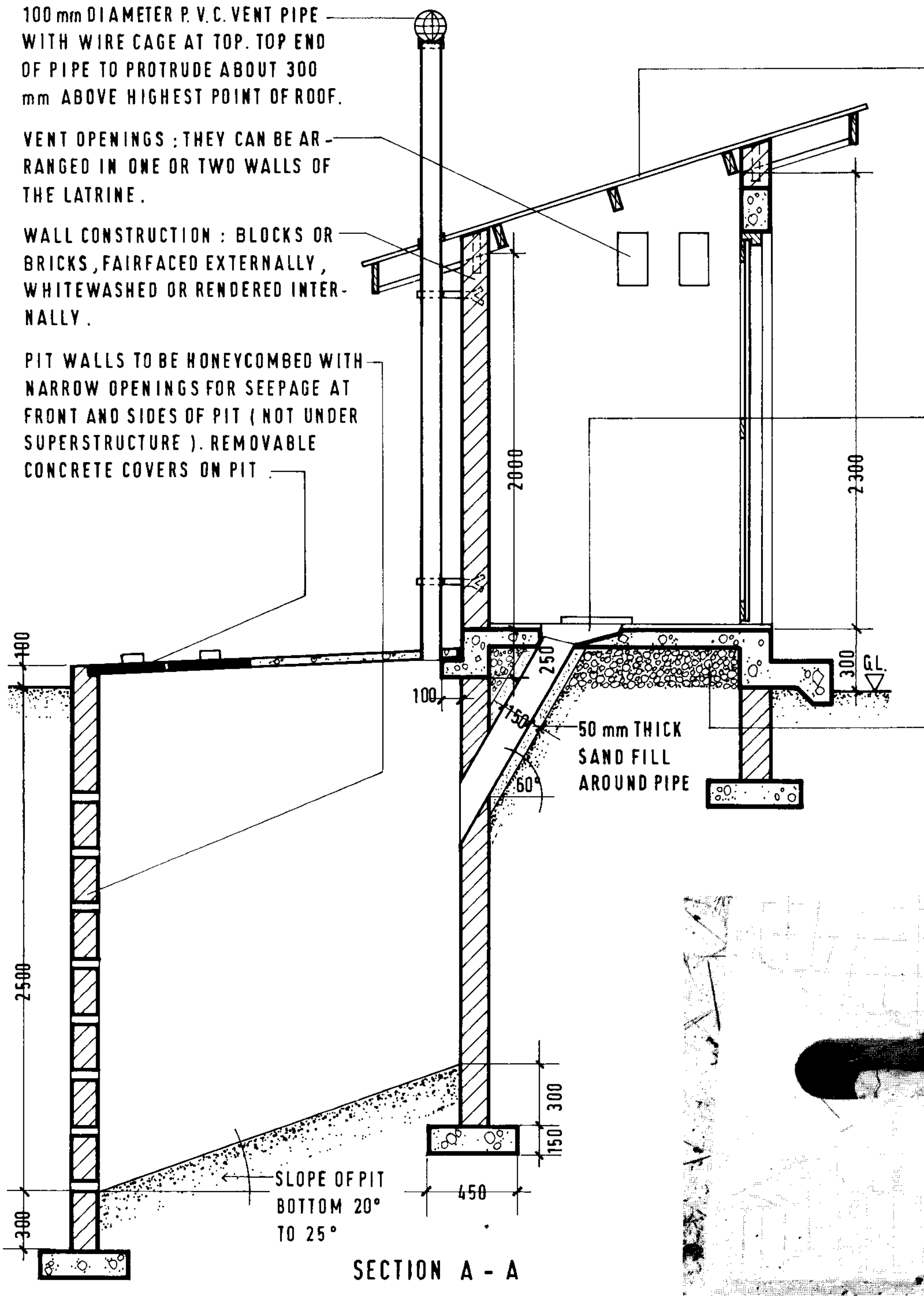
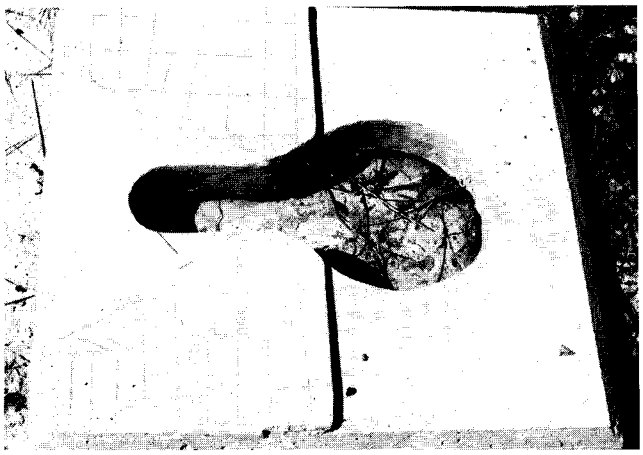


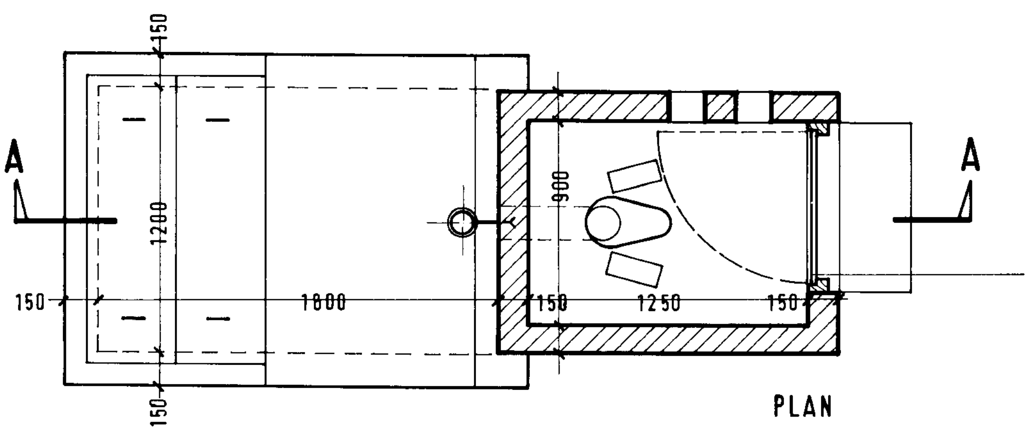
FIG. 384 : **OFF-SET VENTED IMPROVED PIT LATRINE**. MODIFIED DESIGN OF THE 2-COMPARTMENT V.I.P. LATRINE, ENVIRONMENTAL QUALITY DIVISION, FACULTY OF ENGINEERING, U.S.T., KUMASI.



SECTION A - A



THE PHOTOGRAPH ABOVE SHOWS A PREFABRICATED CONCRETE SQUATTING PLATFORM WITH TERRAZZO FINISH WHICH IS SUITABLE FOR THE OFF-SET COMPOST PIT LATRINE. A PIPE CAN BE INSERTED INTO THE DROP HOLE (DESIGNED BY ENVIRONMENTAL QUALITY DIVISION, FAC. OF ENGINEERING, U. S. T.).



PLAN

FIG. 386 : OFF-SET COMPOST PIT LATRINE

THIS DESIGN HAS BEEN ADAPTED FROM "RURAL LATRINES" BY PROFESSOR A. WRIGHT (REPORT ON AN INTERNATIONAL TECHNICAL ADVISORY GROUP MEETING, JULY 1977, KUMASI, GHANA, CIVIL ENGINEERING DEPARTMENT, U. S. T.).

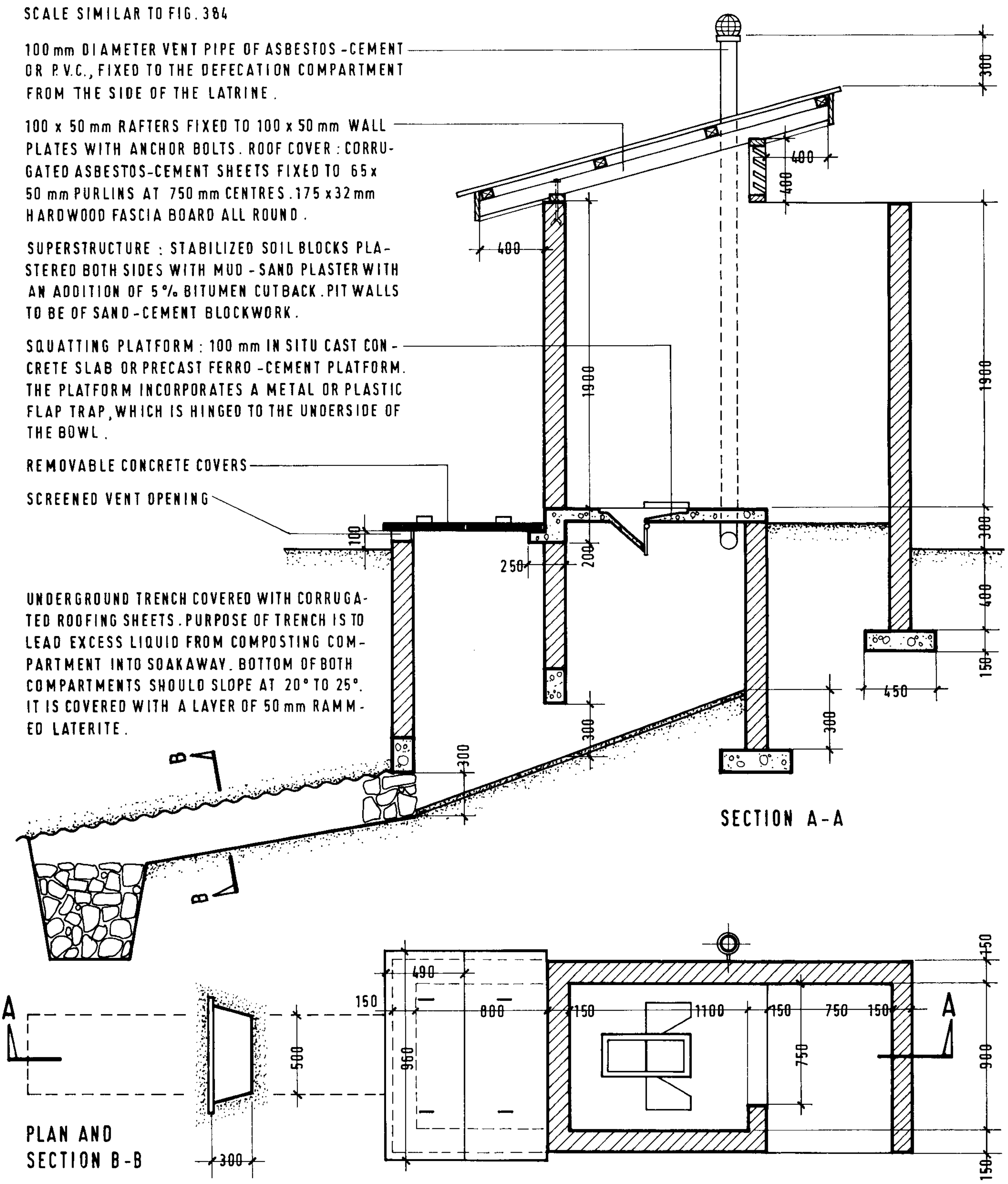


FIG. 387 : UTAFITI - 2-CHAMBER COMPOST LATRINE - TANZANIAN DESIGN, ADAPTED FROM "RURAL LATRINES" BY PROFESSOR A. WRIGHT.

6.3.1.3 UTAFITI LATRINE (Fig. 387):

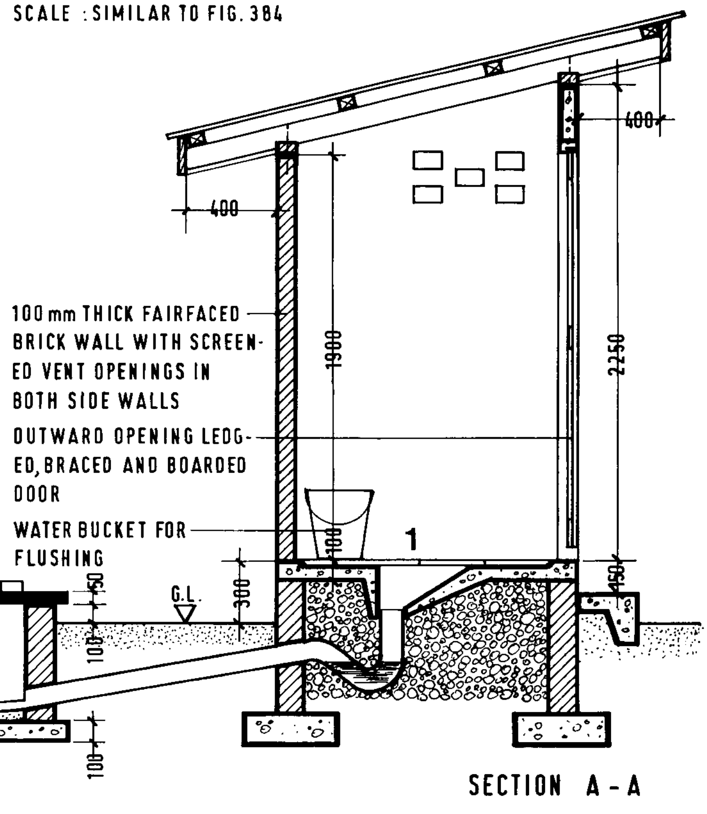
This double chamber compost latrine is very similar to the Multrum latrine. It has, however, additional features, a flap-trap in the squatting plate which reduces odours and fly nuisance and an underground trench leading to a soakaway. This will absorb excess liquid. The composting chamber has no concrete floor as in the Multrum latrine. Construction of the Utafiti latrine is therefore cheaper. The latrine can also be built with a single compartment which is the defecation and composting chamber at the same time, an even cheaper version.

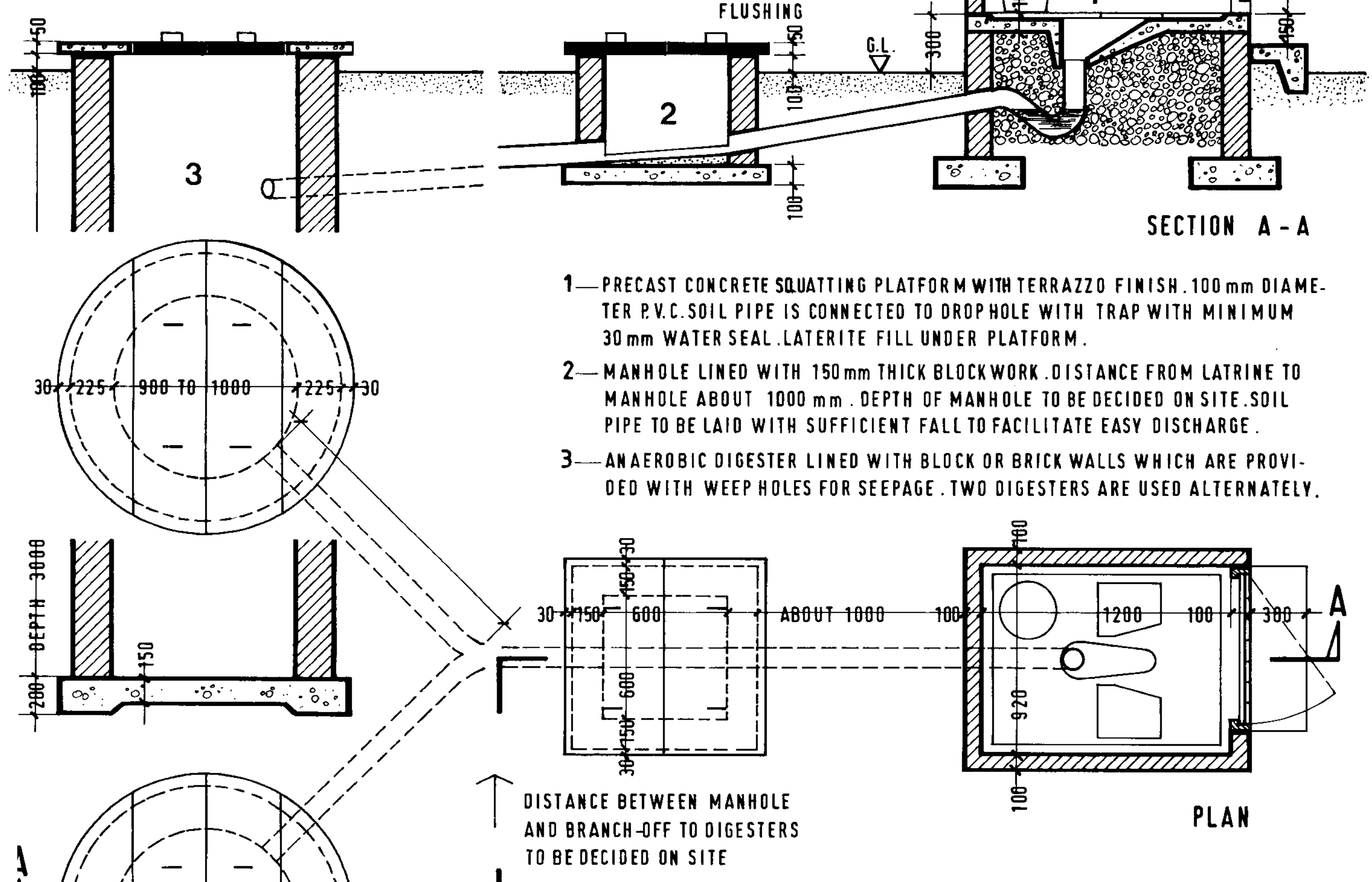
6.3.1.4 OFF-SET PIT WATER SEAL LATRINE (RcA)

This is a water-dependent latrine and therefore suitable in areas where water is available on the site. The latrine pan has a trap which maintains a water seal of minimum 30 mm and is flushed by hand. The trap is connected with a 100 mm diameter pipe to the pit. The RcA latrine, with the off-set pit water seal system, was developed in India (Fig. 388).

The RcA latrine is initially built with one pit of about 1 000 mm diameter. The pit is lined with bricks, sand-cement or soil-cement blocks about 100 mm deep. It is covered with a concrete lid. When the first pit is full, a second pit is dug and the connecting pipe removed from the first pit to the new one. The concrete cover is also removed and fixed over the new pit. The full pit is topped up and closed with soil. Digestion will turn the faeces into fertilizer after about a year.

This is a latrine which uses little water, 1.5 to 2 litre per flushing. It is odourless with the help of the water seal. Its acceptability in places where it has been introduced is high.





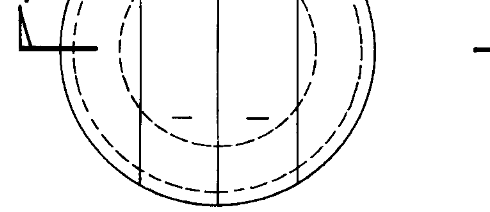


FIG. 388 : OFF-SET PIT WATER SEAL LATRINE (RcA) – ADAPTED FROM "RURAL LATRINES" BY PROFESSOR A. WRIGHT.

6.3.2 URBAN SEWAGE DISPOSAL

Most of the towns and cities in developing countries grew up without any form of public sewerage systems. Many proposals were put forward by commissioned consultants for many decades on different sewerage systems. Plans were drawn up. Most were based on water-borne, piped sewage disposal. But none seems to have been successfully implemented, except for some institutional sewerage systems.

Professor A. Wright, Head of Environmental Quality Division, Civil Engineering Department, U.S.T., Kumasi, states in "Accra – Updating a Feasibility Study", inter alia that:

- The approach to sanitation problem-solving should not be rigid, it should be flexible.
- Surveys should be conducted by a multi-disciplinary team to collect engineering, socio-economic and health data.
- Alternative technological options should be compared.
- Different types of technological solutions may be selected for different sections of a community.

The conventional sewerage system in urban areas is piped sewage from water closets to septic tanks, soakaways or disposal fields. This system has the advantages that:

- The toilets can be integrated into buildings;
- Household and bath waste water can be discharged into the same system;
- The system is completely odourless and the excreta disposal attracts no flies;
- The technology required for the system is comparatively simple and requires little maintenance;
- The system is normally under the control of the local Water and Sewerage Authority which is responsible for the running costs. Individual users pay a water rate and conservancy fee.

The biggest disadvantage of this system is waste of the necessary flushing water.

Sewage treatment on a large scale in sludge basins and lakes with or without additional oxidation or the use of treated sewage for fish cultures will not be described here; it would go beyond the scope of this book. It should only be mentioned here that some developing countries are already successfully using animal waste to feed fish lakes, e.g. Thailand, Indonesia, Philippines. In China treated human excreta have been used for a long time for fish lakes. India has a large fishfarm in Calcutta which is fed by treated sewage from the town.

6.3.2.1 SEPTIC TANK SYSTEM (Fig. 389):

This is a water-dependent system which consists of a piped transfer system, called the sewer line, manholes or inspection chambers, a treatment unit and a disposal system. The defecation unit is normally a vitreous china seating bowl or squatting plate which is fixed with a trap with a water seal of 50 to 75mm (see "Sanitary Appliances", **6.4 Plumbing Installations**). The excreta are flushed out of the bowl with 8 to 10 litres water from a flushing cistern through the sewer pipes (or foul water drains) and manholes into the treatment unit. This is an underground, water-tight tank, normally built in reinforced concrete and known as the "septic tank". It consists of two chambers in which the sewage is decom-

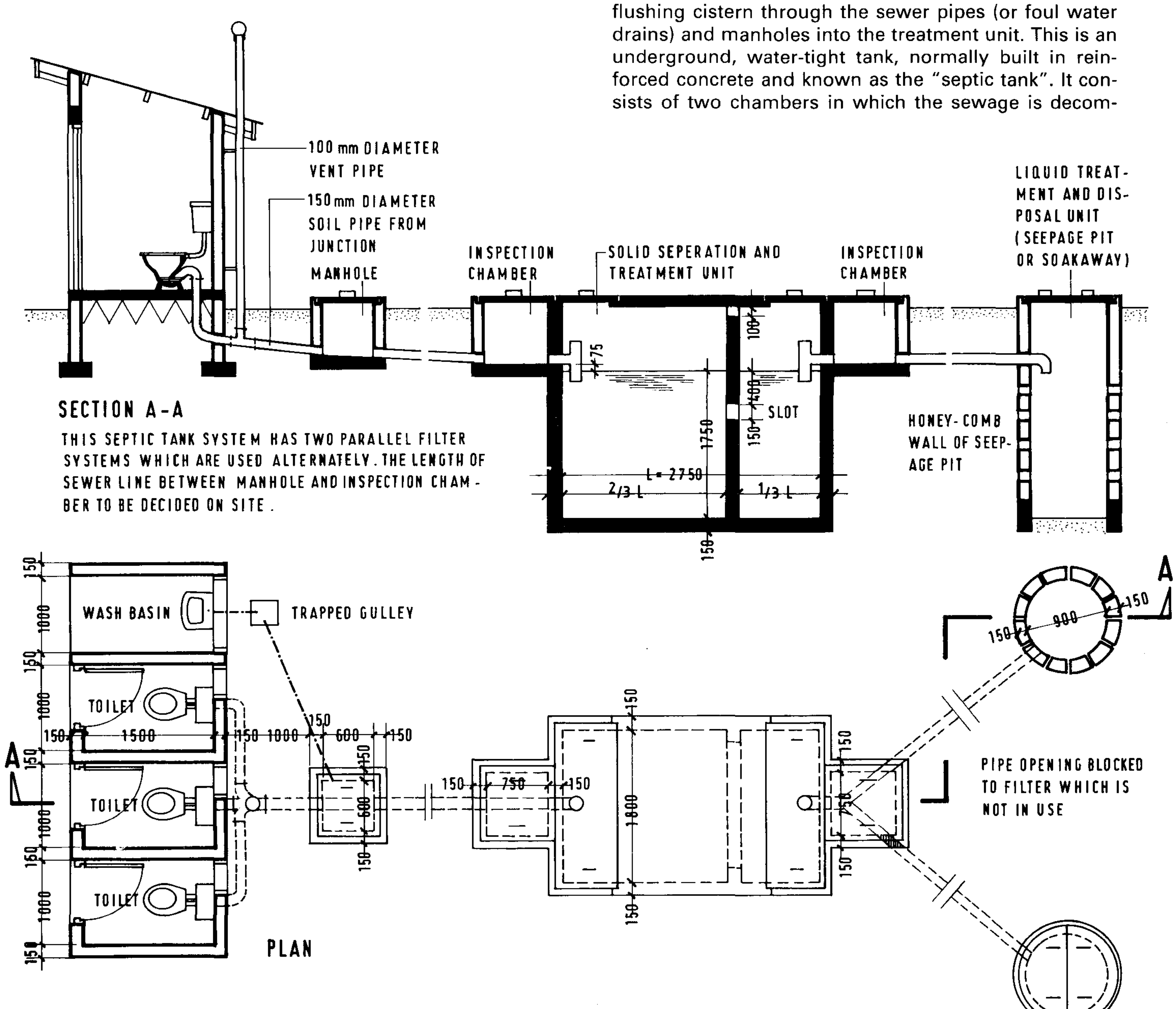


FIG. 389 : SEPTIC TANK SYSTEM

posed by anaerobic bacteria into gases and an effluent liquid which is then rendered harmless by leaching in soil absorption systems (soakaway pits, disposal fields). It is advisable to use two parallel soil absorption or filter systems alternatively to avoid clogging up. Disposal of effluent can be done into water drains following treatment in an anaerobic filter.

If a septic tank has been properly designed and functions correctly, emptying of the sludge should only be necessary at intervals of about five years.

Depending on the number of people occupying the building, sizes and fall of pipes should be designed so that there is no danger of the solids being deposited in the drainage systems instead of being flushed into the septic tank. Pipe sizes for household drains are from 100 to 150mm in diameter. There ist a wide range of different materials and fittings available, from vitrified clayware, cast iron, concrete (and porous concrete for disposal field pipes), asbestos cement to plastics. Consideration must be given in each case to the particular conditions of the site, type of soil, soil stability and type of effluent to be carried.

6.3.3 BIOGAS PRODUCTION

Under airtight conditions organic waste goes through an anaerobic digestion. In this process about 60% of methane (CH_4), carbon dioxide (CO_2), small quantities of hydrogen sulphide (H_2S), nitrogen (N_2), hydrogen (H_2) and carbon monoxide (CO) are released. This mixture is called "Biogas". Apart from the fact that methane alone is an important raw material for the chemical industry, biogas can be used as a fuel of high quality for cooking and lighting. It can also be used for the production of power to be used mechanically (for pumping, grinding) or for generating electricity.

After World War II the production and use of biogas in agriculture was developed in France. In Germany biogas production units and methane digesters were built in the 1950s. But with the then cheap availability of oil and earth gas biogas was not very popular. The picture is different today. The oil crisis which began in 1973 has led to a change of mentality in many countries of the world, especially in developing countries. In these countries it was realised that the development of biogas was very important as a solution to the fuel problem in the rural areas, especially in view of calculations which forecast that by the end of this century about 2,500 million people in Third World countries will be short of firewood for cooking (UN-Conference on New and Renewable Sources of Energy, August, 1981, Nairobi). Many Third World countries are already operating or testing biogas plants, notably China. In China over 7 million biogas plants are operating at present; India had about 70,000 plants in 1979 (Report of the International Biogas Workshop, Bremen, Federal Republic of Germany.)

Biogas is a fuel which is obtained from inexhaustible biological sources, animal waste and human excreta, leaves, grasses, crop waste, garbage, and agricultural and industrial wastes whose organic content is greater than 2%. Where is it acceptable that human faeces are used for the production of fertilizer (the slurry left in the biogas production procress is a very good fertilizer which can increase agricultural yields) biogas plants have a future. The main constraint on the spread of biogas technology, especially in rural areas of developing countries and for small size plants is the cost of the digester.

There are two main types of biogas production plants: The Indian Gobar-Biogas unit (Fig. 390) and the Chinese Biogas Dome (Fig. 391). The Indian Gobar plant with its moving steel gas bell is suitable for community use and as nightsoil plant at institutes, schools etc. For use as an individual family size plant the Gobar unit is not viable. The metal gas bell is susceptible to corrosion and has to be painted every other year with anti-corrosive paint. The use and maintenance of the plant requires thorough understanding and knowledge of the technology.

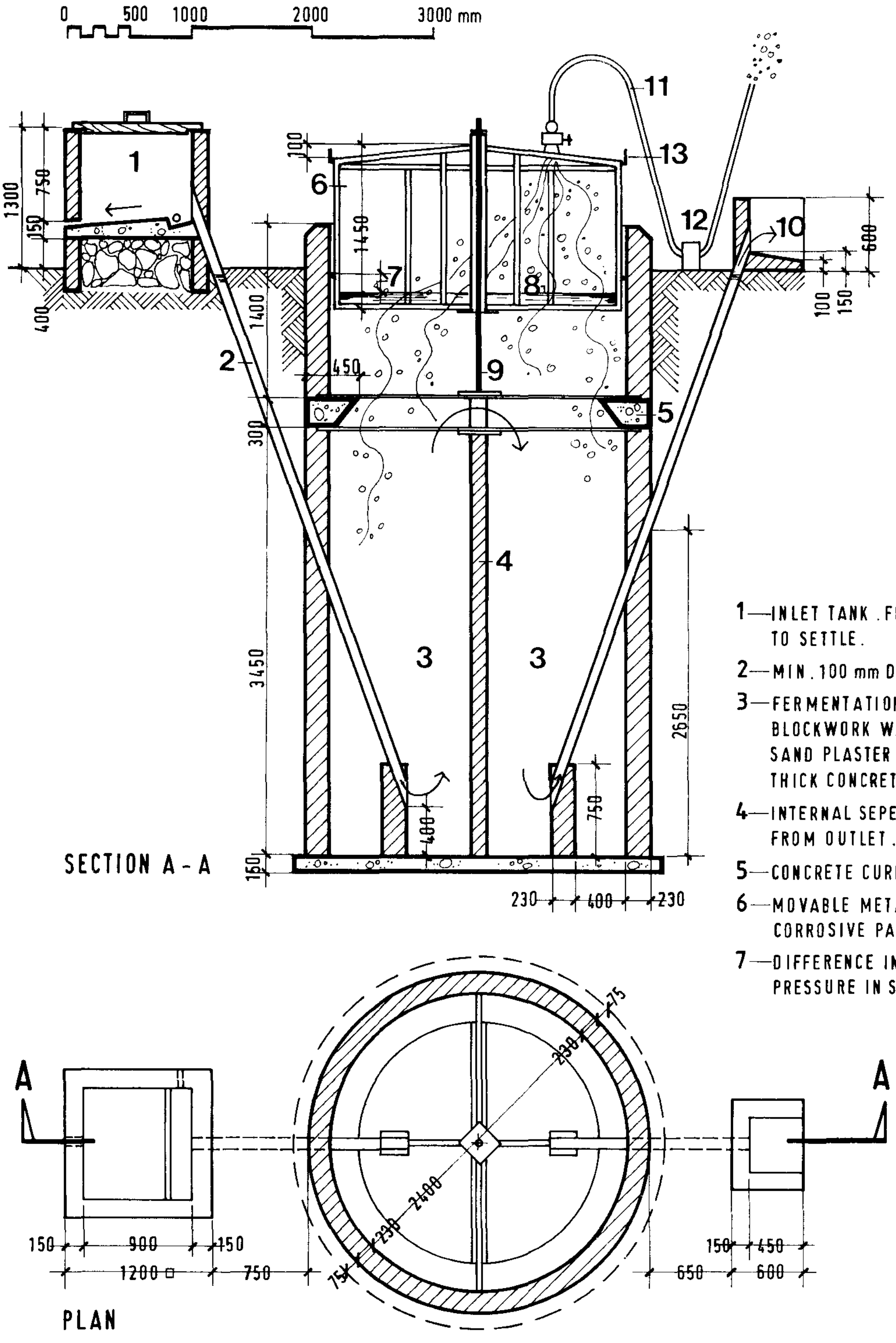
The Chinese Biogas Dome is built from locally available materials. The technology is simple. Although the construction of a brick dome is tricky it should pose no difficulties to a skilled bricklayer. Brick domes may develop leaks. This has been overcome by using concrete for the construction of the digester, which, however, increases the cost of the plant. With instruction at village level the Chinese type of plant can be used as a small plant for a family where the necessary amount of animal waste and human excreta to make the plant function (between 10 to 200kg per day) is available. In China the development of biogas technologies has shown that local communities can assimilate and adapt a technology to their own conditions and needs.

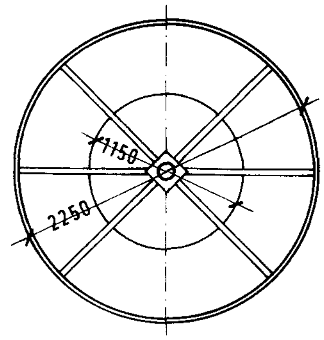
Each year complete forests, to a volume of double the existing forests in the Federal Republic of Germany, are cut in tropical developing countries for charcoal production and firewood. The shortage of firewood is increasing. Oil and fuel imports are becoming prohibitively expensive for developing countries. Biogas production, therefore, should be of concern to all these countries.

This concern should help to gradually overcome cultural and religious objectives against the use of human excreta. The enormous environmental and ecological benefits from waste re-use should be fully understood and accepted. The slurry left-over in the biogas production contains a nitrogen content which has been transformed into ammonia in the fermentation process. This is easier for plants to absorb and therefore greatly improves the fertilizer. On experimental fields where "biodung" was used as fertilizer the yield increased 10 to 30%. The fermentation of organic materials in biogas plants works better in temperatures around 30°C. This is a temperature range which is met in nearly all tropical developing countries (with the exception of desert areas with large temperature changes between day and night).

Some planning guidelines for the building of a biogas plant are:

- It should be placed so that it is exposed to the sunshine throughout the day;
- It should be sited at the shortest possible distance from the "raw material" (toilets, cattle, pig, poultry pens);
- It should be sited at a short distance from the place in which the gas is used (kitchen, living room);
- Minimum distance to a water well should be 20m;
- The fermentation compartment and gas storage tank must be strictly sealed to be completely water and airtight;





PLAN OF GAS BELL :

FRAME OF 35 x 35 x 6 mm MILD STEEL ANGLES(WELDED), WITH 300 x 300 x 6 mm FLANGE PLATE WELDED TO 100 mm DIAMETER M.S.CENTRAL PIPE , COVERED WITH 2.5 mm THICK (12 SWG) MILD STEEL SHEET.

1—INLET TANK . FLOOR TO SLOPE OUTWARD TO ALLOW SAND TO SETTLE.

2—MIN. 100 mm DIAMETER INLET PIPE

3—FERMENTATION TANK WITH 230 mm THICK SAND-CEMENT BLOCKWORK WALLS PLASTERED INTERNALLY WITH CEMENT-SAND PLASTER, 12.5 mm THICK. BOTTOM OF TANK 150 mm THICK CONCRETE SLAB.

4—INTERNAL SEPERATION WALL TO KEEP UNDIGESTED SEWAGE FROM OUTLET.

5—CONCRETE CURB

6—MOVABLE METAL GAS STORAGE BELL, PAINTED WITH ANTI-CORROSIVE PAINT.

7—DIFFERENCE IN LEVEL OF LIQUID AND SCUM SHOWS GAS PRESSURE IN STORAGE CONTAINER.

8—SCUM LEVEL. FREQUENT ROTATION OF GAS BELL BRINGS UP SEDIMENTS FROM BOTTOM OF TANK FOR METHANE PRODUCTION AND QUICKER FERMENTATION. THE SCUM LAYER, IF NOT DISTURBED, PREVENTS THE BIOGAS FROM RISING UP INTO THE GAS TANK.

9—VERTICAL GUIDE ROD FIXED TO METAL FLANGES AND ANGLES WHICH ARE ANCHORED INTO WALL OF FERMENTATION TANK. THE GUIDE ROD ENSURES EASY ROTATION OF GAS BELL AND PREVENTS ITS TILTING OVER.

10—MIN. 100 mm DIAMETER OUTLET PIPE AND COLLECTOR

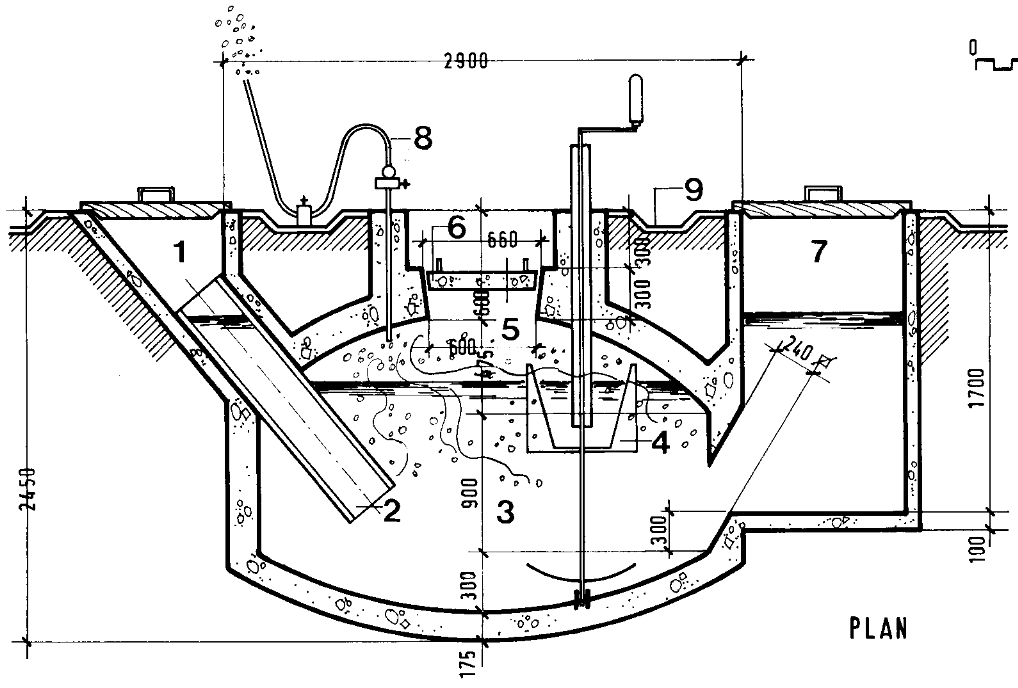
11—FLEXIBLE GAS HOSE (RUBBER OR PLASTIC) WITH MAIN VALVE FIXED TO TOP OF TANK.

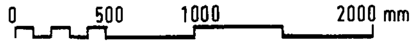
12—SYPHON FOR CONDENSED WATER AT LOWEST POINT OF GAS SUPPLY LINE.

13—HANDLES FOR TURNING

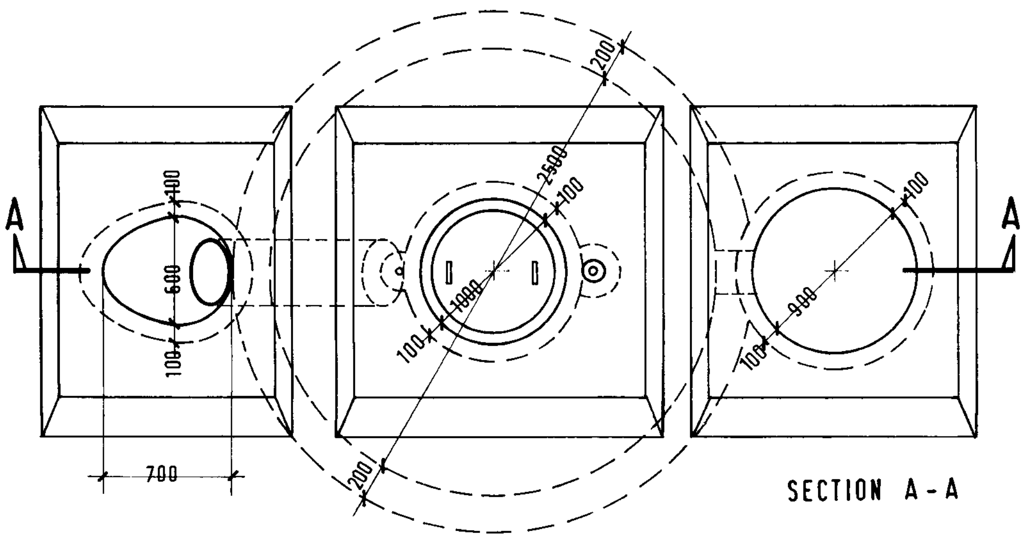
FIG. 390 : **GOBAR BIOGAS PLANT** - ADAPTED FROM "BIOGAS-HANDBUCH", TABLE 24 AND 25, BY G. EGGELING, H. AND R. GULDAGER, G. HILLIGES, L. SASSE, C. TIETJEN, U. WERNER, BREMEN OVERSEAS RESEARCH AND DEVELOPMENT ASSOCIATION.

- The size of the biogas plant chosen should be determined by the volume of gas needed and for what purpose it will be used. The Chinese experience shows that a family of five in rural areas will require about 1 m^3 gas daily for cooking and lighting. In tropical temperatures each cubic metre of plant volume will produce about 0.20 m^3 gas. One should therefore go by the rule that 1.5 to 2.0 m^3 of plant volume should be calculated per head per family for the correct size of a biogas plant (from "A Chinese Biogas Manual", Intermediate Technology Publications Ltd., England).



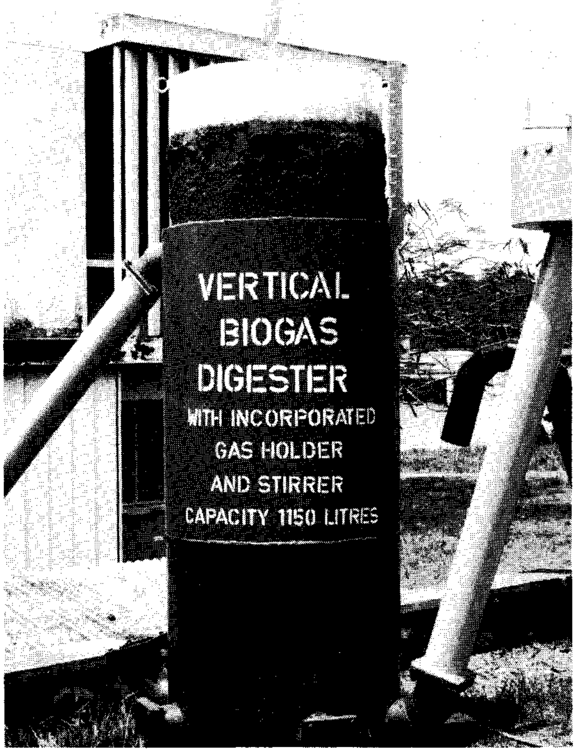


1 — MATERIAL INLET : EXCRETA (HUMAN, ANIMAL), ORGANIC KITCHEN WASTE. INLET
2 — PIPE (250 TO 400 mm DIAMETER) TO BE LONG ENOUGH TO END IN SEWAGE.
3 — FERMENTATION COMPARTMENT BUILT WITH BRICKS OR REINFORCED CONCRETE, PLASTERED WITH MIN. 12.5 mm CEMENT-SAND PLASTER INTERNALLY AND PAINTED WITH BITUMINOUS PAINT.
4 — APPLIANCE FOR STIRRING
5 — GAS DOME FOR STORAGE
6 — GAS-TIGHT CONCRETE COVER TO WEDGE INTO OPENING.
7 — OUTLET TANK. LEVEL OF SLURRY SHOULD NOT FALL BELOW THE UPPER EDGE OF PASSAGE TO FERMENTATION COMPARTMENT.
8 — GAS PIPE WITH MAIN VALVE. TAP FOR SYPHONAGE OF CONDENSE WATER AT LOWEST POINT OF PIPE.
9 — AREA AROUND GAS PLANT WELL SCREEDED TO PREVENT GAS LEAKS AND TO FACILITATE EASY CLEANING.



SECTION A-A

FIG. 391 : **THE CHINESE BIOGAS DOME** - ADAPTED FROM "BIOGAS HANDBOOK", BREMEN OVERSEAS RESEARCH AND DEVELOPMENT ASSOCIATION, AS FIG. 390.



For Fig. 390: An experimental biogas plant produced by J. Wirth, Department of Agric. Engineering, Faculty of Agriculture, U.S.T., Kumasi.

6.4 PLUMBING INSTALLATIONS

Plumbing installations (external and internal) are normally guided by local "Building Regulations", "Building By-laws", or in the absence of those by "General Specifications for Building Works". These regulations or specifications cover "Drainage, Private Sewers, Pipework under and above ground" etc.

6.4.1 WATER SUPPLY AND DISTRIBUTION

In most cases buildings are supplied from a water main or service pipe line which will take treated water from a main public water supply source through tributary pipe lines to a service reservoir straight or through a cold water storage tank into a building. The watermain which sends water into a service reservoir is called the **"Rising" or "Pressure Main"**. The pipe which takes the water from the service reservoir for distribution is called the **"Transmission" or "Trunk Main"**. It is advisable in developing countries to provide a storage tank for each dwelling (or block of flats) from which supply pipes feed each sanitary appliance. This will ensure regular pressure and supply to be maintained in the internal distribution system in the event of the main water supply being turned off (for maintenance purposes or in the case of a breakdown). In buildings of more than two storeys, cold water storage tanks must be provided so that the internal distribution system is independent of insufficient pressure and cut-offs. Water storage tanks should be closed and have filters at airvent and overflow to prevent ingress of dirt, birds, insect larvae (e.g. mosquitoes) etc. (Fig. 392). They should be cleaned and disinfected regularly.

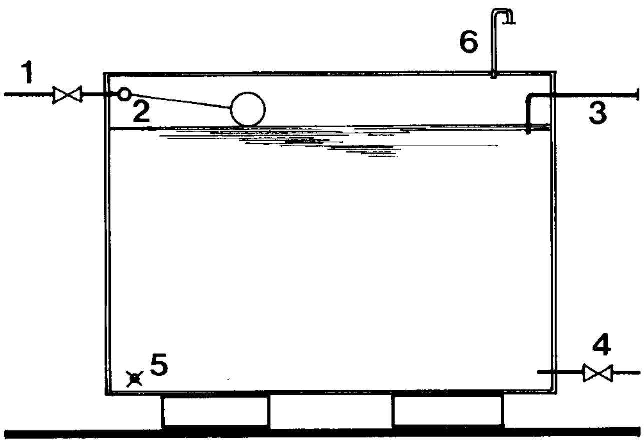


FIG. 392: TYPICAL COLD WATER STORAGE TANK, SCHEMATICAL SECTION

1–SERVICE PIPE
2–FLOAT-OPERATED BALL VALVE
3–OVERFLOW OR WARNING PIPE WITH FILTER
4–DISTRIBUTION PIPE WITH ISOLATING VALVE
5–DRAIN COCK
6–AIRVENT WITH FILTER

To cover 24 hours interruption of water supply a provision of storage of 60 to 80 litres per person per dwelling or flat should be calculated as a minimum.

6.4.1.1 WATER MAINS AND SERVICE PIPES:

Various types of materials are used for water mains, service and supply pipes. The choice of material is influenced by a number of factors:

- The flow characteristics (friction coefficient);
- Life expectancy under tropical conditions and use experience;
- Resistance to corrosive agents present in the air (moisture, sulphuric acid, carbon-dioxide, sulphur-dioxide) and in water containing acids (mineral and vegetable), alkalis and salt;
- Ease of handling and installation;
- Strength to resist structural failure;
- Types of joints used to ensure watertightness and ease of assembly;
- Availability in sizes required;
- Cost of materials, handling and installation.

Water mains generally have an internal diameter larger than 250 mm. Secondary and tertiary mains are from 250 to 100 mm and supply and service pipes from 100 to 12 mm. They are made from the following materials:

Asbestos-Cement Pipes:

These pipes are used as gravity and pressure water pipes. They can be produced in sizes from 50 to 915 mm. Asbestos-cement pressure pipes can be fitted with flexible joints (Fig. 393 shows different pipe joints).

Cast Iron Pipes:

Cast iron pipes are of large diameter (up to 1.2 m are used in places where external loads are high and absolute watertightness is required). They are fitted with caulked spigot and socket joints. Cast iron pipes are susceptible to corrosion both internally and externally.

Mild Steel Pipes:

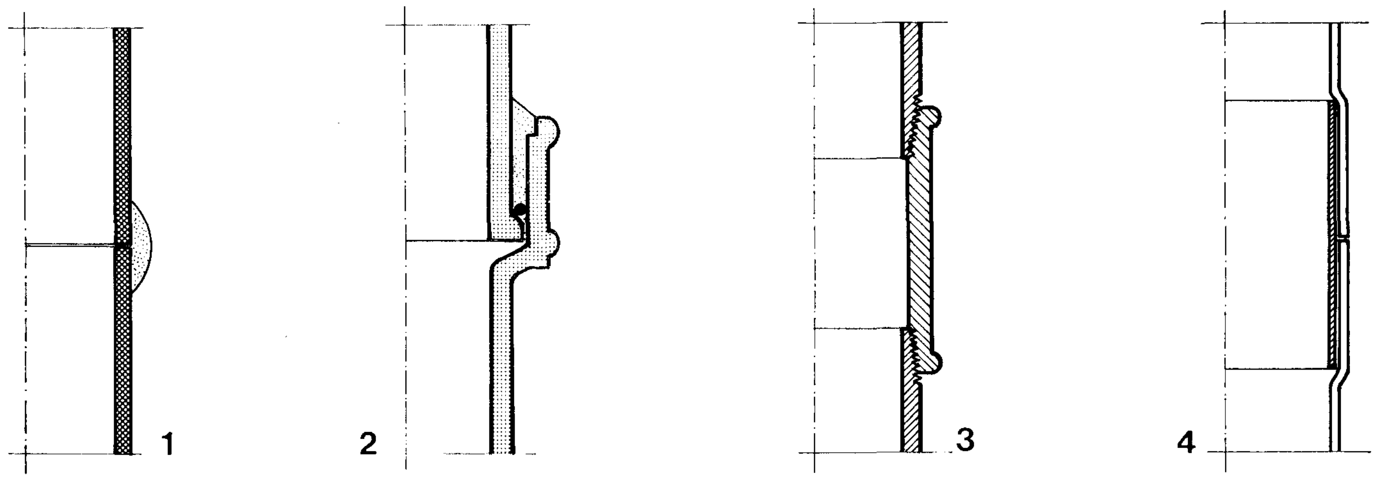
These pipes should always be galvanized. They are very strong and are used for watermains and rising mains in sizes up to 150 mm in diameter. Steel pipes lend themselves to prefabrication of multi-branch units off-site. Joints for smaller diameter sizes are screwed and for larger diameter sizes socketed. Very large diameter pipes can be produced with flanges which facilitate bolting together. When steel pipes are cast into the structure (wall or floor) they should be protected with a wrapping of waterproof paper tape or by painting them with bitumen.

Copper Pipes:

Copper pipes are of high strength and ductility. They can be used in light gauges for cold and hot water pipes in buildings. They are very expensive and in many cases nowadays are replaced with PVC pipes where possible. Jointing of copper pipes is by welding or capillary solder joints.

PVC (Polyvinyl Chloride) Pipes:

PVC pipes are resistant to most acid and alkaline conditions. They are the most commonly used pipes for cold water supply systems, for watermains, service and cold water distributing pipes. They cannot, however be used at temperatures higher than 65 °C and should also not be subjected to shock loads or sustained heavy pressure. Sizes are from 10 to 200 mm. PVC pipes are joined by solvent welding or with rubber ring joints.



1: LEAD AND LEAD ALLOYS JOINTS ARE SURROUNDED BY SOLDER ("PLUMBER'S WIPED JOINT").

2: CAST IRON PIPES SPIGOT AND SOCKET JOINTS, CAULKED WITH MOLTEN LEAD, USING A GASKET RING INSIDE THE LEAD CAULKING.

3: STEEL TUBES SCREWED JOINTS WITH COUPLING PIECES.

4: PLASTIC PIPES SLEEVED JOINTS (USING METAL SLEEVES; COMPRESSION FITTING, AS SHOWN ABOVE), SOLVENT WELDED JOINTS (USING A SOLVENT CEMENT; FOR P.V.C. PIPES), OR RUBBER RING JOINTS (USING A RUBBER 'O' RING; FOR P.V.C. SOIL AND WASTE PIPES).

FIG. 393 : PIPE JOINTS

Lead Pipes:

Lead is a very heavy material, very soft, ductile and malleable. Because it is easily worked, cut and soldered it is used for complicated, shortlength connections in the cold water distribution system. Lead pipes are joined by soft solder.

Concrete:

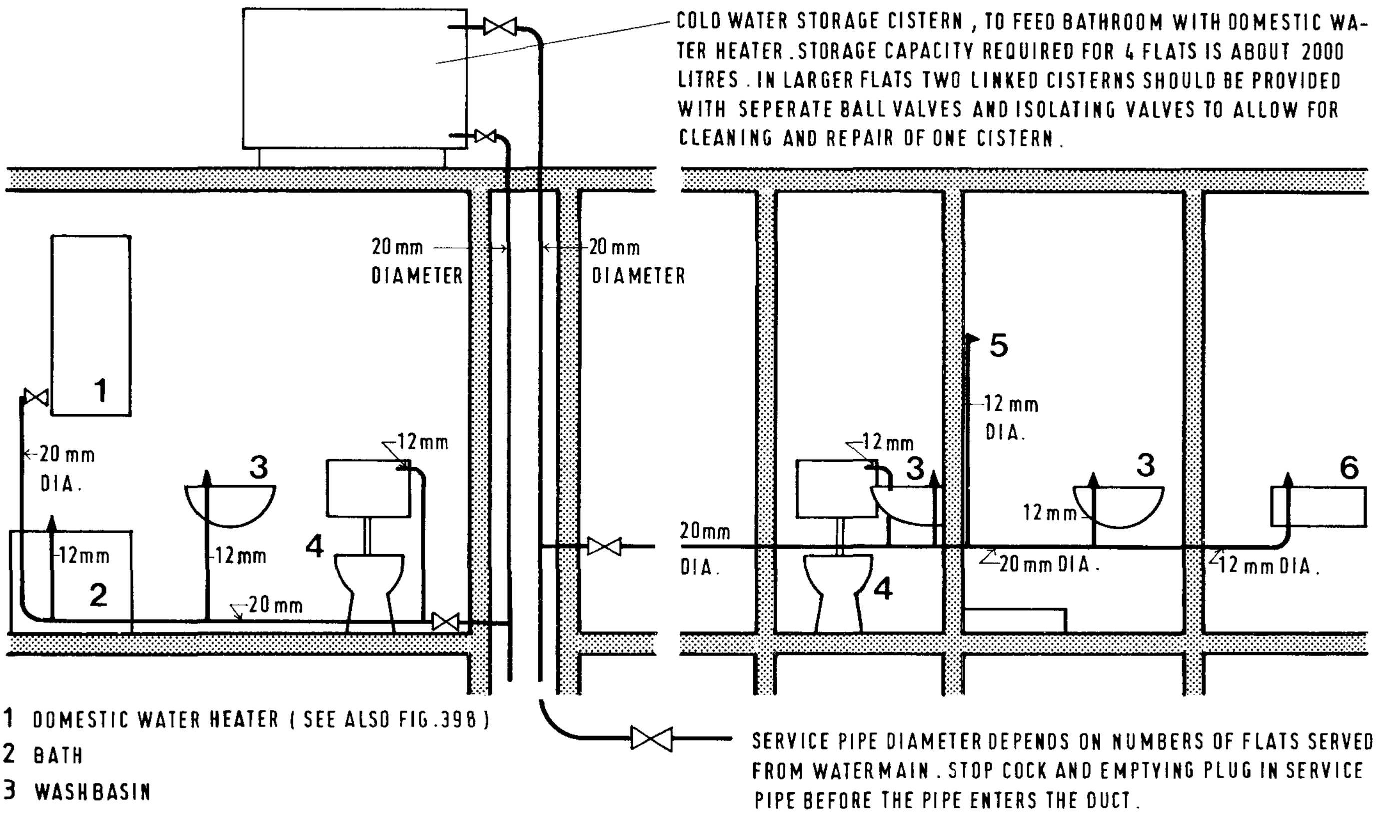
Concrete pipes from unreinforced concrete range from 100mm to 600mm in diameter. Reinforced concrete pipes or spun concrete pipes are from 200mm to over 3 metres in diameter. These pipes are used for large mains where long laying lengths and great strength are required.

6.4.1.2 INTERNAL DISTRIBUTION SYSTEM:

The service pipe enters the building about 750mm below ground. It rises inside at a place which depends on the position of the water storage tank, from where the pipework is distributed to the fittings. Single storey buildings which do not require cold water storage can have all parts of the water supply installation directly from the watermain under mains pressure. The water is delivered to all fittings directly by supply pipes. Water meters are installed in the service pipe before this enters a building. In many countries flat rates per dwelling or per sanitary appliance are charged.
A stop-cock must be provided immediately after the service pipe enters the building for shutting off the installation. All sanitary appliances should be fitted in addition with isolating stop valves to facilitate maintenance. Domestic cold water supply pipes are normally of 12mm diameter throughout. The service pipe diameter at entry is 25mm. This will allow simultaneous use of taps inside a dwelling without restriction of flow.
For high-rise buildings pumps are installed at ground level for raising water to the storage tank and special drinking water cisterns at roof level. Fig. 394 shows an internal cold water distribution system.

6.4.2 SOIL AND WASTE DISPOSAL

Soil and waste pipes convey the flows from sanitary appliances to the first manhole. From there underground soil drainage pipes convey the sewage to the disposal system. Soil pipes are connected to toilets and urinals and carry flows containing excreta. Waste pipes are connected to lavatory basins, showers, baths, kitchen sinks etc. and carry flows from these appliances. Each sanitary appliance is provided with a trap to seal the air in the pipework, so that it cannot enter the room. Water seals are from 50mm to 75mm. Lavatory basins, baths and showers may discharge into a common waste pipe (not exceeding 5m in length) without individual traps, provided the waste is trapped at its outlet and has suitable means for cleaning.
The design problem of how to estimate the flows in the system to ensure that economical pipe sizes are chosen and that equal pressure is maintained in the system depends on the choice of system and also on whether the system is a combined system (soil and waste pipes to discharge into the same sewerage system) or not (waste to discharge into a separate soakaway together with or without surface water). The practice of discharging waste water (or **"greywater"**) into open drains in developing countries is to be discouraged. In many urban settlements and villages there are no drainage systems. In most areas surface drains consist of open channels into which kitchen and bath waste water is also discharged. The water dries up after travelling some distance or stagnates which creates stink and health hazards through mosquitoe breeding (Fig. 395). Although ingenious erosion checking devices are fixed inside the channels (Fig. 396), they cause solid wastes to collect at these points, since these "drains" are not swept and cleaned. The commonly constructed open concrete drains for surface water collection in urban areas produce foul smell if they are used for greywater-discharge, even if they are regularly cleaned. New drainage by-laws establish, among others, the rule that waste water ist to be discharged via a trapped gulley into the sewerage system.



1 DOMESTIC WATER HEATER (SEE ALSO FIG. 398)
2 BATH
3 WASHBASIN
4 W.C.
5 SHOWER
6 KITCHEN SINK

FIG. 394 : **INTERNAL COLD WATER DISTRIBUTION** (BASED ON THE PLAN USED FOR FIG. 398)

Soil pipes are normally 100 to 150 mm in diameter, waste pipes from 32 mm to 50 mm for domestic appliances (up to 76 mm for non-domestic appliances, e.g. in hotels and canteens). Main sewer drain pipes vary in size. Soil and waste pipes are made from the following materials:

Glazed or Unglazed Vitrified Clay Pipes:

These are the traditionel drain pipes. Although brittle, they are very durable. They are joined with cemented sprigot and socket joints or rubber sealing and plastic bedding rings or with plastic couplers. Sizes are from 75 to 750 mm in diameter.

Cast Iron Pipes:

These pipes are used for domestic drainage systems and in places where ground movement might occur or where drains pass under roads or buildings. Sizes are from 50 to 150 mm in diameter.

Asbestos Cement Pipes:

They are used as pressure pipes underground. Sizes are from 100 mm to 600 mm in diameter.

Concrete:

Concrete pipes are normally used for larger drainage systems, but not for domestic purposes where other materials are more suitable and competitive. Sizes are from 100 mm to 2 metres in diameter.

Plastic Pipes:

Unplasticized PVC pipes have become very common as soil pipes, especially for drainage systems with main stack, waste and ventilating pipes placed in a duct. They are light in weight and easily handled. Soil pipes from

Fig. 395: Surface water drain in Anloga, a Kumasi-Zongo, 1978.

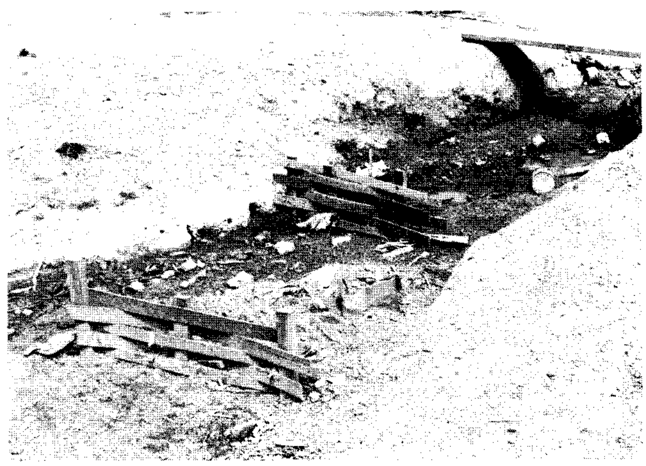


Fig. 396: A local "erosion check" in a surface water drain, Anloga, Kumasi, 1978.

PVC are suitable for normal discharges of effluent up to 65°C. But the best use of PVC pipes is for cold water installations and vent pipes. CPVC (Chlorinated PVC or "High Temperature PVC") pipes are suitable for waste systems. They have high temperature performance and good resistance to chemical reagents.

The minimum internal diameter of domestic waste and soil pipes is:

Wash basins	32 mm
Bidets	32 mm
Kitchen sinks	32 to 38 mm
Baths	38 to 50 mm
Shower bath trays	38 to 50 mm
Washing machines	50 to 70 mm
Urinals	38 to 50 mm
Water closets	100 mm

6.4.2.1 SANITARY APPLIANCES:

The different types of sanitary fittings have developed from utilitarian into quite glamorous features of present day living. The modern lines of fittings are clean, smooth shapes, with many of the appliances being fitted directly to the wall of the bathroom or toilet. Colour has also been introduced. The planning of the technical features now considers scarce water resources, e.g. development of water-saving flushing cisterns, spraying taps etc. The shower is rapidly replacing the bath tub, an avid consumer of water in the house. Or the old bath tub has been replaced with smaller types, often in combination with a shower.
Sanitary fittings should be impervious and have surfaces which are easily cleaned. The main materials used for these fittings are:

Vitreous China Ware:

This is a completely impermeable material, unlike glazed earthenware which is of a permeable material glazed over. Most of the modern W.C. pans, squatting closets, urinals, bidets, wash basins are produced from vitreous china.

Cast Iron:

With a vitreous enamelled finish fired on, very large fittings are normally produced from cast iron (e.g. baths, showertrays).

Stainless Steel:

This material, although noisy, is commonly used nowadays for kitchen sinks. The fittings are produced with one or two bowls and a drain board to be part of a built-in-kitchen fitting. The material is able to withstand impact and abrasion and is very hygienic for use in canteens, institutions etc.

Plastics:

Plastics are very widely used (white and black) in the production of W.C. seats and covers and cisterns.

On the following detail drawings the different sanitary appliances are shown including some anthropometric data for correct installation in relation to the user's space requirements. The fittings are:

– WATER CLOSETS:

There are many different designs in existence, basically for two types, the W.C. pan for sitting and the squatting platform or plate for squatting. The latter is also called the "eastern closet"; it is widespread in Eastern European countries (the Balkan countries, Greece, Turkey etc.). It is the most hygienic appliance for public toilets but is not suitable for use by old and infirm people.
The water closet consists of a pan and a cistern for storing the water for the flushing system (normally 9 litres). Various types of W.C.s have been developed of which the single seal siphonic closet is becoming the "universal" closet, since it does not need such a powerful flush as the ordinary wash-down closet requires for emptying the bowl, and is silent in action. The closets are fixed with 'S' or 'P'-traps. S-traps are used from the first floor up, P-traps for groundfloor installation.

The flushing cisterns, from ceramics or plastics, can be positioned at high level (about 2 metres above floor level), at low level (about 1 metre to the top of the cistern, the most commonly used), or the cistern is a fixed part of the pan. Cisterns are supplied with a ball-valve (float-operated) which controls the flow of water by the movement of a piston or diaphragm. They must be provided with an overflow, which should discharge in a conspicuous position (into the bath for example) and must be in a position to drain away water as fast as possible.

– URINALS:

These are mostly installed in places of public convenience and in offices, institutions etc. for male use. There are three types: the bowl-urinal with a lipped basin and flushing rim, most commonly used these days; the slab type which comprises a flat wall slab, and screens and a floor channel, with automatic flushing cistern; the stall type, made singly or in ranges with concave back and sides, finishing above the floor channel.

The floors or urinal compartments should be of impervious material and the surrounding walls covered with non-absorbent materials, e.g. glazed wall tiles, to facilitate easy cleaning. Urinals should be provided with floor drains for washing the floor.

– BIDETS:

Originating from France the use of this sanitary appliance is increasing and it is included in the layout planning of most bathrooms. Bidets are used for perineal washing and where required are normally fixed in association with a water closet. Water supply is controlled through 12 mm diameter cold and hot water valves. Waste outgo is via a 32 mm diameter pop-up waste and trap.

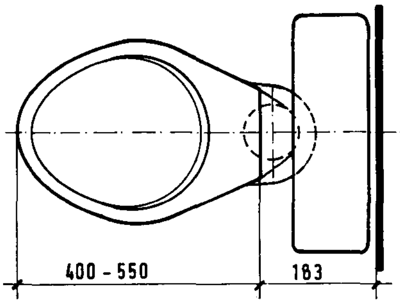
– WASH BASINS:

These are produced in a large range of different designs and sizes and normally made from vitreous china. Waste outgo is 32 mm in diameter. The basins normally have an integral overflow. Control of outgo is by plug and chain or pop-up waste and trap. The water supply is through 12 mm diameter cold and hot water taps.

– BATHS:

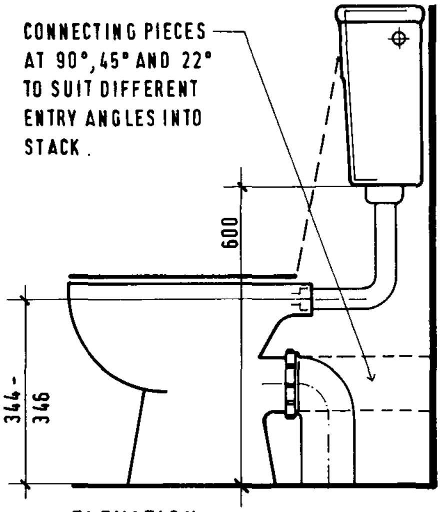
The usual material for baths is vitreous-enamelled cast iron. Plastic baths have also been introduced (from **Perspex**). Baths are produced in different sizes: as free-standing, built-in or cladded, and seating baths. Cold and hot water supply is via 18 mm to 25 mm taps or mixing valves. Wastes are 38 mm for domestic appliances and 50 mm for institutions with trap. Baths can have an incorporated hand shower fitting or a fixed shower.

6.4.2.1 SANITARY APPLIANCES - DETAILS :

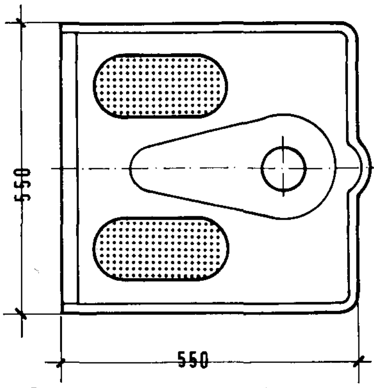


PLAN - UNIVERSAL W.C. WITH HIDDEN 'S' TRAP (SEE SECTION BELOW) OR 'P' TRAP.

1 WATER CLOSETS



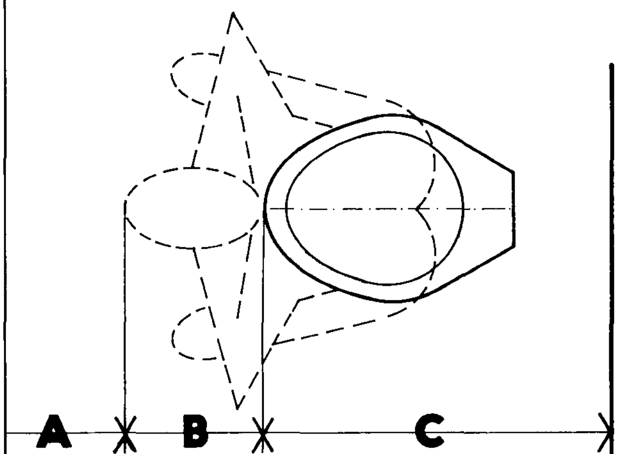
ELEVATION



2 EASTERN CLOSET : PLAN

THE EASTERN CLOSET SHOWN HERE IS A VITREOUS CHINA DISHED TRAY TO WHICH A 100 mm DIA. 'P' OR 'S' TRAP CAN BE CONNECTED.

D : APPROX. 80 TO 100 mm



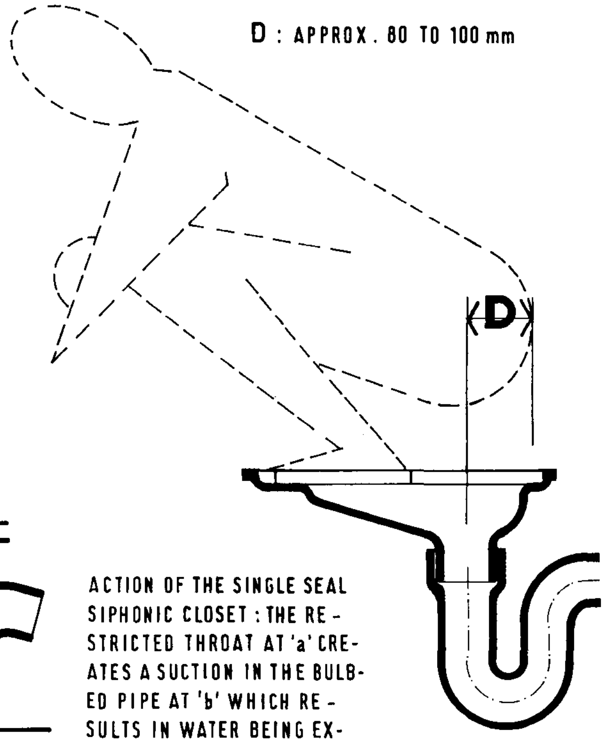
A : 350 (MINIMUM)

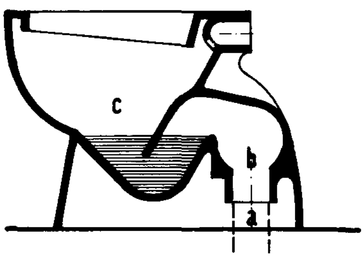
B : 350 - 450, AVERAGE 400

C : 530 - 750, DEPENDING ON THE DIFFERENT TYPES OF WATER CLOSETS WHICH ARE AVAILABLE.

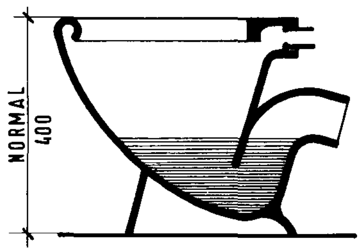
WIDTH OF TOILET OR CUBICLE 900 mm.

ANTHROPOMETRIC DATA





SECTION THROUGH A SINGLE SEAL SIPHONIC CLOSET (UNIVERSAL W.C.)

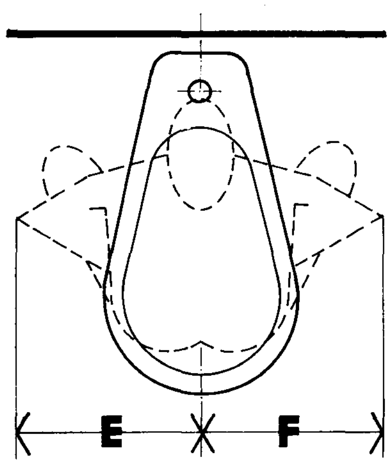


SECTION THROUGH A WASH-DOWN CLOSET

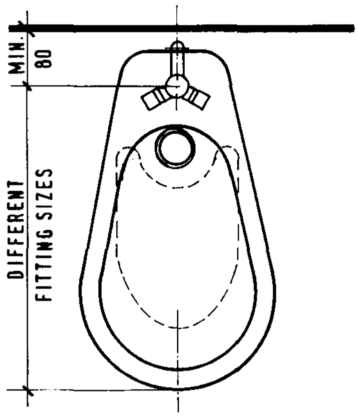
ACTION OF THE SINGLE SEAL SIPHONIC CLOSET : THE RESTRICTED THROAT AT 'a' CREATES A SUCTION IN THE BULBED PIPE AT 'b' WHICH RESULTS IN WATER BEING EXPELLED FROM BOWL 'c' AFTER FLUSHING.

SECTION THROUGH EASTERN CLOSET

SIPHONIC W.C.S AND BIDETS ARE OBTAINABLE AS WALL-HUNG FITTINGS. THIS MAY BE DESIRABLE FOR AREAS WHERE ACCESSIBILITY OF THE WHOLE FLOOR SPACE IS ESSENTIAL FOR EASY CLEANING (HOSPITALS, HOTELS).



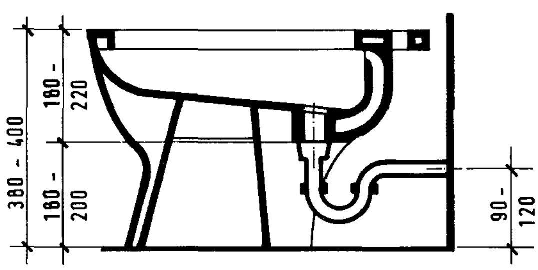
3 BIDETS



PLAN OF STANDING BIDET

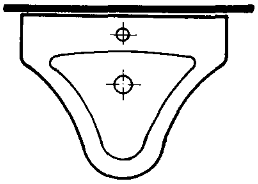
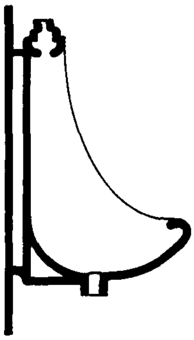
E : 325 - 375 (AVERAGE 350)

F : 325 - 375 (AVERAGE 350)

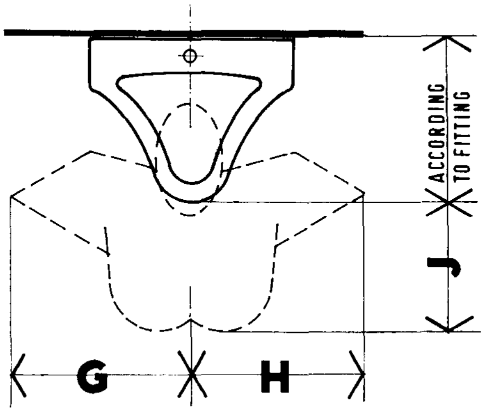


SECTION THROUGH STANDING BIDET

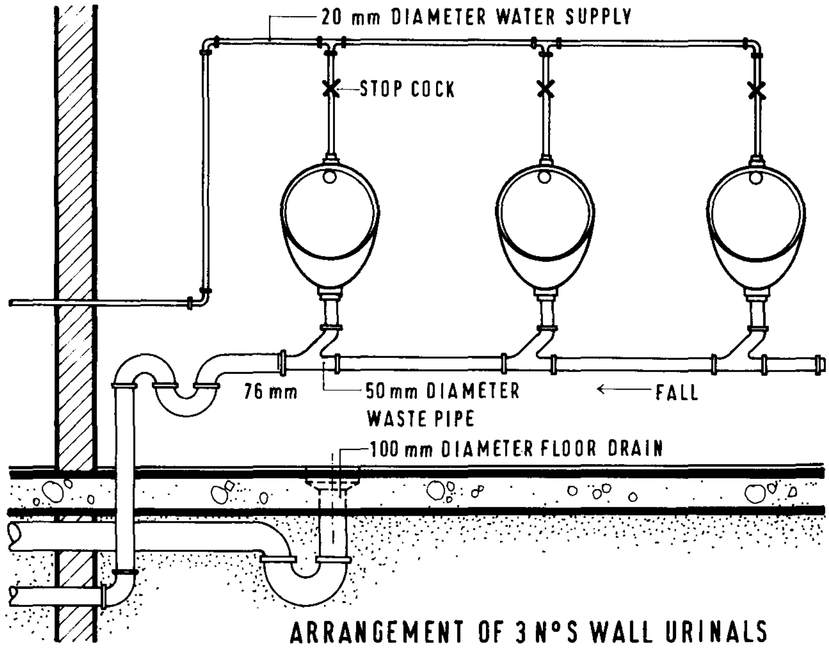
ANTHROPOMETRIC DATA AND BASIC DIMENSIONS ARE ADAPTED FROM "ABWASSERANSCHLÜSSE, SANITÄRPLANUNG" BY FELIX AUER (AKO, KÖLN).

PLAN OF AND SECTION THROUGH A WALL-HUNG URINAL



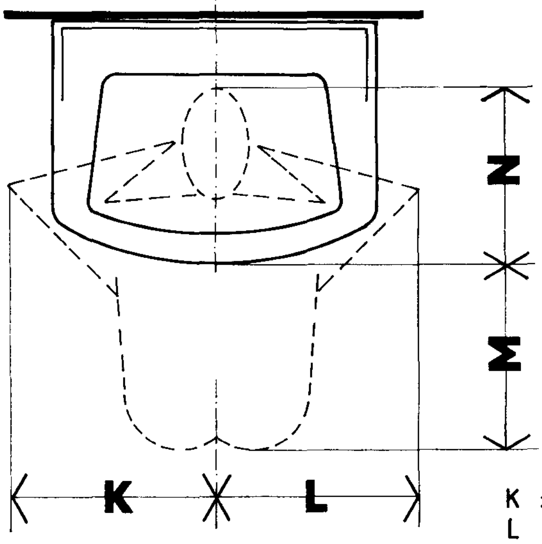
G : 300 - 350 (AVERAGE 325)
H : 300 - 350 (AVERAGE 325)
J : 250 - 350 (AVERAGE 300)

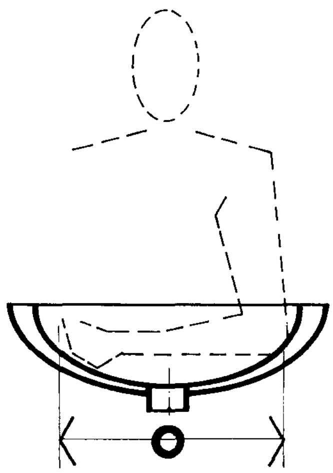


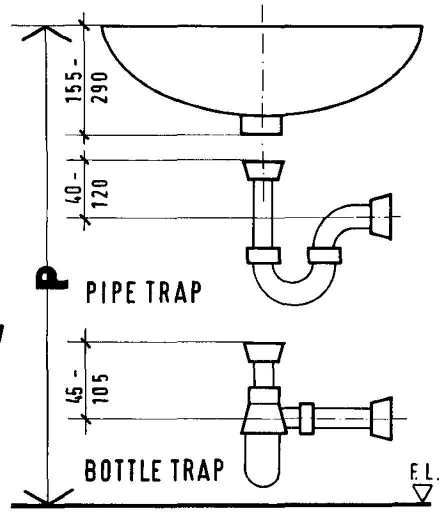
4 URINALS

ARRANGEMENT OF 3 N°S WALL URINALS

WATER SUPPLY PIPES AND WASTE PIPES FROM URINALS ARE SHOWN EXPOSED. EACH URINAL COULD BE FITTED WITH AN INDIVIDUAL TRAP AND WATER SUPPLY AND COMMON WASTE PIPE FITTED INSIDE A DUCT BEHIND THE WALL (URINAL INSTALLATION, POST OFFICE MAMPROBI, ACCRA).



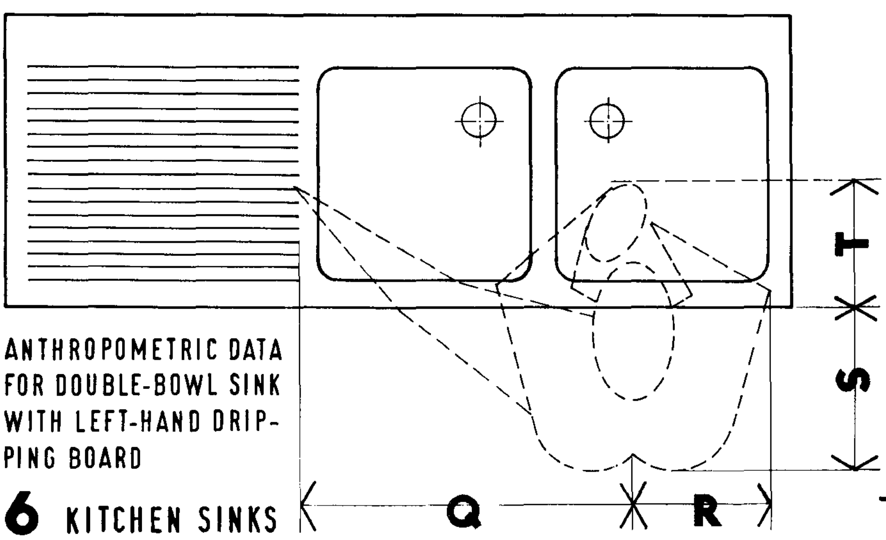


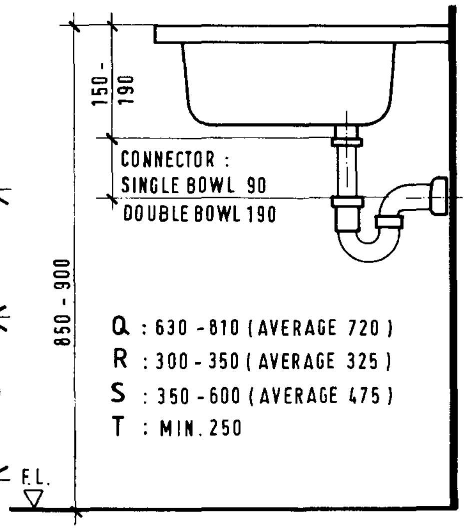


5 WASH BASINS

K : 300 - 450 (AVERAGE 375)
L : 300 - 450 (AVERAGE 375)
M : 350 - 600 (AVERAGE 475)
N : 300 - 500 (AVERAGE 450)
O : 400 - 500 (AVERAGE 450)

P : FOR ADULTS 800 - 900
FOR CHILDREN UP TO 14 YEARS MIN. 760
FOR CHILDREN UP TO 10 YEARS MIN. 660
FOR CHILDREN UP TO 6 YEARS MIN. 560

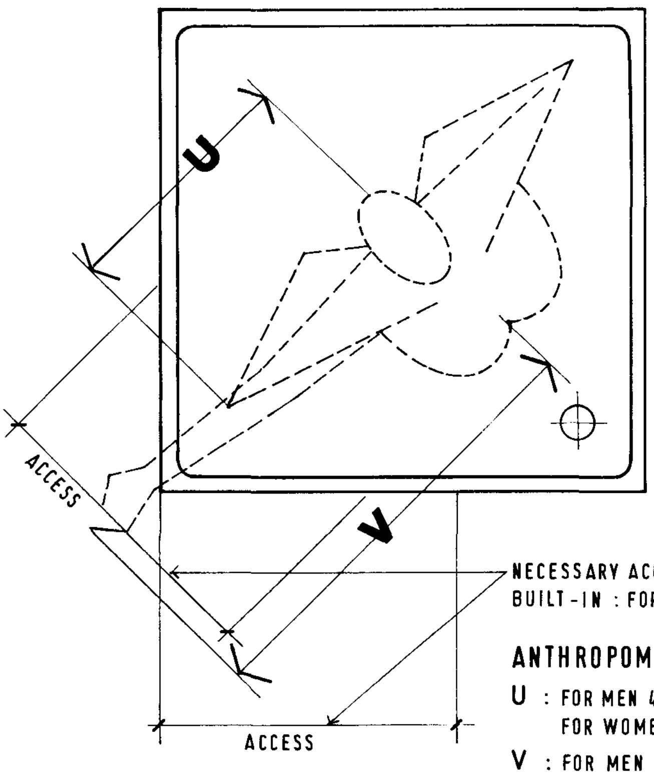




Q : 630 - 810 (AVERAGE 720)
R : 300 - 350 (AVERAGE 325)
S : 350 - 600 (AVERAGE 475)
T : MIN. 250

ANTHROPOMETRIC DATA FOR DOUBLE-BOWL SINK WITH LEFT-HAND DRIPPING BOARD

6 KITCHEN SINKS

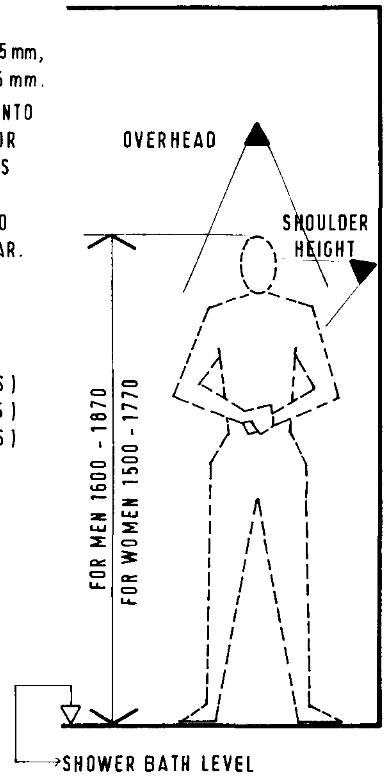


SHOWER BATH DEPTHS ARE :
FOR SHALLOW SHOWERS 50 - 65 mm,
FOR NORMAL SHOWERS 150-175 mm.

SHOWER BATHS CAN BE BUILT INTO THE FLOOR OF THE BATHROOM OR RAISED ABOVE THE FLOOR. SIZES ARE FROM 800 x 800 TO 1000 x 1000 mm SQUARE OR 750 x 800 TO 750 x 1000 mm RECTANGULAR.

HEIGHT OF NOZZLE FIXING :
OVERHEAD :
FOR ADULTS 2200 - 2400
FOR CHILDREN: 1550 (6 YEARS)
1900 (10 YEARS)
2100 (14 YEARS)

SHOULDER HEIGHT :
FOR ADULTS 1600 - 1950
FOR CHILDREN 1150 - 1550



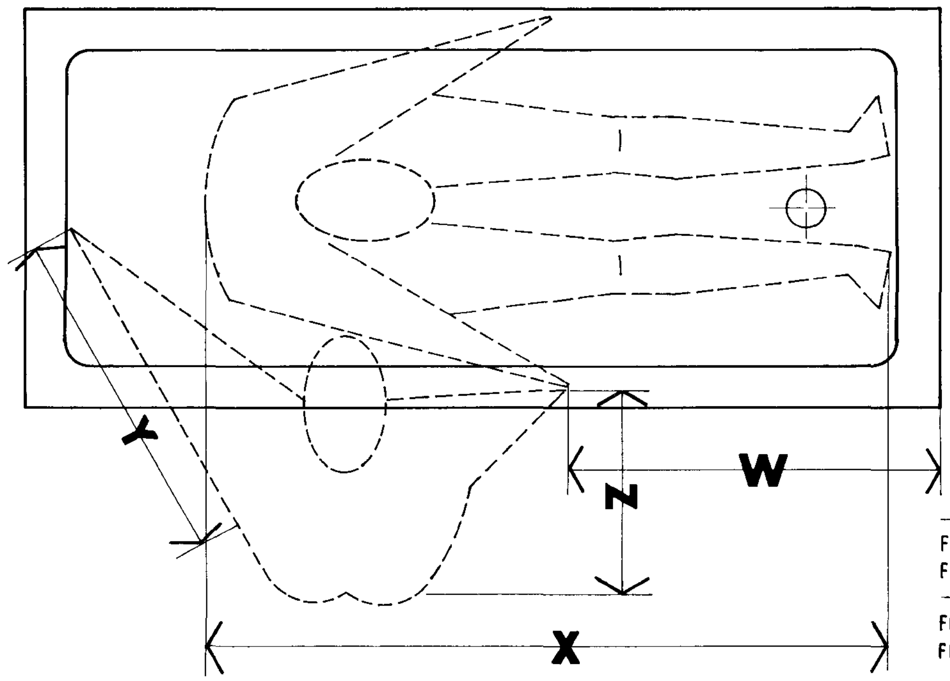
NECESSARY ACCESS TO SHOWER BATHS WHICH ARE BUILT-IN : FOR MEN 550 mm , FOR WOMEN 450 mm .

ANTHROPOMETRIC DATA :

U : FOR MEN 430 - 510 (AVERAGE 470)
FOR WOMEN 390 - 460 (AVERAGE 420)

V : FOR MEN 750 - 1050 (AVERAGE 900)
FOR WOMEN 650 - 950 (AVERAGE 800)

7 SHOWER BATHS



ANTHROPOMETRIC DATA :

W : 700 - 800

X : WITH LEGS STRETCHED OUT :
FOR MEN 960 - 1160 (1060)
FOR WOMEN 860 - 1140 (1000)

Y : FOR MEN 750 - 1000 (900)
FOR WOMEN 650 - 900 (800)

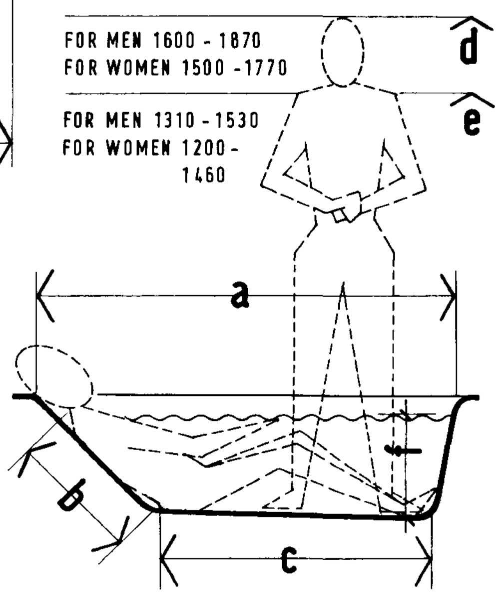
Z : 350 - 600 (AVERAGE 475)

a : FOR MEN 1600 - 1700
FOR WOMEN 1460 - 1550

b : FOR MEN 540 - 640
FOR WOMEN 490 - 590

c : FOR MEN 1090
FOR WOMEN 1020

f : WATERLEVEL TO OVERFLOW 370



NORMAL BATH SIZES ARE 1600 x 700 x 475 (DEEP) TO 1700 x 750 x 475 (DEEP). OTHER SHAPES AND MULTI-PURPOSE BATHS ARE NOT CONSIDERED HERE .

8 BATHS

ANTHROPOMETRIC DATA AND BASIC DIMENSIONS USED FOR 6.4.2.1 : SANITARY APPLIANCES - DETAILS, ARE ADAPTED FROM "ABWASSER-ANSCHLÜSSE , KÖLN 1976 " BY FELIX AUER (PUBLISHED BY AKO-ABFLUSSROHRKONTOR , KÖLN).

– SHOWERS:

When a shower is used independently from a bath it has a vitreous china or vitreous enamelled cast iron shower tray. These are produced in different sizes. The shower is fixed overhead (about 2 metres) or shoulder high (about 1.5m) with a rose or a spray nozzle (which consumes considerably less water than the rose type). Hot an cold water supply is normally controlled by a thermostatic mixing valve. In tropical conditions only cold water supply is more often preferred. Waste discharge is 38mm diameter.

– KITCHEN SINKS:

Domestic sinks are produced from vitreous china, vitreous enamelled cast iron, pressed steel and stainless steel. Stainless steel single and double bowl sinks, incorporating drain boards, are commonly used, since they can be fitted into a built-in kitchen fitting with cupboards, drawers, cooker etc. Water supply is via 12mm taps for domestic sinks and 18 to 25mm for large kitchens in institutions, canteens, etc. Wastes are 32mm to 38mm.

– TAPS:

These are fittings which permit draw-off of water. Fig. 397 shows the different main taps. As already mentioned, in places for hand washing (offices etc.) spray taps are fitted to wash basins. They give a fine spray of water instead of a continuous flow which is adequate for hand washing and economizes on water used.

– VALVES:

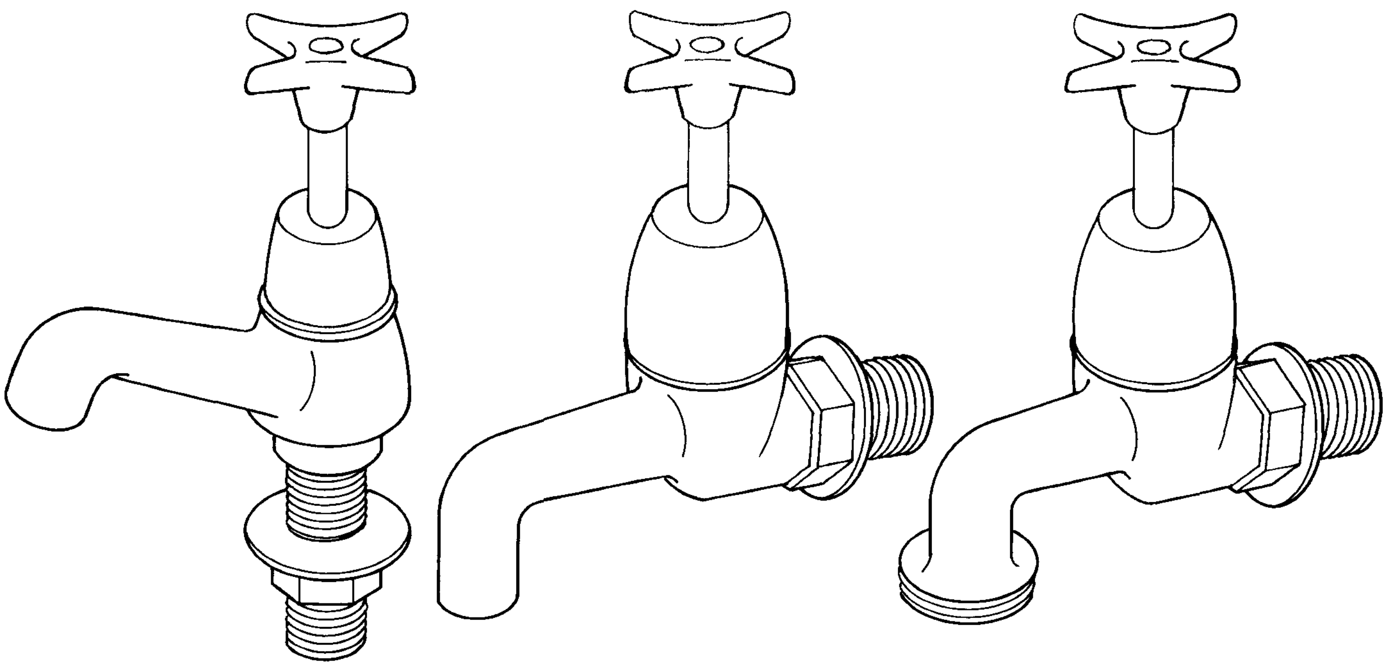
A valve is a fitting which controls the flow of water along the line of supply. Main "stop-cocks" are valves intended for the isolation of pipelines and individual service connections to water closets, baths, wash basins etc. for the purpose of repairs or maintenance (e.g. replacement of washers). Mixing valves (manual and thermostatic) are used to mix cold with hot water to give water of an intermediate temperature. Ball valves which are installed in storage tanks and flushing cisterns are really float-operated taps, opening and shutting the water supply into the cistern.

– OTHER FITMENTS:

When an architect designs a bathroom and toilet layout some additional fittings should not be forgotten. Soap dishes, toilet roll holders, towel rails or hooks can often be ordered together with the glazed wall tiles. Many tile producers include these fittings in their range of products. They are also manufactured from stainless steel.

6.4.2.2 SOIL AND WASTE SYSTEMS:

A soil and waste system conveying the flow from the sanitary fittings to the sewer line must be planned in such a way that the flow is uninterrupted, also at a change of direction, that the system does not leak and that it is adequately ventilated to avoid nuisance from smell. Where a duct is used for housing the system sufficient insulation must be provided to avoid transmission of noise from floor to floor (especially in multi-storey systems). Numerous short radius bends should be avoided in a system so that there are only few accesses required for rodding purposes. Long radius bends should be used at a change of direction.



PILLAR TAP: THIS TAP IS SUITABLE FOR MOUNTING ON A HORIZONTAL SURFACE. IT IS THE TAP MOST WIDELY USED FOR WASH-BASINS. IT HAS A VERTICAL INLET AND A NOZZLE BENT TO DISCHARGE IN A DOWNWARD DIRECTION.

BIB-TAP: THIS TAP IS MOUNTED ON A VERTICAL SURFACE. BIB-TAPS ARE WIDELY USED ON SINKS AND STAND-PIPES. THE TAP HAS A HORIZONTAL INLET AND A NOZZLE BENT TO DISCHARGE IN A DOWNWARD DIRECTION.

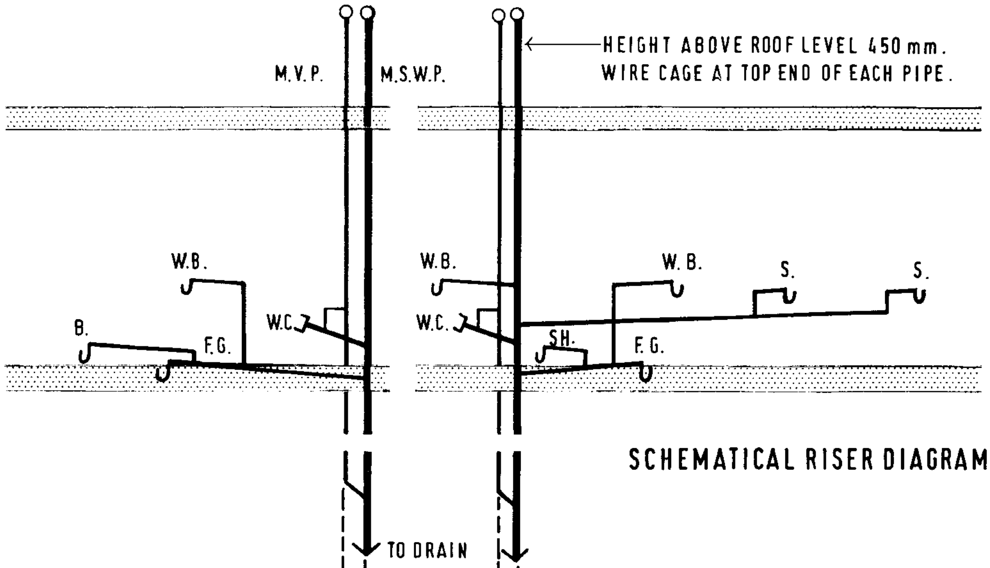
HOSE-UNION TAP: THE NOZZLE OF THIS TAP HAS A MALE THREAD FOR THE ATTACHMENT OF A HOSE UNION. OTHERWISE THE TAP IS LIKE A BIB-TAP.

FIG. 397 : TAPS

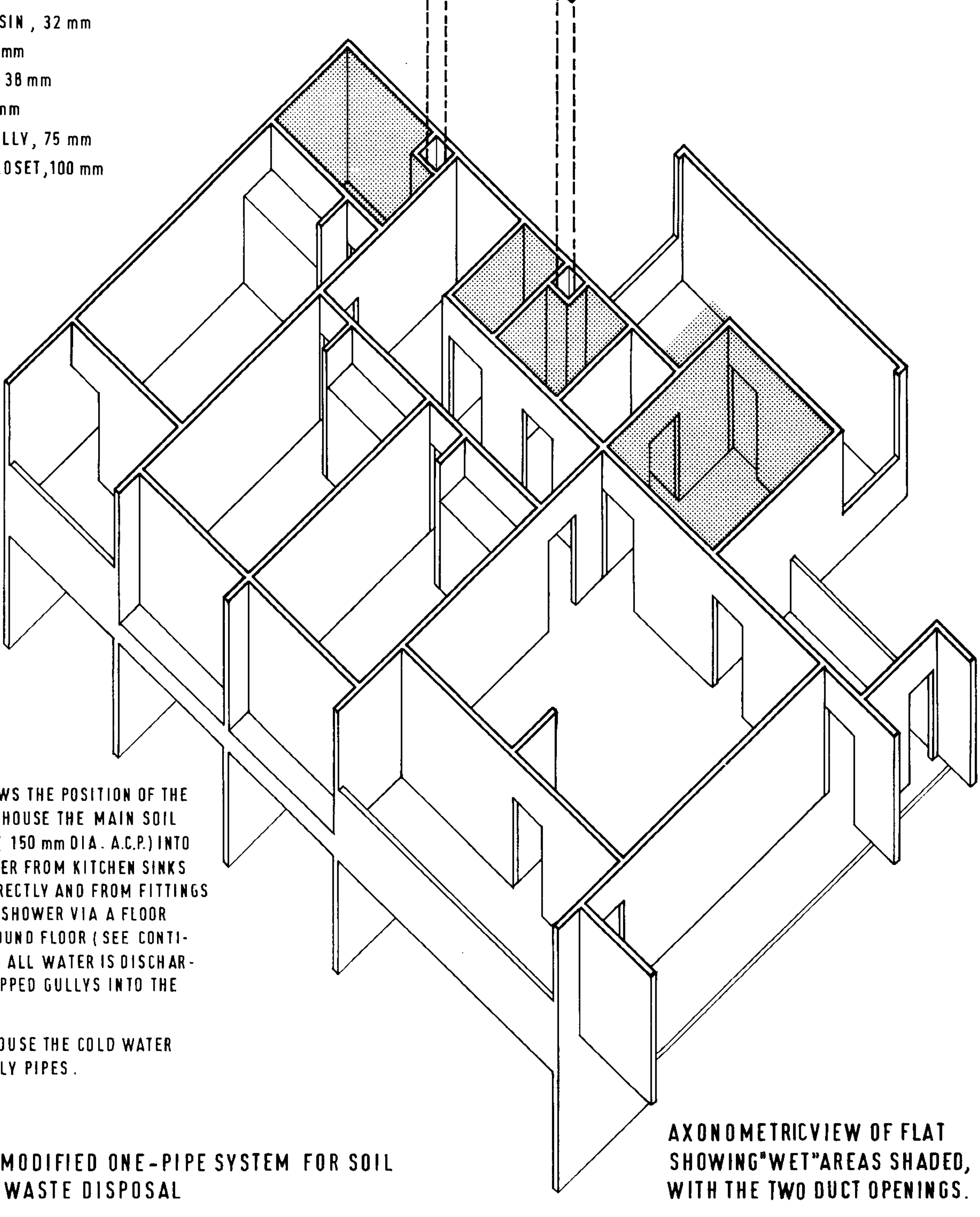
IN THIS SYSTEM THE W.C.S ONLY ARE VENTED WITH BRANCH VENTILATING PIPES CONNECTED TO THE 100 mm DIAMETER P.V.C. MAIN VENT PIPE. TRAPS FROM WASTE FITMENTS MUST HAVE A WATER SEAL OF 75 mm. THE SYSTEM IS EXTENSIVELY USED IN DIFFERENT VARIATIONS FOR MULTI - STOREY BUILDINGS.

IN THE ONE - PIPE SYSTEM EACH SANITARY FITTING HAS A BRANCH VENTILATING PIPE WHICH IS CONNECTED TO THE MAIN VENT PIPE.

M.V.P. = MAIN VENT PIPE, 100 mm DIAMETER P.V.C.
M.S.W.P. = MAIN SOIL & WASTE PIPE, 150 mm DIAMETER A.C.P.
W.B. = WASH BASIN, 32 mm
B. = BATH, 38 mm
SH. = SHOWER, 38 mm
S. = SINK, 38 mm
F.G. = FLOOR GULLY, 75 mm
W.C. = WATER CLOSET, 100 mm



SCHEMATICAL RISER DIAGRAM

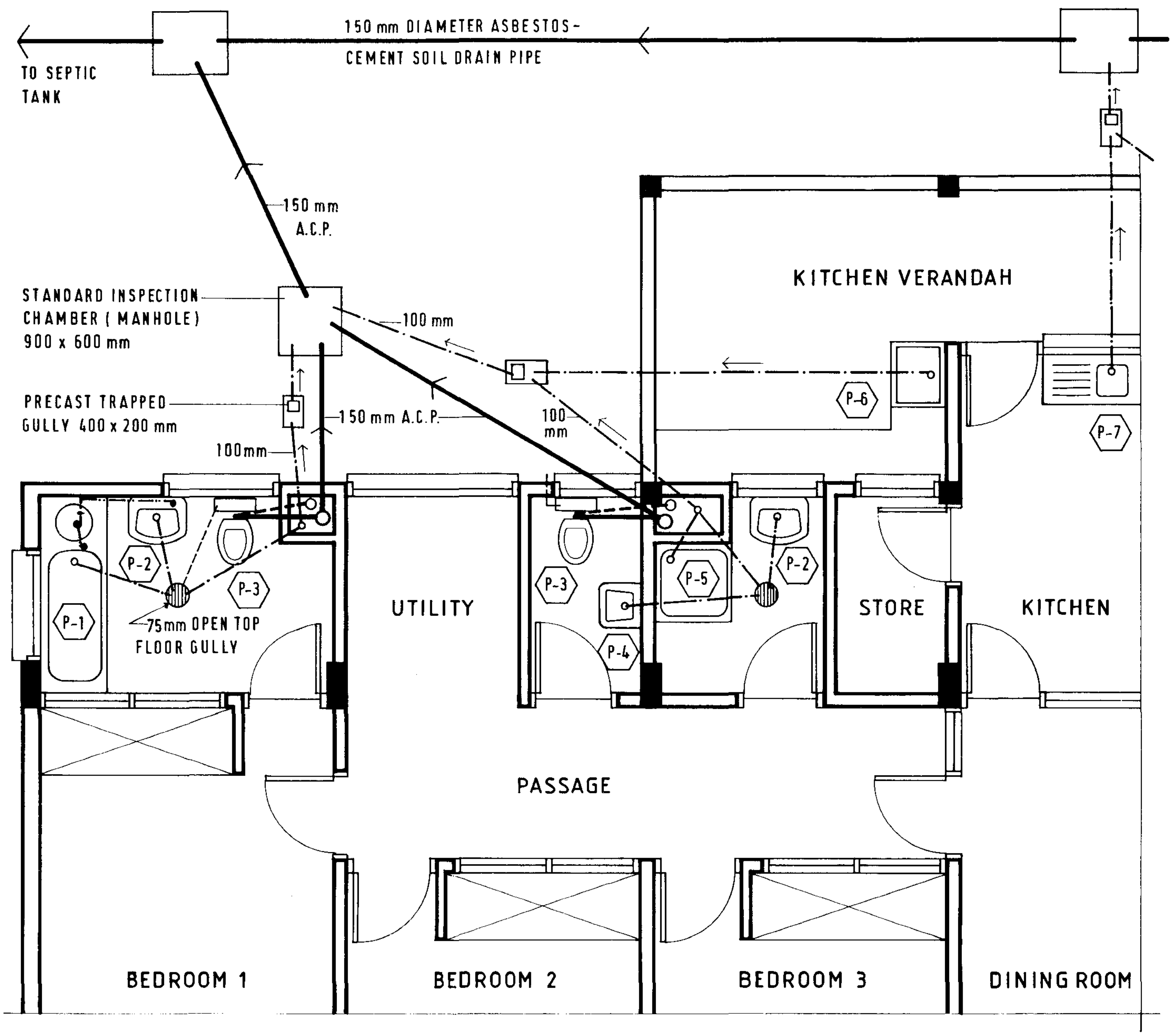


THE DRAWING SHOWS THE POSITION OF THE TWO DUCTS WHICH HOUSE THE MAIN SOIL AND WASTE STACK (150 mm DIA. A.C.P.) INTO WHICH WASTE WATER FROM KITCHEN SINKS IS DISCHARGED DIRECTLY AND FROM FITTINGS IN BATHROOM AND SHOWER VIA A FLOOR GULLY. ON THE GROUND FLOOR (SEE CONTINUATION FIG. 398) ALL WATER IS DISCHARGED THROUGH TRAPPED GULLYS INTO THE SOIL DRAIN.

THE DUCTS ALSO HOUSE THE COLD WATER SERVICE AND SUPPLY PIPES.

FIG. 398 : THE MODIFIED ONE-PIPE SYSTEM FOR SOIL AND WASTE DISPOSAL

AXONOMETRIC VIEW OF FLAT SHOWING "WET" AREAS SHADED, WITH THE TWO DUCT OPENINGS.



SOIL PIPE, ASBESTOS-CEMENT, 100 mm DIAMETER FROM W.C. TO STACK, 150 mm TO MANHOLES AND SEPTIC TANK

100 mm DIAMETER P.V.C. VENT PIPE, FOR W.C.S ONLY (MODIFIED ONE-PIPE SYSTEM)

WASTE WATER PIPE (P.V.C.), 32 mm FOR P-2 AND P-4, 38 mm FOR P-1, P-5, P-6, P-7.

20 mm DIAMETER COPPER PIPE FOR THE HOT WATER SUPPLY FROM DOMESTIC WATER HEATER TO BATH AND SHOWER

20 mm P.V.C. OVERFLOW PIPE FROM W.C. CISTERN TO FLOOR GULLY IN BATHROOM ; TO THE OUTSIDE FROM THE TOILET.

NOTE: THE ABOVE PLAN SHOWS SOIL AND WASTE DISPOSAL AT GROUND FLOOR LEVEL, WASTE WATER OF FITTINGS IN UPPER FLATS IS DISCHARGED STRAIGHT INTO STACK AS SHOWN ON ISOMETRIC SKETCH WITH RISER DIAGRAM.

P-1 ENAMELLED CAST IRON BATH 1850 x 780 mm WITH BATH AND SHOWER MIXER, 12 mm, AND HANDSHOWER FITTING.

P-2 WASH BASIN, VITREOUS CHINA, 560 x 405 mm, WITH 12 mm TAPS FOR COLD AND HOT WATER SUPPLY AND 32 mm POP-UP WASTE.

P-3 W.C.: VITREOUS CHINA SINGLE SEAL SIPHONIC CLOSET, 9 LITRE CISTERN, 12 mm C.W. SUPPLY, 20 mm OVERFLOW, PLASTIC SEAT AND COVER.

P-4 WASH BASIN, VITREOUS CHINA, 450 x 305 mm, 12 mm COLD WATER SUPPLY ONLY AND 32 mm POP-UP WASTE.

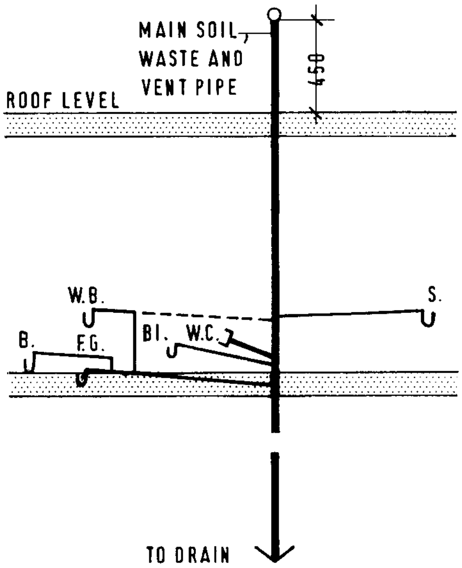
P-5 900 x 900 mm NON-SLIP FIRECLAY SHOWER TRAY, OVERHEAD SPRAY NOZZLE, 12 mm C.W. SUPPLY ONLY.

P-6 600 x 450 mm VITREOUS CHINA KITCHEN SINK, 250 mm DEEP, WITH 12 mm C.W. SUPPLY.

P-7 STAINLESS STEEL SINGLE BOWL KITCHEN SINK, LEFT HAND DRAINER, WITH CENTRAL DISCHARGE NOZZLE FOR 12mm C.W. AND H. WATER SUPPLY (INSTANTANEOUS ELECTRIC WATER HEATER).

CONTINUATION FIG. 398 : **MODIFIED ONE-PIPE SYSTEM : PLUMBING LAYOUT, SHOWING SANITARY FITTINGS AND SOIL AND WASTE DISPOSAL OF ONE FLAT.**

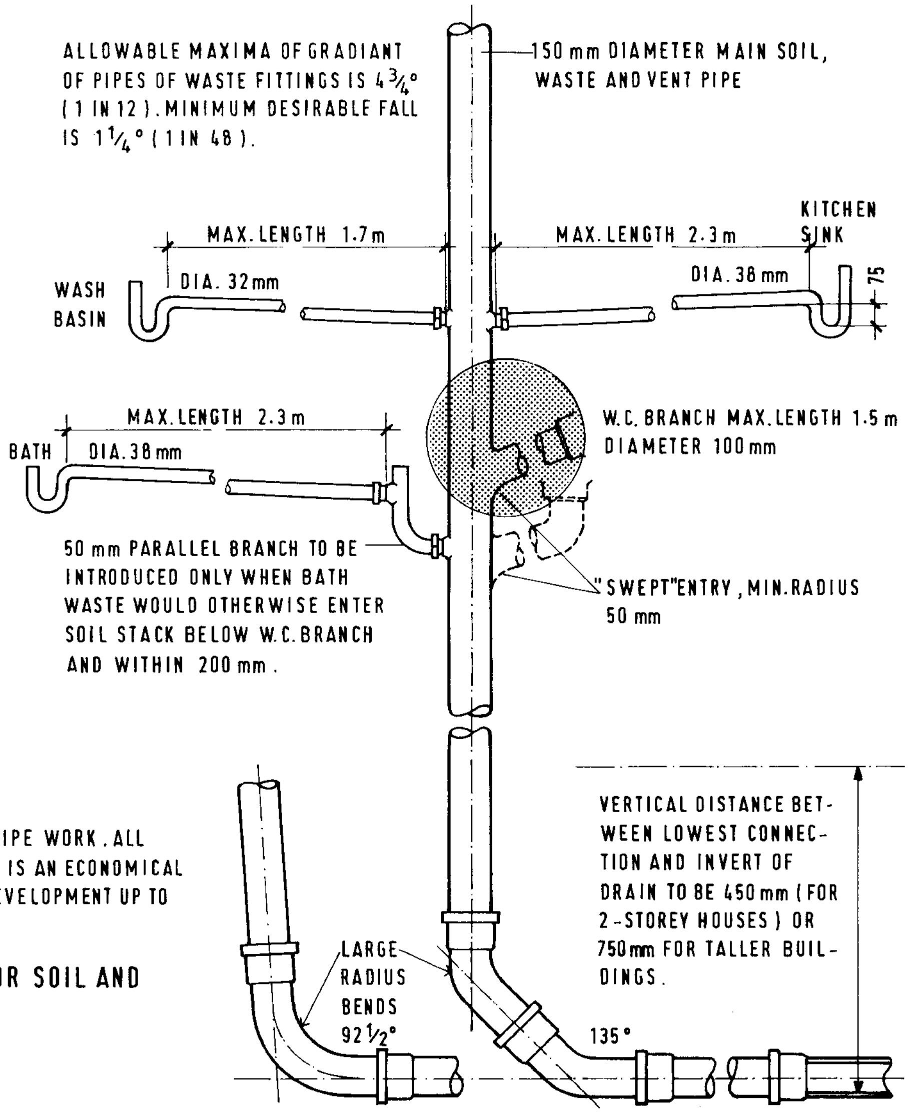
THE DRAWING SHOWS PART PLAN OF BLOCKS OF FLATS FOR U.N.D.P. PERSONNEL IN ACCRA (MODIFIED TEMA DEVELOPMENT CORPORATION HOUSE TYPE T63 ; ARCHITECT : HANNAH SCHRECKENBACH).



W.B. = WASH BASIN, 32 mm POP-UP WASTE
B. = BATH, 38 mm WASTE
BI. = BIDET, 32 mm POP-UP WASTE
W.C. = WATER CLOSET, 100 mm
F.G. = OPEN TOP FLOOR GULLY, 75 mm
S. = KITCHEN SINK, 38 mm WASTE

THE SINGLE-STACK SYSTEM HAS VERY SIMPLE PIPE WORK. ALL WASTE PIPES ARE CONNECTED TO THE STACK. IT IS AN ECONOMICAL SYSTEM WHICH IS SUITABLE FOR LOW-LEVEL DEVELOPMENT UP TO FOUR STOREYS.

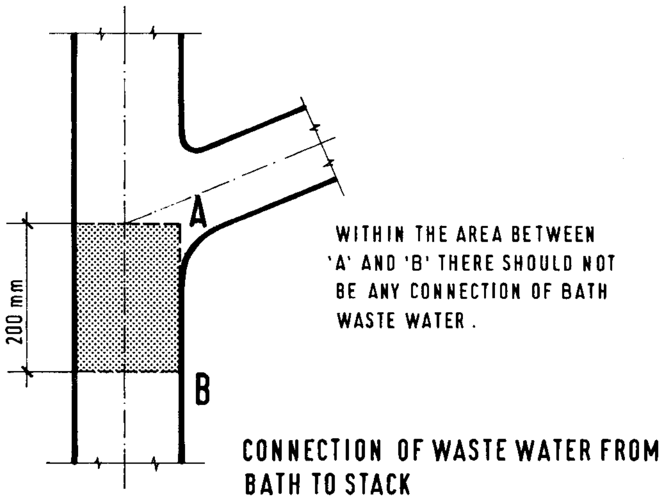
FIG. 399 : **THE SINGLE-STACK SYSTEM FOR SOIL AND WASTE DISPOSAL**



MAIN DESIGN FEATURES OF SINGLE-STACK SYSTEM :

There are basically two systems in use nowadays, the **one-pipe** or **modified one-pipe** system (Fig. 398) for multi-storey buildings and the **single-stack** system for low-level housing (Fig. 399). The single-stack system is the lowest cost system; it has, however, design limitations which must not be overlooked. It is the ideal system for low-level housing development. The following design recommendations should be followed for single-stack plumbing (Fig. 400):

- Traps should have a minimum water seal of 50 mm for water closets and 75 mm for all other waste fitments;
- Traps should be protected from self-siphonage and back pressure;
- Waste pipes should have a small uniform gradient in the direction of the flow (about 3°) and the waste inlet into the stack should be straight;
- At the bottom the stack should have a large radius bend to avoid detergent foam backing up to low level branches.

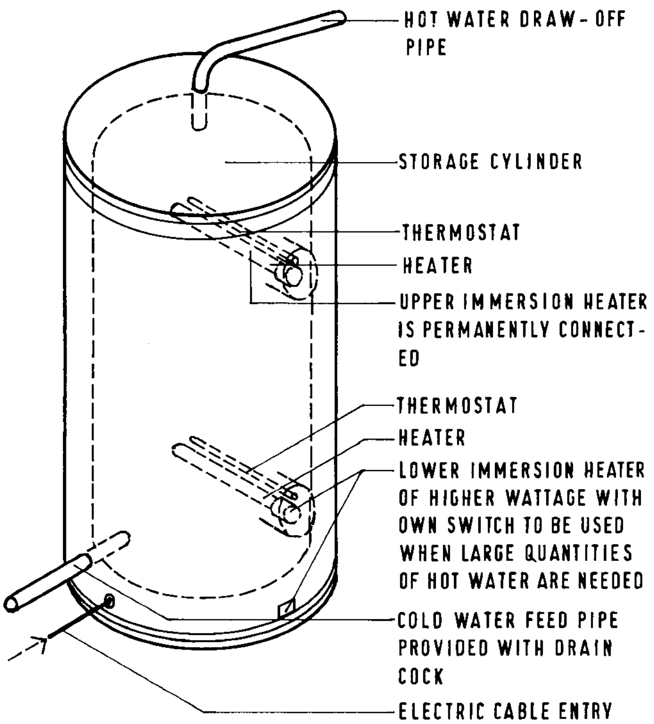


CONNECTION OF WASTE WATER FROM BATH TO STACK

FIG. 400 : **DESIGN RECOMMODATIONS FOR THE SINGLE-STACK SYSTEM**
FROM "SPECIFICATION - 1975", VOLUME 2, PLUMBER/INTERNAL; 2-86, FIG.5, 2-88, FIG.7 BY DEX HARRISON (THE ARCHITECTURAL PRESS LTD., LONDON).

6.4.3 DOMESTIC HOT WATER SUPPLY

The installment of a hot water supply system depends on the plumbing practice adopted for the cold water supply. There are two main practices:



SCHEMATICAL SKETCH OF A PRESSURE TYPE WATER HEATER WITH TWO IMMERSION HEATERS

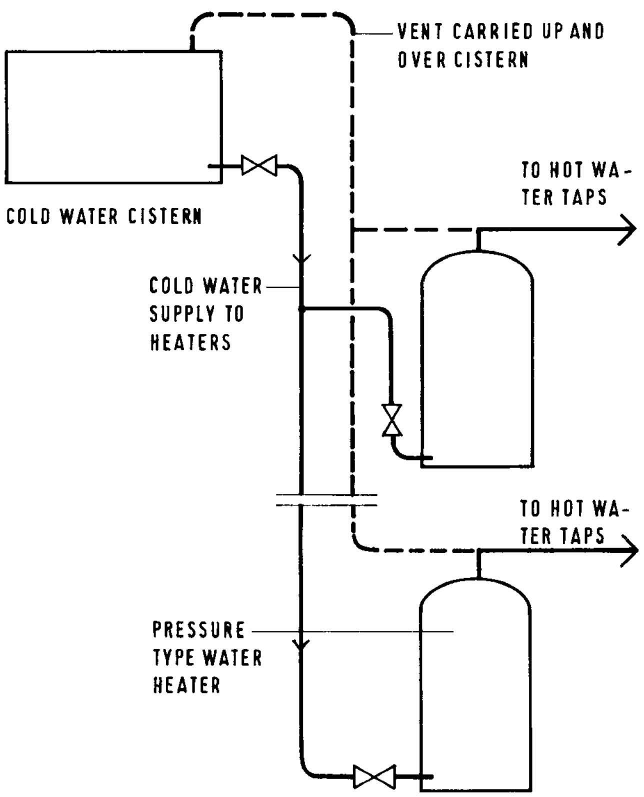


FIG. 401: PRESSURE TYPE WATER HEATER AND PIPING DIAGRAM (ADAPTED FROM "ENVIRONMENT AND SERVICES" BY PETER BURBERRY, MITCHELL'S BUILDING CONSTRUCTION, B T BATSFORD LTD. LONDON).

- The **low pressure system** (used in Britain): The watermain delivers the supply to a storage tank which is situated at the highest convenient point of the building. All pipes, for the cold water and hot water supply, emanate from this tank and derive their pressure from its position. The hot water heater is installed near the position of main use (bathroom, kitchen). It can be fixed inside the bathroom, inside a built-in wardrobe of a bedroom next to the bathroom, or inside a store room between kitchen and bathroom.

- The **high pressure system** (used in most Continental European countries): The cold water supply into the building is at mains pressure (subject to a pressure controlling valve). All fittings, cold and hot, are at this same pressure.

The low-pressure system is more economical for developing countries and they have mostly adopted it, because the high pressure system has disadvantages: higher pressure at taps and valves results in greater trouble from leaks; high wastage of water; in the event of mains failure, the whole system becomes immediately dry and has to be shut down; higher noise level; risk of back-siphonage into the system.

Hot water supply pipes should have "short legs" to reach the fittings from the heater without temperature losses.

6.4.3.1 ELECTRIC WATER HEATING:

In most developing countries electric water heaters are used where electricity is available. In rural areas, when required, hot water is heated with solid fuel. The common type of water heater is the electrical heater with storage capacity of different volumes. These heaters consist essentially of a copper cylinder into which one or more immersion heaters have been installed. The cylinder is normally lagged with cork and the whole assembly is then enclosed in an enamelled steel cover. There are basically three types of such heaters:

- The **free outlet heaters**: Storing from 6 to 80 litres, these heaters are wall-mounted and serve one outlet position only, mostly in the bath.

- The **pressure-type heaters**: They are built similarly to the free outlet heaters. In addition they are fitted with expansion pipe (which must run horizontally for a minimum of 300 mm before it is taken upwards). These water heaters can serve more than one outlet through fixed piping. Pressure-type water heaters must be fed from a cold water storage cistern (Fig. 401). The cold feed pipe to the cylinder should always be of the same size as the hot water feed out of the cylinder, normally between 19 and 25 mm in diamter. Pressure-type water heaters are produced in capacities from 20 litres upwards.

- **Cistern-type water heaters**: These water heaters incorporate a small cistern with a ball valve. They must be mounted above the highest draw-off tap that they are to serve.

Very economical for use in kitchens, bathrooms and showers are the so-called **"instantaneous" electric water heaters** of non-storage type. They can provide up to 10 litres of hot and 18 litres of warm water per minute. These heaters are simple to install and economic in the use of electricity.

6.4.3.2 SOLAR WATER HEATING:

Solar energy has been used in tropical developing countries for generations for drying crops. But the conversion of the solar energy source into different uses in developing countries has been too expensive. However, quite simple so-called passive solar collectors have been built, mostly of the flat plate type. The transfer medium to transfer the heat from where ist is absorbed to the point of use or to a heat store is liquid or a gas. Flat collectors consist of an absorber panel, a glass or plastic cover in front to let in the heat, an insulating panel at the back and a heat storage. They have been quite successfully used for water heating (half of Israel's households use solar heated water – "New and Renewable Energies 1", Earthscan, London). The Technology Consultancy Centre, (T.C.C., U.S.T.), Kumasi, has installed experimental water heaters since June, 1977, with a heat collector medium of water (water pond collector) or old engine oil. The supply pipes laid in the ponds emerged heated to 1°C less than pond temperature. Even during the rainy season, with the sky overcast during most of the day, water was available at 40–45°C from the solar heaters. The collectors using old engine oil did not need to be painted black on the surface; heat losses through evaporation were reduced, the pond reached working temperature earlier and had a 10°C higher peak temperature. Pond collectors require a flat surface. Instead of water or other liquid collecting heat in a pond and transferring the heat to water pipes, coils of such water pipes can be laid into the collector to lead the heat away as hot water. Other working fluids can also be used in such coiled pipes, they give up their heat to water in a heat exchanger (Fig. 402).

More development is needed to make the use of solar energy for domestic hot water heating efficient and economic for developing countries.

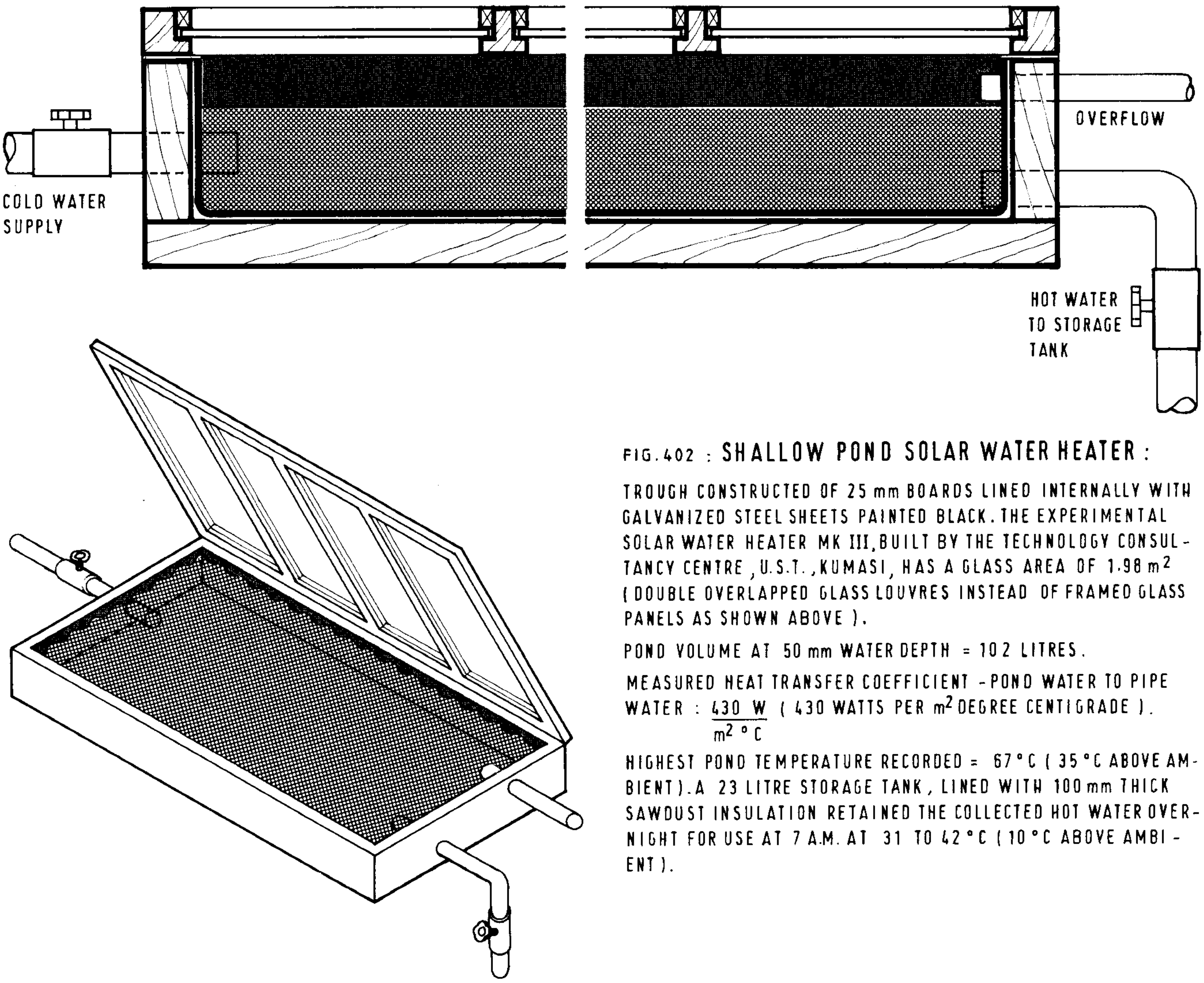


FIG. 402 : **SHALLOW POND SOLAR WATER HEATER :**

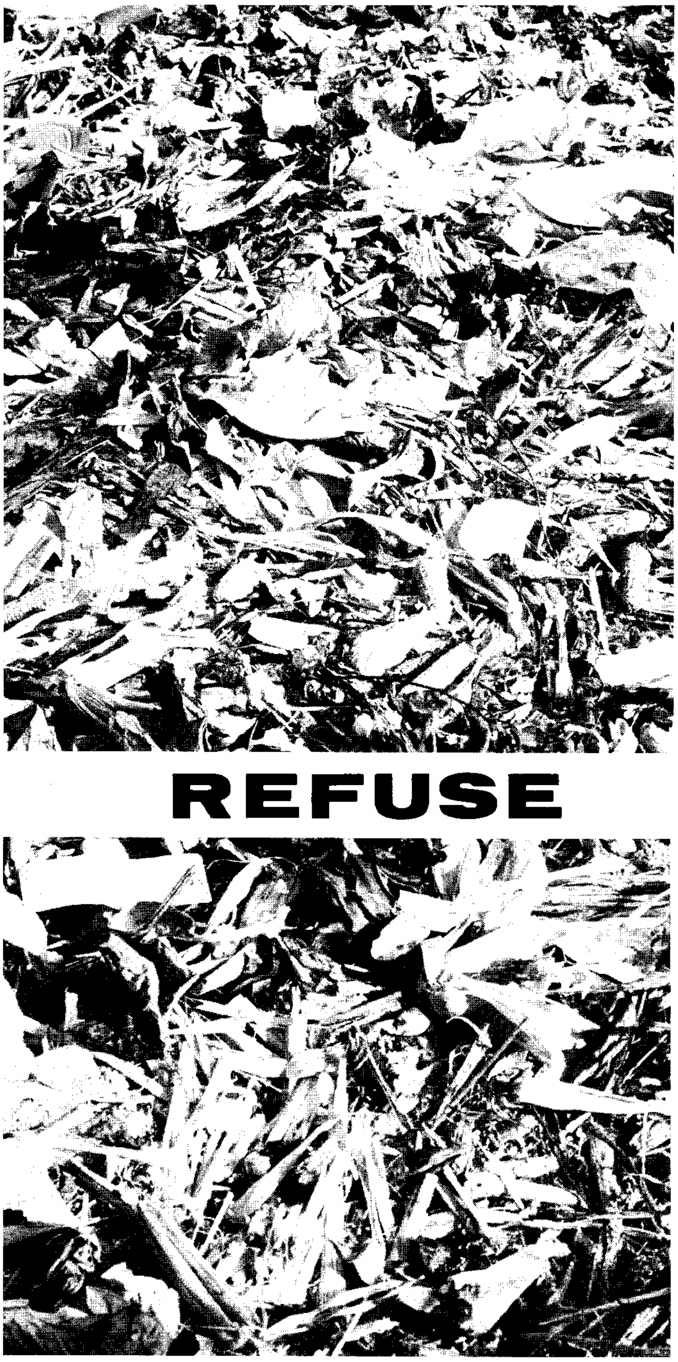
TROUGH CONSTRUCTED OF 25 mm BOARDS LINED INTERNALLY WITH GALVANIZED STEEL SHEETS PAINTED BLACK. THE EXPERIMENTAL SOLAR WATER HEATER MK III, BUILT BY THE TECHNOLOGY CONSULTANCY CENTRE, U.S.T., KUMASI, HAS A GLASS AREA OF 1.98 m^2 (DOUBLE OVERLAPPED GLASS LOUVRES INSTEAD OF FRAMED GLASS PANELS AS SHOWN ABOVE).

POND VOLUME AT 50 mm WATER DEPTH = 102 LITRES.

MEASURED HEAT TRANSFER COEFFICIENT - POND WATER TO PIPE WATER : $\frac{430\ W}{m^2\ °C}$ (430 WATTS PER m^2 DEGREE CENTIGRADE).

HIGHEST POND TEMPERATURE RECORDED = 67 °C (35 °C ABOVE AMBIENT). A 23 LITRE STORAGE TANK, LINED WITH 100 mm THICK SAWDUST INSULATION RETAINED THE COLLECTED HOT WATER OVERNIGHT FOR USE AT 7 A.M. AT 31 TO 42 °C (10 °C ABOVE AMBIENT).

INORGANIC WASTE



REFUSE

ORGANIC WASTE

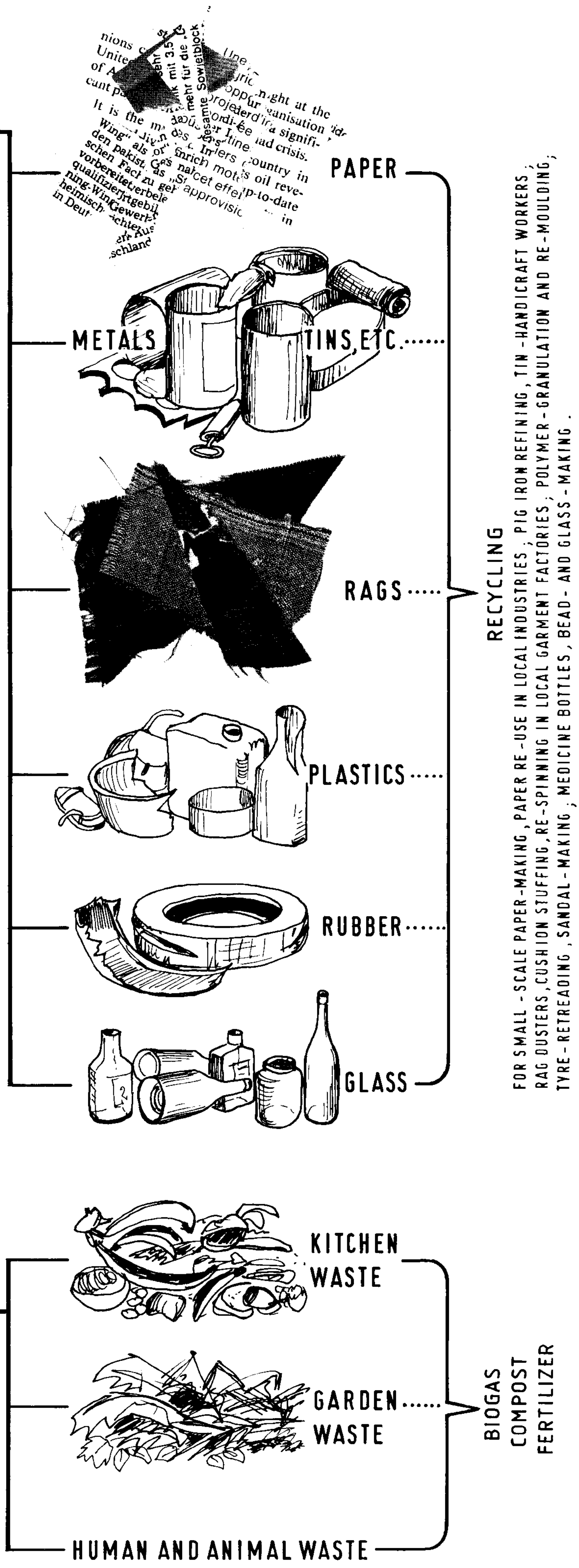


TABLE 20 : DOMESTIC REFUSE

NEARLY ALL DOMESTIC REFUSE CAN BE RECYCLED. THE CAREFUL SORTING AND RECYCLING OF WASTE IS LABOUR INTENSIVE WORK WHICH COULD BE A MEANINGFUL EMPLOYMENT FOR MANY PEOPLE IN DEVELOPING COUNTRIES. RECOMMENDED READING : "WORK FROM WASTE" BY JON VOGLER (INTERMEDIATE TECHNOLOGY PUBLICATIONS LTD., LONDON).

Fig. 403: Uncollected domestic refuse.

6.5 REFUSE DISPOSAL

Domestic refuse disposal, especially in urban areas of developing countries, quite often poses great problems and can, if not dealt with efficiently, cause health hazards (Fig. 403). Even if sufficient dustbins (the traditional method of domestic refuse storage) are available, the regular collection depends on a large fleet of refuse trucks or special collection vehicles (with the necessary workshop service for maintaining and repairing these vehicles) and incinerators for the final disposal of the refuse. This chain, from the collection of household refuse to the final disposal, is an expensive part of the services required by the individual and the community.

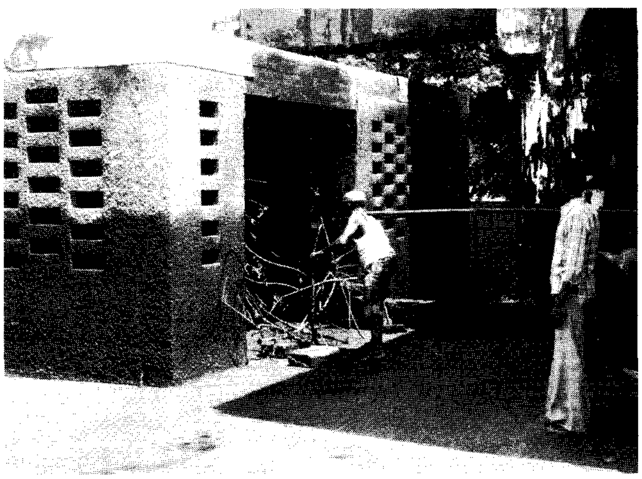


Fig. 404: Hospital incinerator, Korle Bu Hospital, Accra, 1982.

The larger volume of domestic refuse in developing countries is organic matter and could be used for the production of compost, or, where biogas plants exist, for the production of biogas (vegetable, fruit, plant refuse). In flats solid fuel domestic hot water boilers could be installed which use refuse which can be burnt. Institutions like hospitals must have their own on-site incinerators to dispose of hospital refuse (Fig. 404). Small simple incinerators built in bricks would be suitable in urban areas where communal latrines are used. The incinerators could be built in the same locations. Ideally a biogas plant for the production of biogas could serve the same community (light for a community centre, power for a corn mill etc.). It could be fed with the human excreta from the latrines and with organic refuse which is brought to the incinerator together with other refuse. The community would have to organize the management of these services, which would be much more economical and of greater benefit to the people than the refuse disposal in an urban scale run by the respective City Councils. Table 20 explains the possible use of domestic refuse.

Trade refuse will have to be considered separately by the designer (e.g. workshop with engine oil and grease waste etc.) for each project of a kind where this refuse may pose a special problem.

6.6 ELECTRICITY SUPPLY

As already mentioned, electrical energy can be put to many uses, and though it constitutes a basic factor for the development of industrial production, it also contributes towards social and economic progress and satisfies personal needs. In developing countries every effort is being made to rationalize the utilization of existing sources of energy (e.g. hydropower, thermal power) apart from developing new, regenerative sources of energy. And the aim is not only to supply towns with electricity but also to let the rural areas benefit from electrification. This will help to develop rural industries, trades, handicrafts etc.

This part deals with supply of electricity to domestic buildings, offices, etc. on a small scale showing different methods of installation of an appropriate electricity network at this level.

6.6.1 ELECTRICITY

6.6.1.1 CURRENT:

The flow of electrical current through a cable can be likened to the flow of water through a pipe. The pressure in a water pripe can be compared to the potential difference or **voltage** in the electrical cable. The rate of flow of water can be compared to the electrical current or **amperage**. In electrical terms the **"power is equal to the product of voltage and amperage"**. The power, or rate of doing work (electric motor, heat, light) is measured in **"Watt"**, that is, the rate of working when a current of one ampere flows at a potential difference of one volt. Electrical resistance is measured in **"Ohm"** and again, the concept of electrical resistance corresponds roughly to the frictional resistance found in a pipe.

There are two different electrical currents:

- The **direct current** (D.C.), which flows only in one direction;
- The **alternating current** (A.C.), which starts at zero, increases in one direction to reach a maximum, falls to zero, increases in the other direction to an equal but opposite maximum and then falls to zero again.

A complete series is calles 1 cycle (Fig. 405). The normal frequency (numbers of cycles completed in one second) is 50 cycles per second (or 50 Hertz). The nominal voltage of A.C. electrical supply is 240 Volt, and is commonly used in developing countries.

6.6.1.2 SUPPLY:

Electricity supply to a building will reach it either overhead or underground from a local transformer substation where the supply voltage from the town grid (and before that from the national grid) has been reduced to a three-phase, four-wire, 415/240 Volt, 50 cycles per second supply. The supply is distributed by a 3-line cable with one neutral wire which is earthed at the substation. The voltage between any phase wire and the neutral is 240 alternating voltage. (Fig. 406). This 3-phase supply to a building achieves a more balanced load on the phases by serving different areas of the building with different phases, a measure necessary when airconditioners and other electrical apparatus are installed. The object must always be to have as nearly as possible equal loads connected to each phase, so that the current in the neutral may be kept to a minimum. For small buildings and low-cost houses the supply of electricity by two wires, one phase wire and the neutral (known as the single-phase-supply), is sufficient. With a 3-phase supply it is necessary to take single-phase supplies from it to serve the lighting and power sockets. If lighting and socket outlets are connected to any one phase they should be kept at least 2 metres away from outlets fed from another phase. Certain electrical appliances (notably electrical motors and, as already mentioned, airconditioners) are designed for connection to a 3-phase supply.

FUSES

Every electrical circuit must be protected by a fuse or circuit breaker. These are safety devices to prevent overheating of the wiring due to a higher current flowing than that which is safe for the wiring.

Fuses: These consist of a length of fine wire connected between two terminals (normally ceramic). The wire is of such size that it will just carry the current for which the circuit was designed; it will melt if the current rises significantly above the design figure and by doing so interrupts the supply. The blowing of a fuse may also indicate a fault (loose connection, broken wire etc.) in the circuit.

Circuit Breakers: These are automatic switches which turn themselves off if too much current passes. They are easier to turn on again than to replace or rewire a broken fuse, although the latter is cheaper and more useful for the "self-help-person", if fuse wire is available.

EARTHING

If someone touches a bare cable which has been connected to a source of current, or if such wires become displaced and touch any metallic surface, which somebody touches, the person will receive an electric shock.

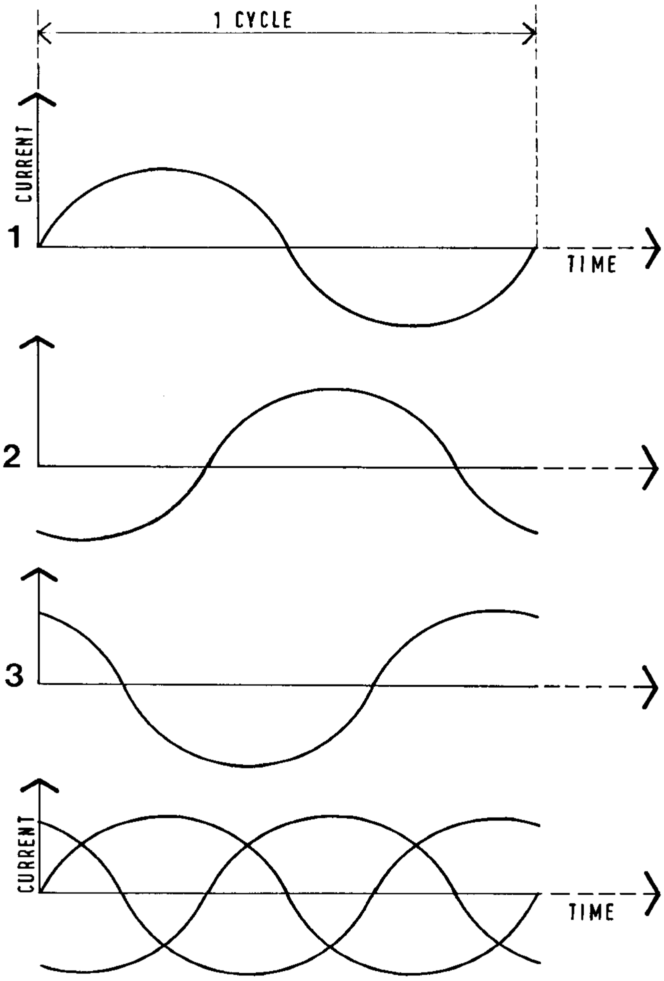


FIG.405 : ALTERNATING CURRENT A.C.
IN A 3-PHASE SUPPLY, AS SHOWN ABOVE, THERE ARE THREE SEPARATE SUPPLIES, EACH OUT OF STEP WITH THE OTHER BY AN EQUAL AMOUNT.

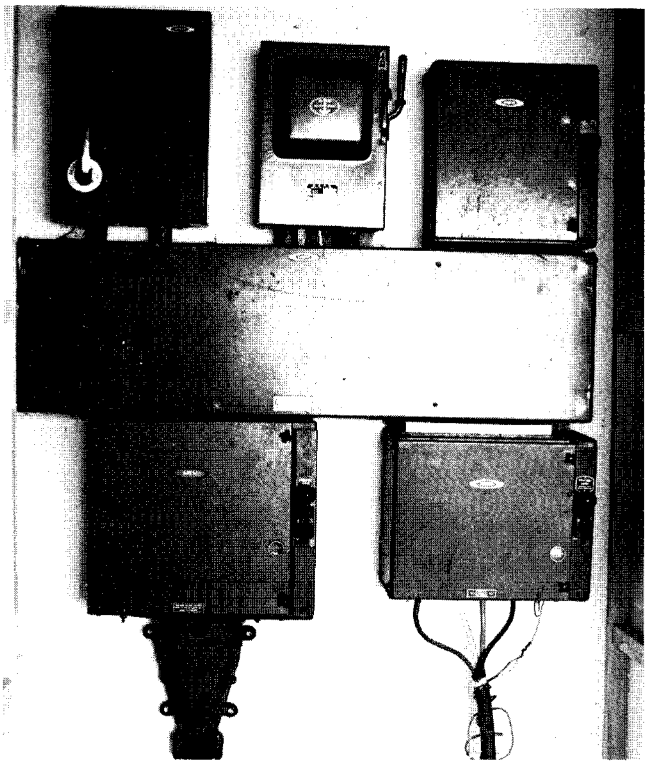


Fig. 406: Entry of 3-phase-supply as underground cable to the main distribution board of the Photocopying Unit, U.S.T., 1982.

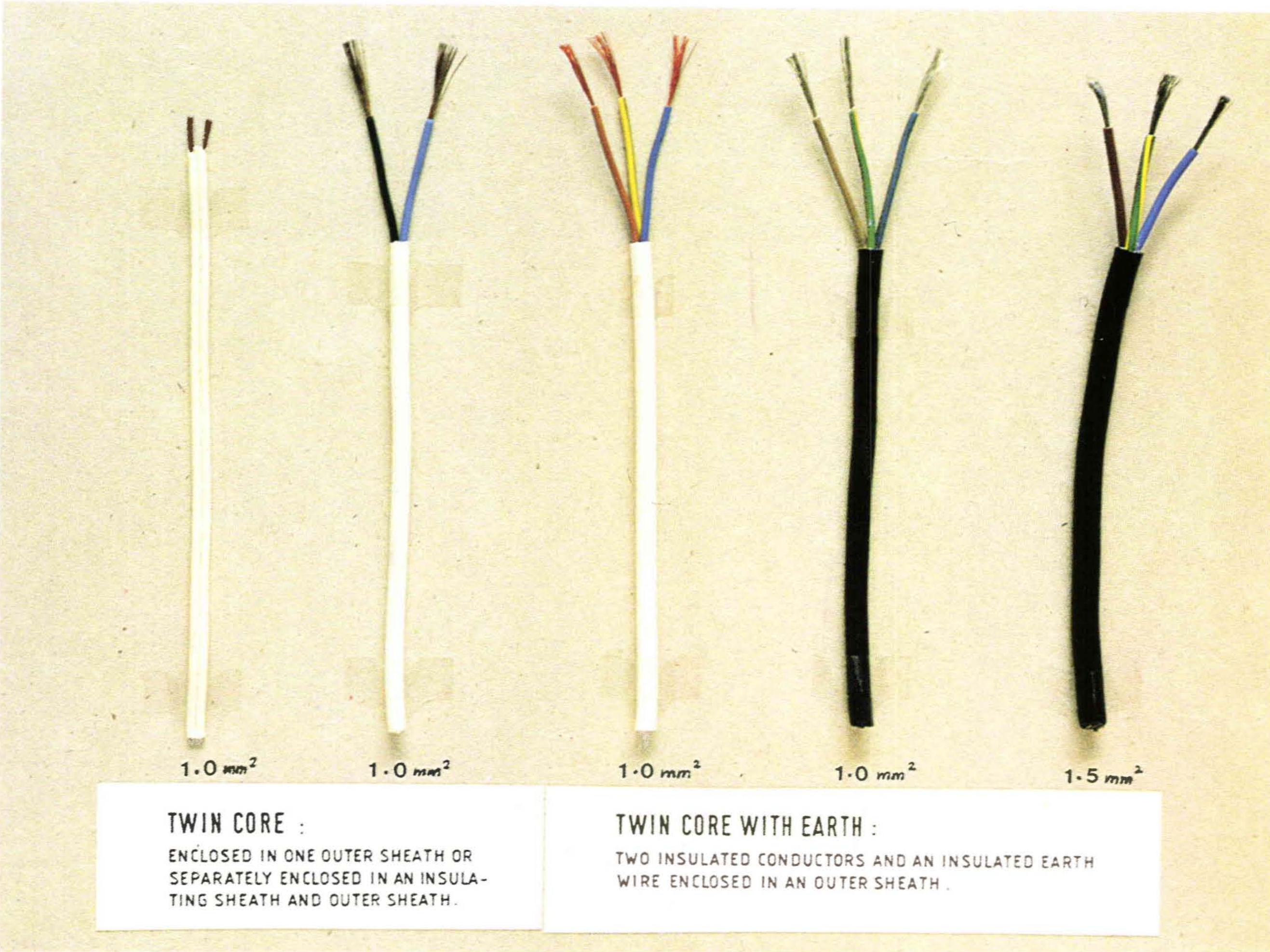


Fig. 407: Electrical Cables.

With a current of 240 Volts this can be very dangerous and cause severe burns or even death. A precaution against this is to connect any exposed metalwork, which may become live, to the earth (the general mass of earth, but in general practice it is often sufficient to earth by connection to a system of metal pipes which are bedded in the ground). An earthing connector or earth electrode consists of a number of copper rods which are driven well into the ground to an appropriate depth, depending on soil conditions.

CABLES (Fig. 407)

All methods of wiring employ electric cables. These are conductors surrounded by insulative material. The conductors will in most cases be made from copper which has a low electrical resistance, although aluminium and other metals are increasingly used. The insulation will consist of rubber, paper or plastic, all of which have a high electrical resistance. PVC is nowadays the most commonly used insulating material for cables. It is less affected by damp than rubber and therefore an ideal material for insulating cables in the humid tropics and for external wiring, where condensation is likely to occur.
One refers to the nominal cross sectional area of the conductor when one talks of the size of cables, e.g. 1.0 mm^2, 1.5 mm^2, 2.5 mm^2 etc. Cables are stranded to make them flexible, for example a 4 mm^2 cable contains 7 strands of wire each of 0.85 mm diameter laid up together (7/0.85). For lighting wiring 1.0 mm^2 is used and 2.5 mm^2 for wiring socket outlets, the strands in the cable are thinner and more in number.

There are different cables:

- **Single Core:** These have one conductor only which is enclosed in a sheath of insulating material;
- **Twin Core:** These have two conductors, which are separately insulated and enclosed in an outer sheath of the same insulating material;
- **Twin Core with Earth:** These are two conductors and an earth wire, each separately insulated (the earth wire may be bare) and enclosed in an outer sheath;
- **Three Core with Earth:** These are three conductors and an earth wire, each separately insulated and enclosed in an outer sheath of the same insulating material.

All earth conductors must be fitted with green or green and yellow-striped sleeving. Electrical conductors usually have blue, brown or black sleeving.

6.6.2 ELECTRICAL INSTALLATION

As already mentioned the electrical cables will reach a house either overhead or underground. In most urban areas the cables are usually underground and are brought to the entry point at ground level or at basement level (if a basement exists). Overhead cables are used for rural electricity supply and in many suburban areas of developing countries; they reach the building at high level.

6.6.2.1 ENTRY INTO A BUILDING:

Power cables, especially underground cables, are normally fortified with steel wires to give them mechanical strength. For protection against corrosion the whole cable is covered with jute, impregnated with bitumen or with PVC. These cables cannot be bent to small radii, which must be borne in mind when the point of entry into the building is chosen. Fig. 408 shows an underground intake into a domestic building. The intake point should be at a convenient place to use the shortest possible cable run and to bring the supply cable in without undue difficulties. At this place the following fittings must be provided:

- The **sealing chamber**: This prevents moisture from entering the installation of the service cable;
- The **main fuse** for the supply cable (switch fuse control unit);
- The **main switch** and **circuit fuses** for the installation (consumer's supply control unit);
- The **meter(s)**;
- The **bell transformer** and bell (if this is to be provided).

It is important to locate the intake point and distribution gear so that:

- There is reasonable access both to read the meter and to repair the fuses (these should have their own cupboard provided);
- The area is not exposed to moisture condensation;
- There is an easy and accessible route for the outgoing circuit cables.

This means, in fact, that the intake point and distribution board should be placed as centrally as possible in the building. It is necessary for an architect to understand the techniques of electrical installation. This will enable him (or her) to make necessary provisions for this in the early stages of the architectural design.

6.6.2.2 DISTRIBUTION CIRCUITS:

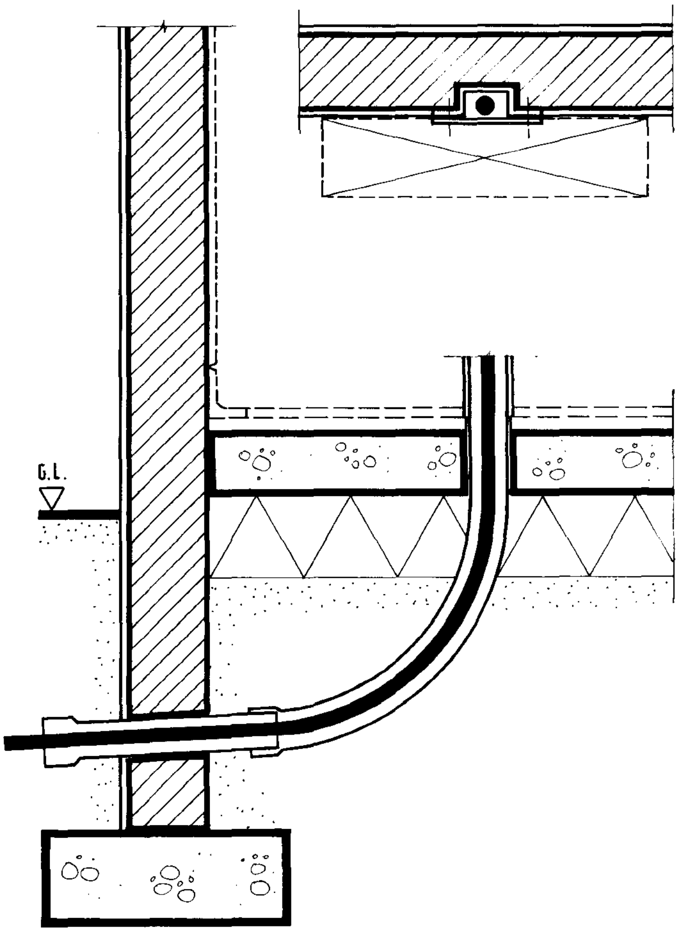
In a building the electricity supply is divided into three circuits:

- For lighting;
- For socket outlets;
- For fixed electrical appliances.

Lighting circuits are normally carried out in 5 amp wiring and fuses. The cables used are 1.0mm^2. One or more lamps are operated by one switch. There may be so-called **one-way switches,** a switch operating one or two lamps, or **two-way switches,** more than one switch controlling one or more lamps (in this system any single switch will switch on one light if it is off, or off it is on).

Socket circuits are normally arranged as ring circuits with 13 or 15 amp wiring and fuses. Electrical appliances are plugged into the sockets where required. There are a large variety of different plugs, round or square-pinned, two or three-pole, with or without built-in fuses. One socket ring circuit should cover a floor area not larger than 100m^2 and can have up to 10 outlets in such a system. It is taken from a 30 amp fuseway on the consumer's unit.

Fixed electrical apparatus are electrical cookers, water heaters, airconditioners etc. These should have their own circuit with individual fuses.



THE ARMOURED POWER CABLE ENTERS THE BUILDING UNDERGROUND, BENT WITH A LARGE RADIUS. IT IS BEDDED INSIDE PLASTIC PIPING WHEN PASSING THROUGH THE FOUNDATION WALL, BACK FILL AND HARDCORE. THE PART PLAN ABOVE SHOWS THE POWER CABLE IN A SHALLOW METAL CHANNEL SET INTO THE WALL. IT IS CONNECTED FROM HERE TO THE DISTRIBUTION BOX AND SEALING CHAMBER.

FIG.408: THE INTAKE POINT

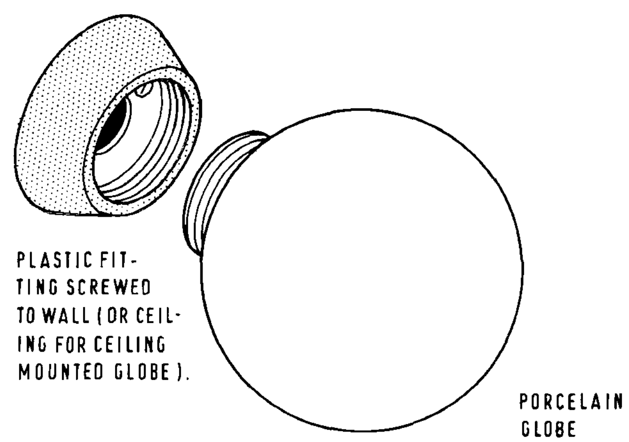


FIG.409: BATHROOM LIGHT FITTING

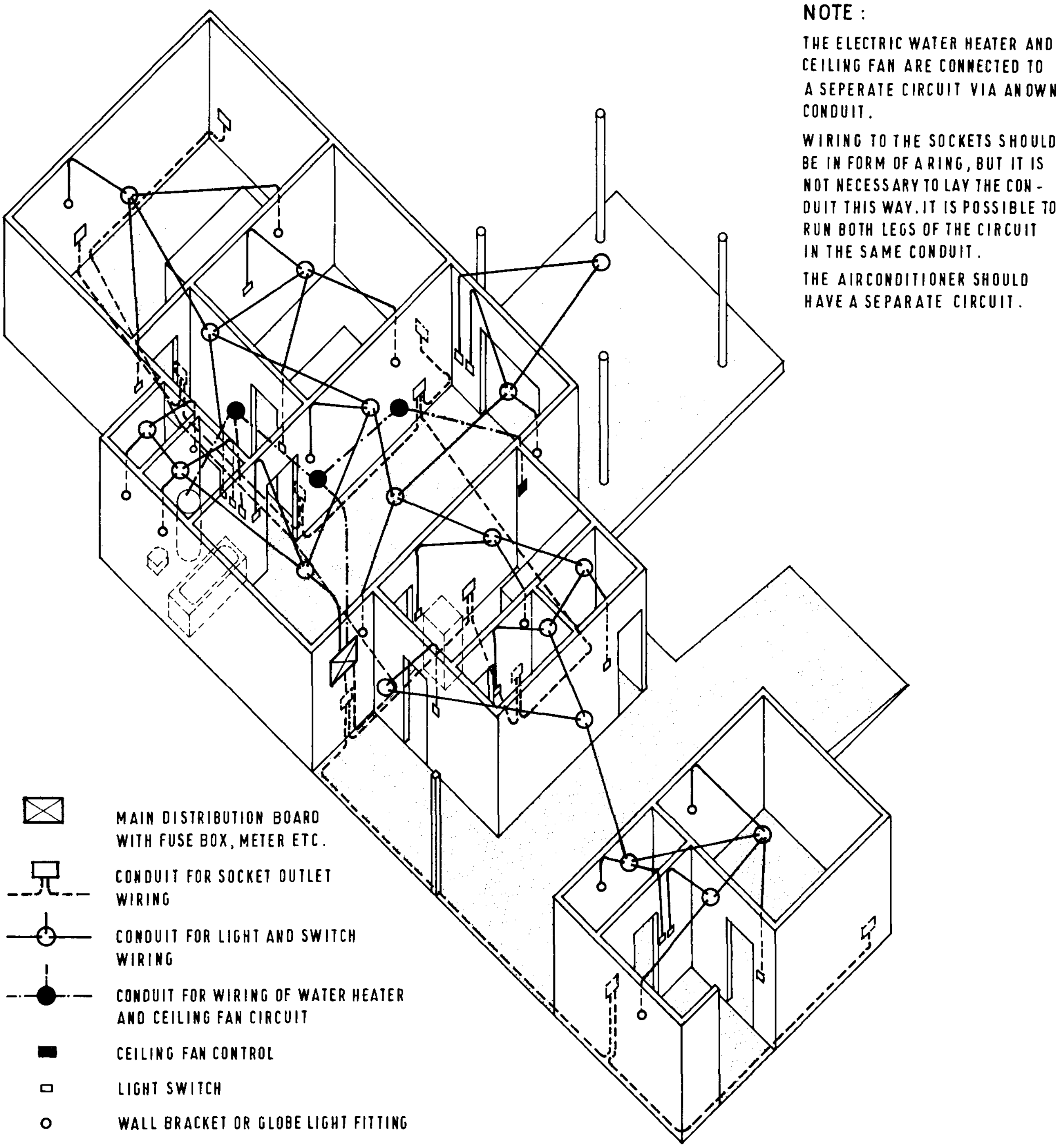


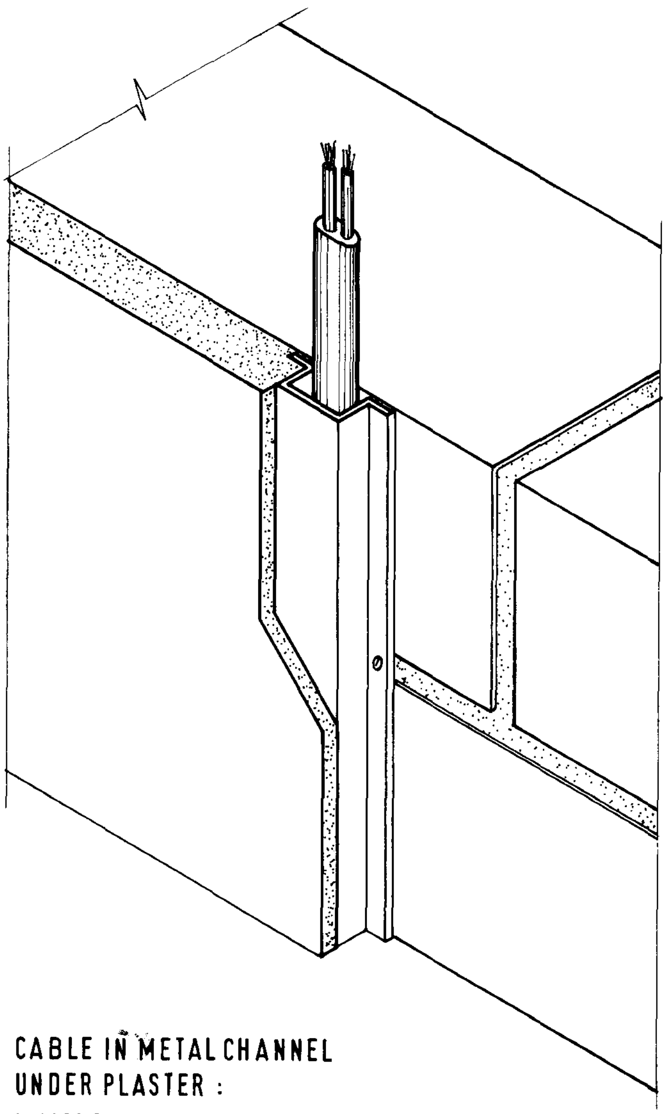
FIG. 410 : DISTRIBUTION CIRCUITS - TO BE READ IN COJUNCTION WITH PLAN SHOWN IN FIG. 414.

No socket outlets are permitted in bathrooms and showers because of the presence of water. If a water heater is fixed in the bathroom, the metal cover of it should be earthed and the supply cable should be heat-resisting and well insulated and not smaller than 1.5 mm^2. Light switches and the water heater control switch (with an indicator light to show when the heater is on) should be positioned outside the bathroom, or if a pull-cord switch for the light fittings is used, then high up on the ceiling or next to the light over a wash basin. Light fittings in bathrooms or showers should not contain any exposed metalwork, normally they are porcelain globe-wall fittings or ceiling-mounted fittings (Fig. 409). Fig. 410 shows a layout of distribution circuits for lighting, socket outlets and fixed equipment in a single storey domestic building.

6.6.2.3 WIRING SYSTEMS:

There are basically three types of wiring systems employed in buildings. For low-cost houses, small dwellings, farm and rural buildings **"Surface Wiring"** is used, that is sheathed wiring which is laid on the surface and fixed with non-ferrous metallic buckle clips. It can be concealed in timber floors, suspended ceilings and also fixed under or on top of plaster in special flat metal channels (Fig. 411). The cables should not be bent sharply, when turning corners, the minimum bending radius should be about eight times the maximum diameter of the cable. When passing through a wall the cables should be enclosed in a short piece of conduit. Care must be taken that the cables are laid well away from water pipes. They must also not be laid in a duct provided for water pipes.

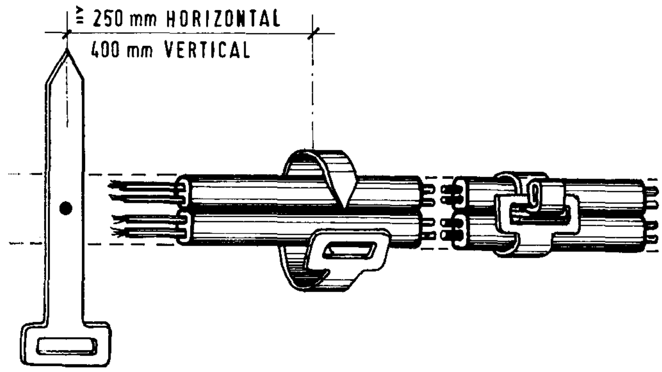
In larger domestic buildings (two-storey), flats, schools, institutions, smaller office buildings etc. **"Conduit Wiring"** is used. This is a system most widely used for electrical distribution. Cables are drawn into conduit tubing. These are laid (normally on the surface of the concrete slab and covered by the screed and concealed in the wall construction) to the points where electricity is required. The function of the conduit is to give mechanical protection to the cables. Conduits are available in different materials:
- Galvanized drawn steel tubes with screwed joints. This is still the most commonly used conduit tubing. It is watertight and gives a good earth continuity.
- Plastic conduits. These are usually flexible or medium and high impact rigid tubes from 16 to 45 mm diameter. Their use is becoming more widespread, because they are easy to fix, airtight and very suitable in exposed and damp conditions. They need a separate earth conductor or an earthed cable, which steel tubes do not need; earthing is achieved here by the conduit itself. Joints and bends can be screwed or glued. Glued plastic conduits are absolutely airtight, screwed assemblies are more readily adjusted or inspected (Fig. 412).



CABLE IN METAL CHANNEL
UNDER PLASTER :

CABLES TO SWITCHES AND ON THE RING CIRCUIT, RUNNING UP AND DOWN, CAN BE FIXED IN SHALLOW METAL CHANNELING UNDER THE PLASTER. CHANNELS MUST BE PAINTED WITH RED LEAD PAINT TO PREVENT RUSTING THROUGH THE PLASTER.

FIG. 411 : SURFACE WIRING



FIXING OF CABLES TO WALL SURFACES WITH NON-FERROUS METALLIC BUCKLE CLIPS

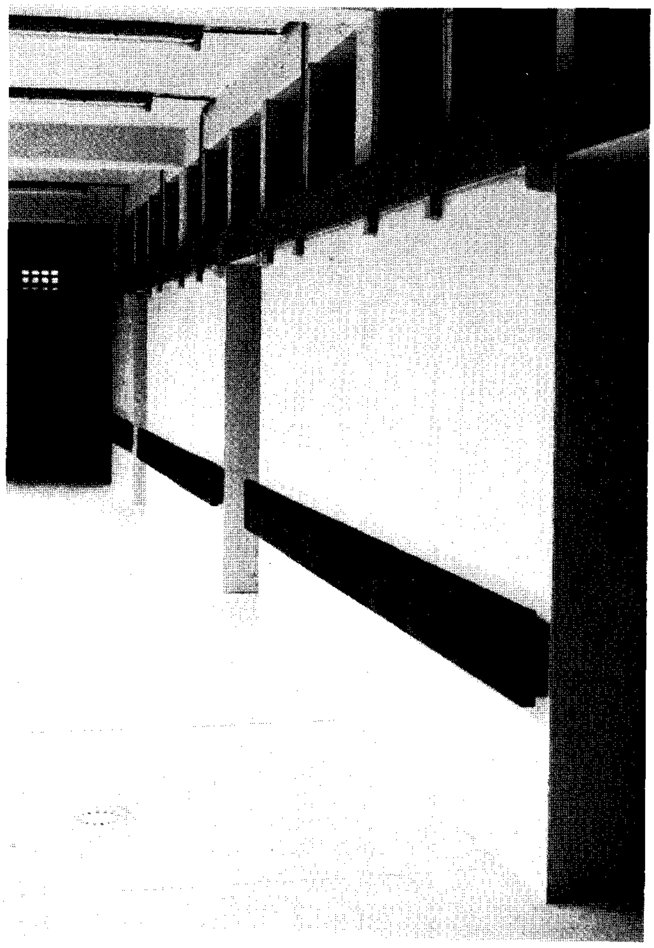
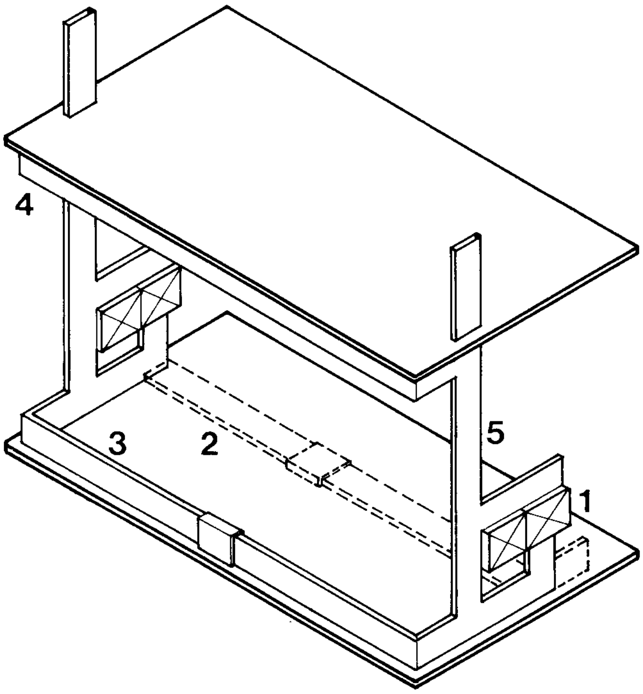
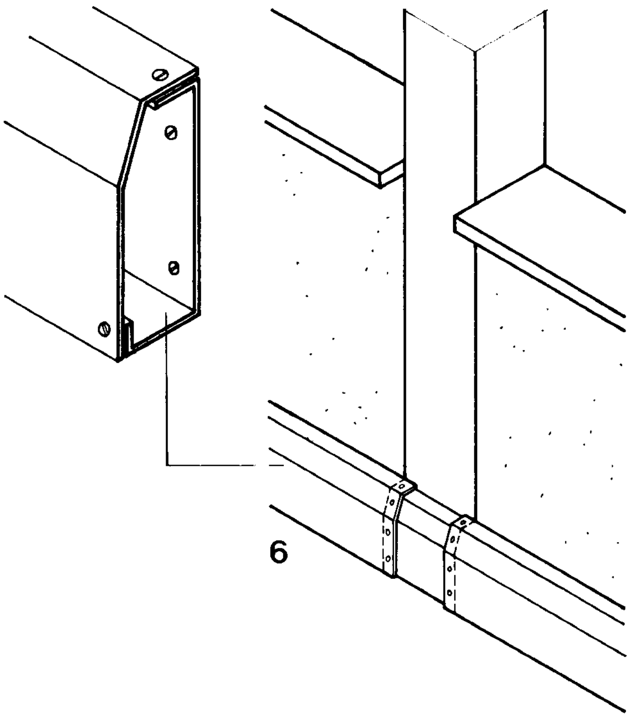


Fig. 412: Trunking fixed above door level with conduits on wall surfaces leading to light switches and hight fittings. Lomé Hospital, Togo; Architect: G. LIPPSMEIER.



1 DISTRIBUTION BOARDS AND INTAKE POSITION
2 FLOOR TRUNKING. THE DUCT IS BEDDED INTO THE SCREED OR INTO THE FLOOR.
3 SKIRTING TRUNKING
4 OVERHEAD TRUNKING. THE PHOTOGRAPH BELOW SHOWS OVERHEAD TRUNKING AT DOOR LINTEL HEIGHT IN THE NEW SURGICAL WARD OF THE HOSPITAL IN LOMÉ, TOGO (ARCHITECT: GEORG LIPPSMEIER).
5 RISING DUCT

SCHEMATICAL SKETCH SHOWING DIFFERENT TRUNKING ARRANGEMENTS - NOT TO SCALE.



6 SKIRTING TRUNKING SUITABLE FOR OFFICES WHERE DEMOUNTABLE PARTITIONS ARE USED. AT GRID OR MODULE POSITION A FIXED SECTION OF TRUNKING IS USED. THE TRUNKING IS MADE OF HIGH IMPACT PLASTICS OR GALVANIZED STEEL SHEETING.

FIG. 413 : **TRUNKING FOR LARGE INSTALLATIONS**

For multi-storey offices and in factories with large installations **"Cable Trunking"** is used, especially in areas where many cables have to follow the same route. Trunking consists basically of a metal trough with detachable lids in the sizes 50 × 50 mm, 75 × 50 mm, 100 × 50 mm, 100 × 100 mm, 100 × 150 mm, 100 × 200 mm, 100 × 250 mm. Normal practice is to lay the trunking from the intake position to each area or floor (Fig. 413). In some factories overhead draw-off conduits are installed to serve individual machines etc.

6.6.2.4 ELECTRICAL LAYOUT:

For small buildings the architect should prepare an electrical layout indicating where and which kind of electrical appliances are to be fitted. Detailed specifications describing the chosen wiring system and each appliance must be prepared in addition (Fig. 414). Detailed wiring plans and a specialist installation design are necessary for larger and more complex buildings (hospitals, offices, institutions etc.).

For telephone cables, sound and television distribution systems, teleprinters, tape-machines, alarm systems etc. different layouts from the electrical layout must be prepared. The telecommunication circuits must be separated from the light and power circuits and require their own conduit system.

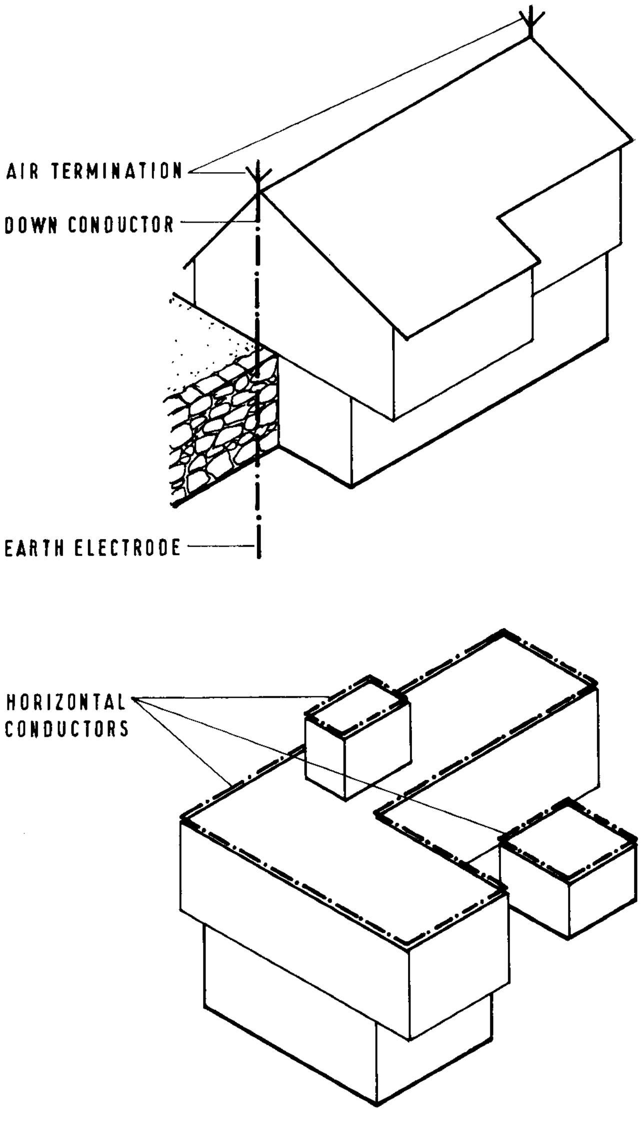


FIG. 415 : **LIGHTNING PROTECTION FOR BUILDINGS**

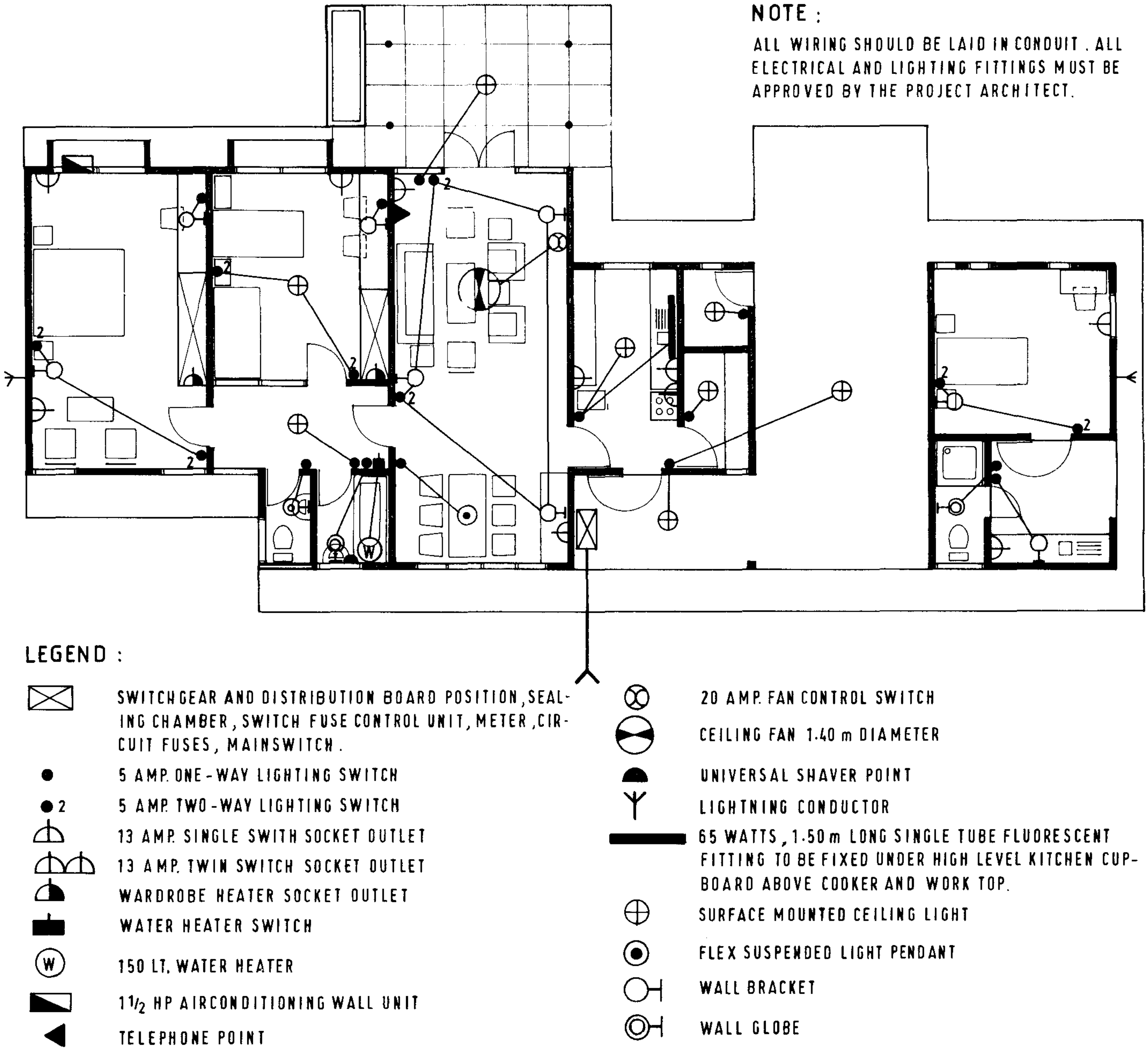


FIG. 414 : ELECTRICAL LAYOUT - FOR STANDARD P.W.O. BUNGALOW 100, DESIGNED BY H. SCHRECKENBACH.

LIGHTNING PROTECTION

It is essential in tropical countries to protect a building against that form of lightning which strikes from thunderclouds to the ground. Such a stroke of lightning normally averages a peak current of 20,000 amps, but may reach 2 million amps (from "Environment and Services", Mitchell's Building Construction, by Peter Burberry). One can imagine the damage and risk of fire if such lightning strikes an unprotected building.

Protection is achieved by conductors which are arranged in a protective system of:

- **Air terminals**: These are copper, aluminium or phosphor bronze rods, or horizontal conductors installed at the highest point of the roof (normally at both gable ridges) and along the outer perimeter of the roof (in case of a flat roof). The air terminals intercept the lightning.
- **Down Conductors**: These convey the current of lightning to the earth terminal. One down conductor is sufficient for a floor area of up to 90 m^2. There should be an additional down conductor for every extra 275 m^2 of plan area over 90 m^2. The conductors are made from copper or aluminium strip 20mm × 3mm or 10mm in diameter.
- **Earth Terminal**: The down conductor should be connected to the general mass of the earth by the most efficient means possible, an earth electrode. This consists of one or more copper or aluminium rods driven at least 2.5 metres into the ground. The down conductors are clamped to the rods (Fig. 415).

6.6.3 ARTIFICIAL LIGHTING

Whereas the relative dullness of the climate in Northern Europe has led to the development of large windows for the admission of sufficient daylight, window openings in the Mediterranean areas are small. Tropical countries between the Tropics of Capricorn and Cancer are normally exposed to intense daylight through bright sunshine and require only small window openings to admit sufficient daylight. However, over the years the acceptable levels of illumination, especially in offices, schools, institutions etc. have been raised so that it is difficult, even in tropical conditions to achieve the desired levels by the use of daylight alone. This has led to a permanent supplementary artificial lighting in interiors of such buildings.

Of the two principal sources of lighting in buildings the artificial lighting is constant and controllable. Daylight and sunlight are continuously varying with the seasons of the year (dry and rainy season) and the weather (thunder, rain, Harmattan).

Artificial lighting can be classified as:

- **Indirect**: Good diffusion, no shadows, low source brightness;
- **Direct**: Shadows. Precaution needed against glare (direct or reflected glare);
- **Direct-indirect**: Intermediate systems.

6.6.3.1 LIGHT SOURCES:

The two most commonly used light sources are:

- **Incandescent Bulbs**: These provide a point source of light which can be focused or directed over a limited area. Light bulbs are of different wattage to provide different levels of brightness from 10 to 1500 Watts. They are available in a wide variety of sizes, shapes and colours with screw or bayonet base, clear or opaque glass (Fig. 416).

Fig. 416: Incandescent light bulbs.

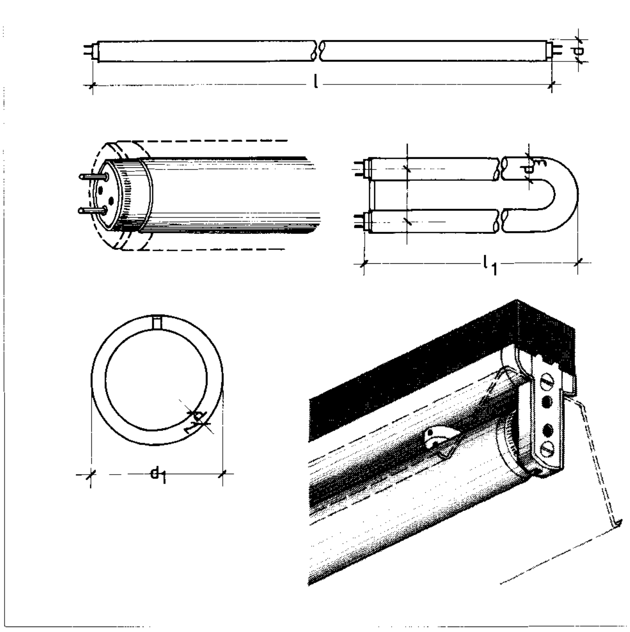
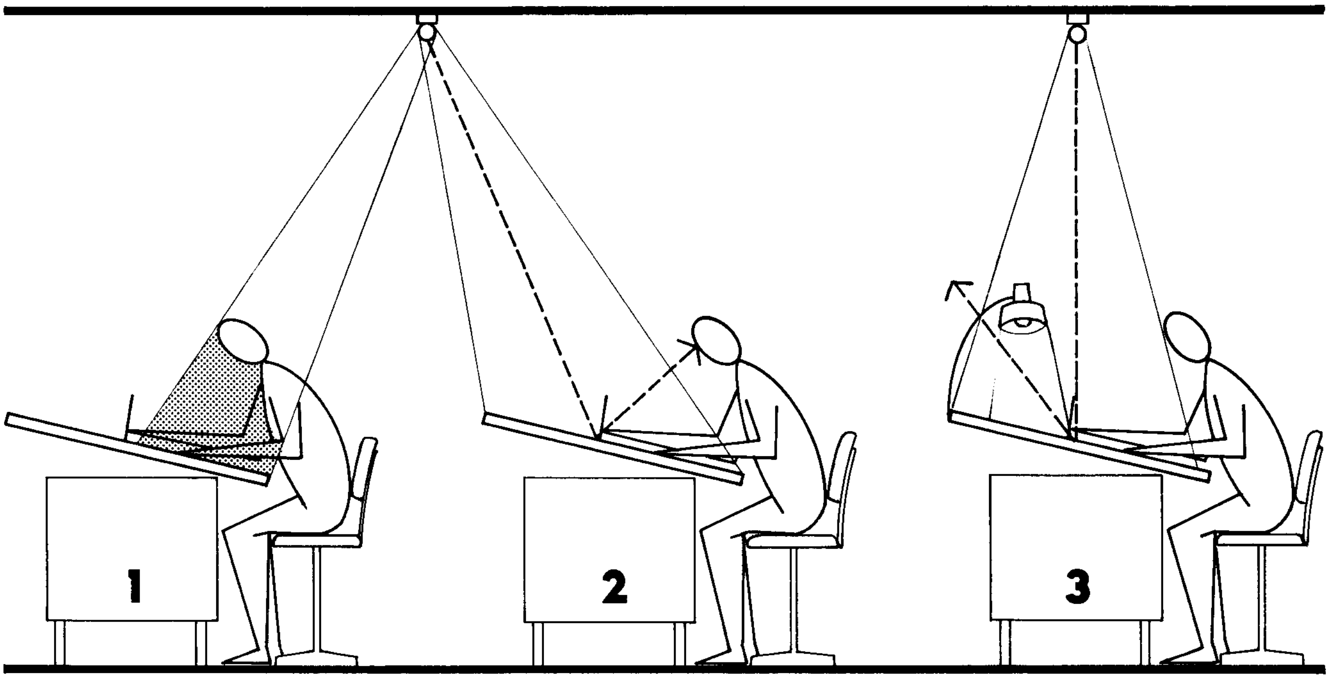


Fig. 417: Fluorescent Fitting.



POSITION 1 : VERY BAD
LIGHTING UNIT IS PLACED SO THAT THE BODY OF THE DRAUGHTSMAN OBLITERATES THE LIGHT SOURCE ON THE WORKING AREA.

POSITION 2 : UNSUITABLE
REFLECTED GLARE FROM TABLE SURFACE THROUGH INCORRECT POSITION OF LIGHTING UNIT.

POSITION 3 : CORRECT
CORRECT POSITION OF LIGHT ABOVE TABLE. BEST LIGHTING QUALITY IS ACHIEVED BY FITTING A TABLE LAMP WITH A FLEXIBLE ARM TO THE DRAWING BOARD.

FIG. 418 : LIGHTING UNITS IN A DRAWING OFFICE

- **Fluorescent Tubes**: These are tubular light sources, with higher light efficiency, cooler operating temperatures and longer life. They have different sizes and shapes, from 4 Watts (20 mm diameter, 450 mm long) to 100 Watts (38 mm diameter, 2400 mm long). Fluorescent tubes provide a line of light and are very useful above kitchen working surfaces, above bathroom mirrors, in offices, drawing offices, classrooms etc. They provide three to four times as much light per Watt of electricity as incandescent fittings, with less heat produced, and have an operating time about eight times that of incandescent bulbs. Fluorescent tubes are however, expensive fittings since they require a starter and a current limiting and control device (ballast) (Fig. 417).

6.6.3.2 LIGHTING QUALITY:

When designing the lighting layout and choosing the light sources an architect will have to consider the following:

- The **Room Finishes**: Walls, floors and ceilings are important factors in determining the brightness ratios between the light sources and the surroundings. The choice of positioning the light sources will influence colour and texture of room surfaces and shape and form of equipment and furniture in the room, apart from the direct influence on the user. Appearances of colours under different artificial light sources vary in comparison with daylight. In tropical conditions cool colours (white, light blue etc.) on walls and ceilings, light grey on floors, with fluorescent light bulbs as light sources, will give comfortable working conditions in offices, classrooms etc. The fluorescent lamp can also be chosen as "cool white" with an opaque cover or diffuser to cancel out the visible flicker of fluorescent lamps (stroboscopic effect).
- **Equipment and Furniture:** All furniture and equipment should have a light finish that harmonizes with the room surfaces and the light sources and promotes "seeing" comfort.

A factor often overlooked in designing the lighting layout is the required light quality at each working place. It is therefore recommended that an architect should design a furniture and equipment layout before planning the lighting layout. In areas like typing desks, drawing boards, writing desks, it is essential not only to protect the eye from the potential direct glare zone of a direct light source but also to protect the immediate "seeing" area of the working place from reflected glare. The protection of the eye in the potential direct glare zone of a light can be achieved simply by using shields in front of or plastic diffusers over the fluorescent tube fittings. Fig. 418 explains the correct positioning of a lighting unit in relation to a draughtsman's drawing table.

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Appendix I – GLOSSARY:

Abosom	An Akan word for fetish, meaning also "lesser Gods".
Adinkra (cloth)	The name for a cloth which is linked with King Adinkra of Gyaman. D.Mc Leod in his book "The Asante" states that "a Kumasi court tradition claimed that the cloth was introduced by the Takyimanhene when he was captured and brought to Kumasi by the Asantehene Opoku Ware". The cloth is printed by hand with stamps which are artistically cut from calabashes in the form of different symbols signifying religious expressions, all-day features and traditional wisdom.
Aseda	An Akan word expressing gratitude.
Ashmoh process	Description of a process producing rice husk ash cement which was developed in the Indian Institute of Technology, Kampur.
Basel Mission	Christian evangelical Mission from Basel in Switzerland which was active in Ghana since colonial times in the middle of the 19th century and predecessors of the Presbyterian Church of Ghana.
Blaine (fineness)	Measurement of surface area of powder using " Blaine" fineness tester. A permeameter is connected to the low pressure side of an U-tube manometer. Air is allowed to flow through the powder bed to equalize the pressure in the two arms of the manometer. The time required for a specified movement of the manometer is used for calculating the surface area.
Boucherie (process)	From "boucherization": immersion, dipping or soaking in copper sulfate.
Branbury (mixer)	A mixer used for stirring, mixing, dissolving and homogenizing powdery and granular solids.
Bremen Mission	Christian evangelical Mission from Bremen (Norddeutsche Missionsgesellschaft), especially active in the Volta Region of Ghana (part of the former German Colony of Togoland) since the late 19th century and predecessors of the Evangelical Presbyterian Church of Ghana.
Buoyancy (foundation)	A reinforced concrete raft foundation so designed that the total of its own and all loads which it carries is approximately equal to the weight of the soil or water displaced.
Caisson	A floating structure which may be placed across the entrance to a basin, lock, or dry dock, thereby excluding water from it. Or a boxlike structure with cutting edges, used in constructing bridge foundations and well bottoms, ultimately becoming part of it.
Cambium	Describes the inner surface of the bark of a tree.
Cheops	Pharao of Egypt about 2600 B.C. Under his regime the biggest pyramid at Gizeh near Kairo was built.
China Clay	A hydrated silicate af aluminium, resulting from the decomposition of the feldspars in igneous rocks by pneumatolysis. It contains a high percentage of aluminium silicate and is of great value in the ceramic industry. It is also called kaolin or porcellain clay. The Chinese were famous for the production of the finest porcellain in the world, hence the word "China" for the description of porcellain.
Colosseum	Roman amphitheatre, built under Emperor Vespasian (69–79 A.C.). Its antique name was Amphitheatrum Flavium. The name "Colosseum" dates from the Middle Ages after the colossal statue of Nero nearby.
Cuirasse	Laterite rock or hardpan.
Gobar (plant)	Gobar – Indian word for cow-dung. The Gobar biogas plant was designed by the Indian Khadi & Village Industries Commission (Bombay).
Greywater	A description for waste water from kitchen sinks, wash basins, baths and showers.
Hatschek process	In the Hatscheck process for the production of asbestos-cement the slurry mixture is picked up by wire-mesh covered cylinders, transferred to a felt and then wound round a roller until the required thickness of the sheet is obtained.
Hoffman kiln	A furnace for burning bricks or limestone.
Kenaf fibre	A fibre produced from Hibiscus cannabis, a 3–4 metre high Savannah shrub. In Angola and Sudan it has been found that Kenaf was cultivated as far back as 4000 B.C.
Ohm	Unit of electrical resistance.
Pantheon	The best preserved antique temple of Rome, today S.Maria Rotonda. The Pantheon was built under Emperor Hadrian 115–125 A.C.
Perspex	Proprietary thermoplastic resin of polymethyl methacrylate of exceptional transparency and freedom from colours in the unpigmented state.
Posolen	Insulative building paper.
Pumice	An "acid" vesicular glass, formed from the froth on the surface of some particular gaseous lavas. The sharp edges of the disrupted gas vesicles enable pumice to be used as an abrasive.
Ramseyer	One of the early missionaries of the Basel Mission who brought Christianity to Kumasi.
Revetment	A reinforcement, normally used on banks from different materials to retain the soil.
Roman pattern	A traditional laying pattern of burnt clay roofing tiles dating from Roman times. Halfround hollow tiles are laid in such a way that two open tiles are covered by one tile laid upside down.

Sagrenti War "Sagrenti" is the corrupted form of Sir Garnet Wolseley. The Sagrenti War describes the Ashanti War of 1873–74 which was fought by Queen Victoria of Britain against the Ashantis under the command of General Sir Garnet Wolseley.

Surkhi An Indian word for pozzolana derived from burnt clays.

Tindana In some ethnic groups in Northern Ghana he is the Earth's custodian. In former times the Tindanas of these ethnic groups or clans were the keepers of the land and everything on it. With the colonial administration chieftaincy was introduced in the North. With it and the advance of Christianity and Islam in these parts of the country the power of the Tindanas waned.

Volt Unit of electrical potential or e.m.f. such that the potential difference across a conductor is 1 volt when 1 ampere in it dissipates 1 watt of power.

Watt Unit of electrical power, equal to 1 joule/sec or 10 erg/sec. Thus, 1 horsepower equals 746 watts.

Yaa Asantewa A brave Asante queenmother from Ejisu who led the uprising against the British in the Gold Coast colony in 1900.

Zongo A Hausa word for stranger quarters.

Appendix II – TIMBER CATALOGUE

GHANA TIMBERS AND WOODY PLANTS

Their names, properties and possible uses in building construction, referring to the heartwood, if not otherwise described; colour refers also to heartwood.

LEGEND:

N.D.I. = Not durable, suitable if completely impregnated
D. = Durable
M.D. = Moderately durable
V.D. = Very durable

+ = Resistant to fungi and decay
++ = Resistant to termites
x = Resistant to ship worm and marine borers
xx = Resistant to insects
○ = Resistant to salt water

Ash = Ashanti
W = Wassa
F = Fanti
E = Ewe
Nz = Nzima

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
1. AFRORMOSIA ELATA (PERICOPSIS ELATA)	Kokrodua (Twi)	Afrormosia	–	V.D.	Bright brownish olive; for high class furniture, first class joinery, flooring, fittings, used as TEAK-substitute; wood air and kiln-dries well, is easy to work.
2. AFRORMOSIA LAXIFLORA (PERICOPSIS LAXIFLORA)	Duabeyifo (Ash)	–	Satin wood, witch tree	D.	Dark violet-brown, blackish-olive; for house posts, turnery and cabinet work, shingles. Heavy wood, difficult to work.
3. AFZELIA AFRICANA	Papao Opepao (Twi)	Afzelia	–	V.D. ++ x	Light, red-brown; for heavy construction, docks, bridges, sleepers, stair treads, flooring, veneers (when figured). Heavy wood, difficult to work, air seasons and kiln-dries well.
4. ALBIZIA CORIARIA	Awiemfo-Samina (Twi)	–	Poor man's soap	D.	Brown; for heavy furniture (oak-substitute); wood is easy to work.
5. ALBIZIA FERRUGINEA	Awiemfo-Samina (Twi)	Albizia	Poor man's soap	M.D. +	Light to dark red-brown; for general exterior and interior and light construction work; wood medium light and hard, good to work.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
6. ALBIZIA ZYGIA	Okoro (Twi)	Okoro	–	M.D.	Dark brown; for general building purposes, house posts, doors, plywood.
7. ALSTONIA BOONEI	Sinduro Nyamedua (Twi)	Alstonia	Stool wood, Sky god's tree	N.D.I.	White, yellowish; for light carpentry, veneers; wood seasons well.
8. ANOGEISSUS LEIOCARPUS	Hehe (E)	–	–	D. ++	Darkbrown, nearly black; for rafters, forked stems for house posts
9. ANINGERIA ALTISSIMA	Samfona (Twi) Opapie (Ash)	–	–	M.D.	Pale pink; for general constructional work. Wood is easy to work, semi-hard.
10. ANINGERIA ROBUSTA	Anenkyen (W) Asamfona (Ash)	Aningeria	–	N.D.I.	Yellowish white; for light constructional work and general joinery; fairly hard wood.
11. ANOPYXIS KLAINEANA	Kokote (W, F)	–	–	M.D. ++	Reddish brown or yellow; for heavy constructional work, eg. railway sleepers and flooring (after impregnation with preservatives); hard and heavy wood, good to work, seasons well.
12. ANTIARIS AFRICANA	Kyenkyen (Twi)	Antiaris	Bark cloth tree	N.D.I.	White to greyish yellow, for plywood and plywood cores, light joinery; wood is easy to impregnate.
13. ANTROCARYON MICRASTER	Aprokuma (Twi)	Antrocaryon	–	N.D.I.	Rich reddish-brown; for utility furniture and planks.
14. AVICENNIA AFRICANA	Amutsi (E)	–	Black or olive mangrove	D. ++ O	Light brown; for house building, utility furniture (chair legs etc.)
15. AZADIRACHTA INDICA	Nim tree	Nim tree	Margosa tree	D. xx	Resembles mahogany, darkens on exposure; for furniture.
16. BALANITES AEGYPTIACA	Krobodua (Twi)	–	Desert date, Soapberry tree	D. xx	Soft and straight grained, pale yellow; for some kinds of cabinet work and joinery; wood is easily worked.
17. BALAMITES WILSONIANA	Krobodua (Twi) Kurobow (Ash)	–	–	D.	For general constructional work; wood is soft, is easily worked.
18. BAMBUSA:					
18.1 BAMBUSA VULGARIS	Bamboo	Yellow and green striped bamboo	–	N.D.I.	For poles and temporary buildings.
18.2 DENDROCALAMUS STRICTUS	Bamboo	–	Male bamboo (india), green stemmed bamboo	D.	For house building, framework, scaffolding, fences, furniture, masts.
18.3 OXYTENANTHERA ABYSSINICA	Pamplo (E)	–	Savannah bamboo	D.	for rafters, roofing, fences, furniture.
19. BLIGHIA SAPIDA	Takwadua (Twi)	–	Akee apple	D. ++	Reddish brown; for utility furniture & joinery work.
20. BORASSUS AETHIOPUM (BORASSUS FLABELLIFER)	Makube (F) Ago (E)	Agobeam	Fan palm, Desert palm, Palmyra palm	V.D. (older trees) + ++ O	For roof beams, bridges, telegraph poles, wharf piles, heavy construction work.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
21. CANARIUM SCHWEIN-FURTHII	Bediwunua (Akan)	Canarium	African elemi, Incense tree	N.D.I.	Pale pink to light brown; for general joinery, house posts, light construction work, flooring, furniture, decorative doors; for utility plywood and rolled veneer.
22. CARAPA PROCERA	Kokuo-besi (Twi) Kraa-besi (W)	Crabwood	Monkey cola	D. ++ (Fire resistant)	Red-brown to dark-brown; for general building work, local carpentry (house posts, furniture, joinery), interior decoration, cabinet-work; used as mahogany substitute; wood is fairly heavy, hard and strong, quite easy to work.
23. CASUARINA EQUISETI TIFOLIA	Whistling pine	Casuarina	Beefwood	M.D. ++	Reddish-brown; for poles and rafters.
24. CEIBA PENTANDRA	Onyina (Twi)	Ceiba	Silk cotton tree, Kapok tree	N.D.I.	White, greyish; for local utility furniture; wood is very light and easy to work. Bark used for hut doors.
25. CELTIS MILDBRAEDII	Esa-fufu (Twi)	Celtis	–	M.D.	Whitish, pale yellow; for joinery, flooring, furniture-framing, commercial plywood, light-coloured veneer.
26. CHLOROPHORA EXCELSA	Odum (Akan)	Iroko	African or Nigerian teak	V.D. + ++	Brownish, dark brown with age; for constructional work of all kinds, sleepers, house posts, staircases, high class furniture, special high quality joinery, flooring, cabinet-work; air and kiln-seasons well.
27. CLEISTOPHOLIS PATENS	Ngo-ne nkyene (Twi)	Otu	Salt and oil tree	N.D.I. ++	White; for utility joinery, plywood.
28. COCOS NUCIFERA	Neti (E)	Coconut	–	–	Leaflets, with split midribs for thatching; petioles and mid-ribs for rafters.
29. COMBRETUM GHASALENSE	–	–	–	D.	For hut poles; leaves and leafy twigs sometimes mixed with thatching grass.
30. COMBRETUM GLUTINOSUM	–	–	–	D.	Yellowish; for hut posts.
31. COMBRETO-DENDRON MACROCAR-PUM Petersiathus Africanus)	Esia (Twi)	Esia	Stinkwood tree	V.D. ++ xx	Red, dark and reddish brown; for heavy and general construction work, in mines, for sleepers.
32. COPAIFERA SALIKOUNDA	Entedua (Ash)	Bubinga	–	V.D.	Light, reddish-brown; wood is very hard and heavy, excellent for veneers.
33. COULA EDULIS	Bodwe (Twi)	African walnut	Gaboon nut	D. ++ ○	Red to reddish-brown; for heavy carpentry, stair treads, doors, turnery, house posts, sleepers, bridge piles; wood is hard and heavy.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
34. CYLICODISCUS GABUNENSIS	Denya (Twi)	Okan	African green-heart	V.D. +	Yellow to brown; for general construction work, bridges, house-building, posts, block flooring; wood is strong and hard, works quite well; liability to surface shakes and to distortion are against its use for furniture.
35. CYNOMETRA ANANTA	Ananta (W)	Ananta	–	V.D.	Dark reddish-brown; suitable for posts, bridge-building, sleepers, mining timber. Hard and heavy wood.
36. CYNOMETRA MEGALO-PHYLLA	Awhirewa (Ash)	–	–	V.D. ++	For local house-building (posts, door frames); wood is hard and heavy.
37. DANIELLIA OGEA	Hyedua (Twi)	–	Gum copal tree	N.D.I.	Greyish with dark streaks; for decorative veneer.
38. DANIELLIA THURIFERA	Sopi (W)	–	Niger copal tree	N.D.I.	Pinkish to reddish-brown with dark-streaks; for furniture linings, backings and veneers, interior joinery.
39. DETARIUM SENEGALENSE	Bowisi (Twi)	–	Tallow tree	D. ++ ○	Dark red-brown; for carpentry and joinery; wood is hard, not easy to work.
40. DIALIUM GUINEENSE	Asenaa (Twi)	–	Velvet tamarind Sierra Leone tamarind	D. ++	Pinkish brown to dark red-brown; for framework, cabinet work and turnery.
41. DIOSPYROS KAMERUNEN-SIS	Omena (Twi)	–	Cameron ebony (the black heart-wood)	M.D.	Pink with grey-brown bands; for house posts, poles; wood is hard, heavy, tough, resilient, works well.
42. DIOSPYROS CANALICULATA (DIOSPYROS XANTHOCHLA-MYS)	Twabiri (Twi)	–	Flint bark	V.D.	Light yellow; for general timber framework, mining timber; wood is hard and heavy.
43. DIOSPYROS MESPILIFORMIS	Kisibiri (Twi)	–	West African or swamp ebony	D.	Heartwood black; for heavy planking in house building, utility furniture; wood is hard, compact, planes easily but will not take nails.
44. DIOSPYROS SANZAMINIKA	Kusibiri (W)	–	Flint bark	V.D.	White when fresh, darkens to brown; for mining timber, poles; wood is hard, compact.
45. DISTEMONAN-THUS BENTHA-MIAMUS	Bonsamdua	Ayan	African or yellow satin-wood	D. ++	Yellow, light brown; for general utility, light construction, interior decoration, turnery, furniture, cabinet-work, flooring (parquetry), veneers (rotary-cut); wood seasons well, is strong, works well, comparable to ODUM.
46. ELAEIS GUINEENSIS	Oil palm	Oil palm	–	–	Fronds are used for roof thatching, petioles for hut poles, rafters and fences.
47. ENTANDRO-PHRAGMA ANGOLENSE (E. MACRO-PHYLIA)	Edinam (Twi)	Gedu nohor	Bondondo mahogany	M.D.	Red-brown; for high class furniture, interoir decoration, shop fittings, veneers; seasons well, works easily with all tools.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
48. ENTANDRO-PHRAGMA CANDOLLEI	Pepedom (W)	Candollei	Unscented mahogany, sapele-heavy	M.D.	Similar use as SAPELE, although harder, for flooring.
49. ENTANDRO-PHRAGMA CYLINDRICUM	Penkwa (Twi)	Sapele	West African cedar, scented mahogany	M.D. +	Red-brown; for high class furniture, high quality joinery, flooring, panelling, veneer; wood is hard, works well with all tools.
50. ENTANDRO-PHRAGMA UTILE	Efuobrodedwu (Ash)	Utile	Sapele mahogany	D.	Rich red-brown; for light construction work, interior decoration, cabinet-work, veneers.
51. ERYTHRO-PHLEUM SUAVEOLENS (E. GUINEENSE)	Potrodom (Twi)	Potrodom	Ordeal tree, red water tree sasswood or sassy bark	D. + ++ x	Reddish with dark veins; for interior carpentry, utility furniture, flooring, mining timber, piles, sleepers, bridge building; heartwood is hard and heavy, rather difficult to work.
52. ERYTHRO-PHLEUM AFRICANUM	Prekese (Ash)	–	African blackwood	D.	Reddish; for joinery, parquet floors, turnery. Seasons well.
53. ERYTHRO-PHLEUM IVORENSE	Potrodom (Twi)	Potrodom	Ordeal or sasswood tree	V.D.	Red-brown; for general construction and carpentry work, for harbour work, bridges, sleepers; wood is very heavy and difficult to work.
54. FAGARA MACROPHYLIA	Oyea (Twi)	–	–	D.	Bright yellow; wood resembles satinwood, is hard and heavy, for furniture, cabinet-work, interior carpentry.
55. FAGARA LEBRIEURII	Okuo (Ash)	Angolensis	–	M.D.	Pale yellow; wood resembles satinwood, suitable for general carpentry, plywood.
56. FUNTUMIA AFRICANA	Mama (Ash) Okea (W) Osese (Twi)	–	False rubber tree	N.D.I.	White; for light carpentry; wood is soft.
57. GILBERTIO-DENDRON SPLENDIDUM (MACROLO-BIUM SPLENDIDUM)	Tetekon (W)	–	–	D.	Yellowish-brown; for general construction work; wood is hard and easy to work.
58. GUAREA CEDRATA	Kwabohoro (Twi)	Scented guarea	–	V.D. ++	Pinkish brown, darkening later; for interior decoration (panelling), high class furniture, decorative veneers (sliced); wood works well.
59. GUAREA THOMPSONII	Kwadwuma (W)	Black guarea	–	M.D.	Pinkish brown, darkening later; for furniture, cabinet-work, interior decoration, flooring, turnery, veneers; wood hard, modestly heavy, tough and strong, works well with all tools.
60. HIPPOCRATEA AFRICANA	–	–	–	V.D. ++	Woody climber, split stems for binding material in house building and fence building.
61. HOLARRHENA FLORIBUNDA (H. WULFS-BERGHII)	Sese Osese (Twi)	Osese	False rubber tree	N.D.I.	Pale yellowish-white; for light carpentry; wood works well (for carving and stools).

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
62. IRVINGIA GABONENSIS	Abesebuo (Twi)	–	Wild mango	D.	Pale greenish-brown; for house posts, ships' decks, planking, wooden paving; wood hard and heavy
63. KHAYA ANTHOTHECA	Kruben (Ash) Ahafo timber	White mahogany	Smooth-barked African mahogany	M.D.	Pinkish-white; for good-quality joinery, furniture, interior decoration wood is lighter than K. IVORENSIS.
64. KYAYA GRANDIFOLIOLA	Odupon (Ash)	Broad-leaved mahogany	–	M.D.	Pink, turning rich brown; for the same purposes as true MAHOGANY.
65. KHAYA IVORENSIS	Odupon (Ash)	African mahogany	–	M.D. +	Pale red, darkens on exposure; for high-class furniture, interior decoration, good-quality joinery, excellent for plywood and veneers ("figured" mahogany); air and kiln-dries easily, works easily with all tools.
66. KHAYA SENEGALENSIS	Kuka	–	Dry-zone mahogany	D. ++	Pink-brown to deep red-brown; for good quality joinery, furniture, interior decoration.
67. KLAINEDOXA GABONENSIS	Koroma (Twi)	Oblongifolia	Ironwood	V.D.	Reddish-golden-brown; for heavy carpentry, planking of ships decks, piles, stair treads, wooden paving, poles, railway sleepers; wood is hard and heavy.
68. LOPHIRA ALATA	Kaku (Twi)	Ekki	Red ironwood meni oil tree	V.D. x xx	Dull purple-brown, very hard; for heavy construction work, mining timber, wharf piles, stair treads, flooring, switch boards (high electrical resistance).
69. LOVOA TRICHILIOIDES (L.KLAINEANA)	Timabiri (W) Dubinibiri	African walnut	–	M.D. +	Brown, golden-brown; strong and hard wood, works fairly easy; for high class furniture, cabinet-work, panelling, veneers, high-class joinery.
70. MAESOPSIS EMINII	Owamdua (Ash)	–	Hornbill's tree	N.D.I.	Yellow-green, darkens to brown; for general construction work, fencing.
71. MAMMEA AFRICANA (OCHROCARPUS AFRICANUS)	Bompegya (Twi)	African apple	African mammy apple	M.D.	Dark red; for good, heavy furniture, hard and fairly heavy wood.
72. MANSONIA ALTISSIMA	Apronu (Twi)	Mansonia	–	V.D. ++	Yellowish, greyish brown; for high quality joinery, interior decoration (panelling), shingles, furniture; wood air-seasons and kiln dries well, easy to work.
73. MITRAGYNA CILIATA	Subaha (Twi)	Abura	Poplar	M.D. xx	Light to pale reddish-brown; for first-class carpentry work of general utility, for fittings, cabinet-work, doors, floorings, plywood, veneers; wood seasons and works well.
74. MITRAGYNA INERMIS	Nyimo (E)	–	–	D. ++ ○	Pale-brown, yellowish; hard but easy to work, for building and for furniture.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
75. MITRAGYNA STIPULOSA	Subaha (Twi)	–	–	D. O	Yellow, brownish yellow; for floor boards and weather-boarding, general joinery work and furniture.
76. MORINDA LUCIDA	Konkroma (Twi)	–	Brimstone tree	D. ++ xx O	Yellow, yellow-brown; for housebuilding, furniture, cabinet-work, mining timber; wood is fairly hard.
77. MORUS MESOZYGIA	Wonton (Twi)	Wonton	–	D.	Yellow, turning coffee brown; wood is hard, heavy, properties and uses similar to ODUM.
78. MUSANGA CECROPIOIDES	Owuma (Twi)	–	Umbrella tree, cornwood	N.D.I.	Pinkish white in colour; very light wood, used for rafts and floats. Shavings suitable for wood wool slab production.
79. NAUCLEA DIDERRICHII	Kusia (Twi)	Opepe	–	V.D. + ++ x	Golden-yellow, darkening later; for heavy construction work, planking, harbour work, underground construction; for furniture, flooring, interior decoration, turnery and cabinet-work, sliced veneer. Wood works and finishes well.
80. NESOGORDONIA PAPAVERIFERA	Danta (Twi)	Danta	–	M.D. + ++ xx	Reddish brown; for light construction, flooring, utility joinery, poles; wood is tough and elastic, works and finishes well.
81. PARINARI EXCELSA	Afam (W) Kotosima (W)	–	Rough skinned grey or Guinea plum	D. +	Reddish brown; for house building, furniture; wood rather heavy and difficult to work.
82. PARINARI ROBUSTA	Kokodua (Twi)	–	–	D. ++ x	Red; for house building, piles, sleepers; wood heavy and hard, resembles MAHOGANY.
83. PENTADESMA BUTYRACEA	Abotomasebie (W)	–	Butter or tallow tree	D. ++	Dark brown, fine grained; for general construction work, mining timber, poles.
84. PIPTADENIASTRUM AFRICANUM	Dahoma (Akan)	Dahoma	–	D. ++ O	Light to dark-brown; for general construction work, joinery, flooring, sleepers, harbour work; wood is strong, should be air-dried before kilning.
85. PSEUDOCEDRELA KOTSCHYI	Krubeta (Ash)	–	Dry-zone cedar	D.	Reddish brown with figuring; for general utility, furniture, joinery, ornamental wood; wood is hard but works easily.
86. PTERYGOTA MACROCARPA	Kyere (Ash)	Pterygota	–	N.D.I.	White, turning greyish-red; for veneers; wood seasons rapidly, is easy to impregnate, is soft.
87. PYCNANTHUS ANGOLENSIS	Otie (Twi)	Pycnanthus	African nutmeg	N.D.I.	Greyish to yellowish white, darkening; for utility joinery, plywood, veneer, shingles (after preservative treatment); wood seasons well, is permeable to preservatives.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
88. RAPHIA HOOKERI	Alati (E)	Raphia palm	–	–	Petioles and rachis for roof beams, framework for huts, leaves are used for thatching, split midribs for screens.
89. RHIZOPHORA	Atrasi (E)	–	Red mangrove	D. xx ○	Dark red-brown to yellowish red; for piles and underwater work, house poles, framework, hard, heavy wood.
90. RICINODENDRON HEUDELOTII	Wamma (F)	–	–	N.D.I.	Dull white, pale yellowish; very light wood, seasons well and is permeable to impregnation. For timber rafts, carving.
91. SACOGLOTTIS GABONENSIS	Tiabutuo (W)	–	–	D.	Purple-red, brown; wood resembles MAHOGANY, is hard and heavy, easily worked. For furniture, interior decoration, general joinery.
92. SCOTTELLIA CHEVALIERI (S. KLAINEANA)	Tiabutuo (Twi)	–	–	N.D.I.	Yellowish-white; for utility furniture, flooring; wood is hard and heavy.
93. SCOTTELLIA CORIACEA	Kroku	Odoko	–	N.D.I.	Whitish, pale yellow; for house posts and joinery, plywood and veneer.
94. STERCULIA OBLONGA (S. ELEGANTIFLORA)	Ohaa (Twi)	Yellow Sterculia	–	D.	Yellowish white; for planking, bridges, utility furniture.
95. STERCULIA RHINOPETALA	Wawabima (Twi)	Sterculia brown	–	M.D.	Yellowish to reddish brown; wood is hard, moderately heavy, seasons slowly. For light construction work, interior joinery, utility furniture.
96. STERCULIA TRAGACANTHA	Sofo (Twi)	African Tragacanth	–	N.D.I.	Pinkish; for light interior joinery, fresh stems used for live fences, soft.
97. STROMBOSIA GLAUCESCENS (Var. LUCIDA)	Afena (Twi)	Afina	–	D. + xx	Pinkish, purplish brown; for poles, posts and pit-props, flooring. Wood is hard and heavy.
98. SYMPHONIA GLOBULIFERA (S. GABONENSIS)	Ahurke (Nz) Asoduro (W)	–	–	D. + xx (heartwood)	Yellowish-reddish-brown; for light construction work, utility furniture, flooring, veneer, generally as MAHOGANY substitute.
99. SYZYGIUM GUINEENSE	Ayeforoanhu (Ash)	–	–	V.D.	Dark red; for house building and flooring; wood is hard, strong, easily worked.
100. TARRIETA UTILIS	Nyankom (W, F)	Nyankom	Cola mahogany	D.	Light, reddish brown; for general construction work, good quality furniture and joinery, flooring, fittings, shingles. Substitute for MAHOGANY.
101. TECTONA GRANDIS	Teak	Teak	–	V.D. (Heartwood)	Golden brown, darkening; for highclass joinery, interior and exterior structural work, doors, door and window frames, furniture, veneer. Wood seasons well in air and kiln, works easily.

BOTANICAL NAME	LOCAL NAMES	TRADE NAME	OTHER NAMES	DURABILITY	USES IN BUILDING CONSTRUCTION
102. TERMINALIA IVORENSIS	Emeri (Twi)	Idigbo	Black bark, yellow Terminalia, shingle wood	V.D. + xx	Light to dark brown; for roof shingles, general construction, good quality joinery, furniture, panelling, window and door frames, skirting, stair treads, veneers (if figured); strong wood.
103. TERMINALIA SUPERBA	Ofram (Twi)	Afara	–	M.D.	Light yellowish brown; for light construction work and joinery, light flooring, utility furniture, plywood, veneer (rolled).
104. THALIA GENICULATA	Babadua (Ash)	–	–	–	Shrub, stems are tied into the framework of houses before daubing, split stems for mats.
105. TIEGHEMELIA HECKELII (MIMUSOPS HECKELII)	Baku (Twi)	Makore	–	D. ++ xx	Pink to rich brown; for good quality furniture, fittings, flooring, shingles, decorative veneers; wood is dense, hard, fairly easily worked.
106. TRIPLOCHITON SCLEROXYLON	Wawa (Twi)	Obeche	African whitewood	N.D.I.	Creamy white to pale yellow; for interior joinery, planking, plywood; wood is fairly soft, air and kiln seasons easily, easy to work; bark for roofing huts.
107. TURRAEANTHUS AFRICANUS	Apapaye (Twi)	Avodire	–	D.	Creamy white to pale yellow to golden yellow; for decorative veneers, cabinet-work, panelling, furniture, high quality joinery.
108. UAPACA GUINEENSIS	Kontan (W)	–	Sugar plum, Red cedar	D.D.	Red; for planks, beams, general carpentry, utility furniture; wood hard.
109. UAPACA HEUDELOTII	Kontan (W)	–	–	D.	Mahogany brown; for general construction work, planks.
110. XYLOPIA AETHIOPICA	Hwentia (Twi)	–	Ethiopian pepper, Spice tree	D. ++	Pale yellowish brown; for house posts, scantlings, masts; wood is fairly hard, heavy and elastic.
111. XYLOPIA QUINTASII	Obaa (Twi)	–	–	M.D.	Yellowish, brownish; for house poles. Wood heavy and tough.
112. XYLOPIA STAUDTII	Duanam (W)	–	–	M.D.	Whitish yellow to light brown; for house poles (stems), cabinet-work, planks, utility furniture; wood is tough and strong, works easily.

DURABILITY OF TIMBER

This describes the composite resistance of sound, untreated heartwood of timber species to decay, borer and termite attack, to splitting, checking, and brooming when used in exposed conditions. (Note: This does not include resistance to fire).

V.D. = VERY DURABLE:

Timbers listed in this class may be used with confidence in permanent structures in contact with the ground, in areas of exposure to fungus and termite attack, e.g. transmission poles, railway sleepers, bridging timber, mining timber, foundation timber, fencing posts, etc.

D = DURABLE:

Timbers listed in this class may be used for the exposed parts of permanent structures, which will give long service without preservative treatment under normal conditions, including ground contact in damp situations, e.g. framing timber, sills, etc.

M.D. = MODERATELY DURABLE:

Timbers listed in this class should not be used in contact with the ground unless treated with suitable preservatives, but for a short period they can withstand exposure to damp conditions. They are suitable for those parts of permanent structures which are protected from the weather, e.g. rafters, joists, etc.

N.D. = NON-DURABLE:

Timbers listed in this class must be treated with preservatives. They can, however, be safely used for internal joinery and furniture and in exterior position after treatment and when protected with paint coatings.

Appendix II: TIMBER CATALOGUE – References:

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Appendix III – Table 10:

STRENGTH PROPERTIES OF SUPERIOR AND HIGH QUALITY WESTAFRICAN TIMBER SPECIES AT 12% MOISTURE CONTENT:

Botanical Name	Standard Name	Specific Gravity	Bending Tension parallel to Grain kg/cm²	Compression parallel to Grain kg/cm²	Shear parallel to Grain kg/cm²	Modulus of Elasticity (mean) kg/cm²
Afrormosia Elata (Pericopsis Elata)	Afrormosia	0.63	1,363.12	727.60	146.65	126 540
Afzelia Africana	Papao	0.71	1,208.81	775.41	149.11	126 540
Albizia Ferruginea	Albizia (Awiemfo-Samina)	0.63	1,007.82	633.05	149.11	105 450
Chlorophora Excelsa	Odum (Iroko)	0.62	874.88	535.68	126.82	105 450
Combretodendron Africanum	Esia	0.81	1,343.92	732.45	147.63	126 540
Cynometra Ananta	Ananta	0.86	1,335.83	762.76	147.98	–
Cylicodiscus Gabunensis	Okan	0.87	1,356.79	837.98	201.06	126 540
Diospyros Sanzaminika	Kusibiri	0.86	1,539.57	738.15	153.25	–
Distemonanthus Benthamianus	Bonsamdua (Ayan)	0.64	1,047.47	562.40	130.76	105 450

Botanical Name	Standard Name	Specific Gravity	Bending Tension parallel to Grain kg/cm^2	Compression parallel to Grain kg/cm^2	Shear parallel to Grain kg/cm^2	Modulus of Elasticity (mean) kg/cm^2
Entandrophragma Angolense	Edinam	0.53	747.99	456.25	112.62	–
Entandrophragma Candollei	Candollei	0.74	856.18	506.51	133.57	–
Entandrophragma Cylindricum	Sapele	0.64	1,081.99	576.45	160.85	105 450
Entandrophragma Utile	Utile	0.59	1,001.78	591.23	151.57	105 450
Guarea Cedrata	Scented Guarea	0.54	955.09	531.33	137.92	87 875
Guarea Thompsonii	Black Guarea	0.60	1,035.17	587.71	121.28	87 875
Khaya Anthotheca	White Mahogany	0.49	801.44	435.16	111.99	87 875
Khaya Grandifoliola	Broad-leaved Mahogany	0.57	941.67	539.90	155.29	87 875
Khaya Ivorensis	African Mahogany	0.46	752.21	454.14	105.45	87 875
Lophira Alata	Ekki (Kaku)	1.03	1,944.08	927.82	175.04	126 540
Lovoa Trichilioides	African Walnut	0.50	803.39	471.71	87.70	87 875
Mansonia Altissima	Mansonia (Aprono)	0.57	1,182.09	575.75	138.56	105 450
Mitragyna Stipulosa	Abura	0.56	808.45	456.25	126.54	87 875
Nauclea Diderichii	Kusia (Opepe)	0.67	1,162.06	701.88	153.39	126 540
Nesogordonia Papaverifera	Danta	0.75	1,395.45	609.43	140.06	105 450
Piptadeniastrum Africanum	Dahoma	0.70	927.96	511.78	113.89	105 450
Sterculia Rhinopetala	Brown Sterculia (Wawabima)	0.69	1,195.45	658.05	111.99	105 450
Strombosia Glaucescens	Afina	1.02	1,488.25	724.09	170.83	126 540
Tarrietus Utilis	Nyankom	0.56	889.29	506.16	113.82	87 875
Tectona Grandis	Teak	0.56	939.91	475.93	112.48	–
Terminalia Ivorensis	Emeri (Idigbo)	0.51	808.45	468.90	108.26	87 875
Terminalia Superba	Afara (Ofram)	0.54	833.83	475.23	119.51	70 300
Tieghemelia Heckelii	Makore (Baku)	0.54	981.74	521.69	128.64	105 450
Triplochiton Sceroxylon	Wawa (Obeche)	0.35	527.60	276.98	69.32	70 300
Turraeanthus Africanus	Avodire	0.54	965.78	504.75	143.41	87 875

Source: From "Compilation of Data on the Properties of some Tropical Hardwoods Indigenous to West Africa" by Isaac K. A. Okoh, Technical Note No. 22, Forest Products Research Institute, U.S.T.

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