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TECHNICAL AND ECONOMIC COMPARISONS BETWEEN WOOD AND OTHER BUILDING MATERIALS COMMONLY USED IN TROPICAL REGIONS [1]

prepared by

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CONTENTS

INTRODUCTION

The purpose of this study is to analyze the present situation of the use of wood for building in the tropical countries, to examine its advantages and disadvantages in construction and to explore its use for future demand, especially for the construction of low-cost dwellings.

It refers mainly to tropical countries which are in the process of developing their wood natural resources for industrial purposes.

Forest products have generally constituted a readily available and low-cost building material in most tropical countries, and construction and auxiliary industries have been the principal consumers for industrial woods. A coordination between the producers of forest products and the consumers for housing projects would be of benefit to all concerned.

During the preparation of this paper, it was noted that a great amount of information in relation to wood is disseminated all over the world, especially in the more industrialized nations where a particular interest in the use of wood and wood-based products exists. The tropical nations are beginning to gather and publish basic information regarding their timber resources and production facilities for wood-based products. In this study an attempt has been made to resume the most important data affecting the use of wood as a building material in the tropical countries.

The study has been divided in five chapters considering different aspects on the use of wood as a building material. These aspects are closely interrelated for the scope of the work presented.

In Chapter I, an analysis of the building materials used in tropical countries is made, discriminating between the rural and the urban sector. This marked division is rather noticeable in tropical countries, where there are still large sectors of the population living in huts, dispersed all over large extensions of land. This part of the population has not received the impact of industrialization, and they are still using indigenous building materials, wood to a large extent.

The other sector of the population which lives in towns and cities which are considered as urban, range from having minimum basic public utilities, like water, sanitary drainage and electricity to complete and comfortable housing. Here is where the great change is being realized in the use of building materials through industrial development. Cement blocks, pre-fabricated concrete panels, pre-stressed structures, laminated wood trusses, wood based panels, etc. are increasingly being used.

The second chapter, Utilization of Wood. As a building material wood has been a traditional one throughout the ages and will continue to be so, if man does not destroy his natural resources in forests. Wood based products are being manufactured as a substitute for natural wood looking for its qualities of resistance, durability, flexibility and ruggedness and cost. This chapter analyses the drawbacks of wood and how to improve its use by protecting it with modern treatment methods. The use of new wood-based products and their basic characteristics are included as part of the information provided. The use of bamboo as a building material is also presented with recommendations on how to overcome its shortcomings.

The third chapter deals with the production facilities of wood in the tropical countries; how wood is being used as a raw material and selected for wood-based products. Emphasis is made on the need of increasing production facilities that are within the economical range of tropical countries. Examples of large industrial complexes for production facilities of wood-based products are also presented. Building boards and their characteristics, and the more industrialized production of bamboo based products on a scale which can be adopted by tropical countries are also considered.

In chapter [illegible] presented in relation to the use of locally produced and imported materials for building purposes. Giving examples by percentage and costs in various tropical countries, the process of developing the Building Materials Industry in the Tropics is also considered as well as estimates on wood demand for building purposes for low-cost dwellings. For example, by reducing the weight of the main structure of the building, savings can be obtained through easier handling and speeding the construction process. Steps that can be taken to substitute the use of imported materials like steel, metal sheets for roof covering, metal frames, glass, etc., introducing the appropriate use of wood as a substitute for the imported materials are also indicated.

In the last chapter, Future Uses of Wood in Building in Tropical Countries, due emphasis is given to the relation that exists between the financing factors of low-cost dwellings regarding the life span of the buildings. For instance, it has been verified that they have been stretched to such a proportion that designers and builders are obliged to use inorganic building materials, because they consider that these will outlast the financing period of the dwelling therefore limiting the use of materials like wood for that matter. Other factors which are also affecting the use of rough timber and sawn wood for dwellings in tropical countries are also considered.

Furthermore, considerations are given to standardization of sizes of trees, as well as the selection of adequate species recommended according to soil and climatic conditions. Likewise, the introduction of the metric system in the working sizes, marketing and designing purposes would increase theuse of wood and reduce its cost.

The planting and use of soft woods which develop in approximately ten years is also suggested, balsa wood for example can develop in approximately 3 years and can be used as core material for panels. The planting of bamboo in tropical countries where it can grow rapidly is also recommended, because it can replace the use of hardwoods originally used for the structures of the dwellings in rural and urban areas of tropical countries.

I. TRADITIONAL BUILDING MATERIALS USED IN THE TROPICS

1. General Considerations

There are great sectors of the population of Africa, Asia and Latin America that still derive their economy from agriculture and farming. The rural sector of the population lives dispersed and without basic public facilities (water, sanitary drainage or electricity) and makes use of indigenous materials for building. The urban sector of the population has absorbed in part the use of new materials and methods for building.

The purpose of this chapter is to identify the building materials used in the rural and urban sector; considering that economical and social conditions vary in these two sectors of tropical countries. In Africa and Asia the majority of the population is rural, in Latin America it is approximately 50 per cent rural and 50 per cent urban.

2. Building materials commonly used in rural areas

2.1. Adobe - It is a rectangular hand compressed block made of soil, mixed with grass or straw of approximately 40x40x10 cm.; it is found in the hot humid and hot dry tropical regions, and is used for walls which usually carry the weight of the roof.

2.2. Bahareque or daub construction - The main structure is made of wood, with bamboo or reed lateral reinforcement and filled with a mixture of clayish soil and grass. Plastering is usually done on the exterior and interior surfaces with a mixture of cow dung and clay finished with a lime white wash.

2.3. Burnt bricks - The production of burnt clay bricks for walls is mostly done as a family tradition in the tropical regions whereby a group of families engage in the production of bricks to build their own homes. This tradition has been predominant wherever clay soil is available; the bricks are used for walls, 2.3. (Cont'd) columns and floors.

2.4. Clay tiles - Produced the same way as the burnt bricks mentioned in (2.3) above, the type of roman tile predominates because it is easier to mould. The mixture of clay and sand is made thick and plastic and is stretched out about two centimetres in thickness, cut and placed over the wood mould to give it the desired curved shape. These tiles are used for roofs in the more traditional and permanent type of housing.

2.5. Wood - The farmer in the rural areas uses [illegible] for the roof and wall structures, fence parts, bridges, to make furniture, etc. He also makes cooking coal out of certain types of wood. In some regions the bark from the trees is used to make cloth, and from the tree he extracts even dyes and medicaments. He manufactures his weapons, even dishes and spoons; actually wood is part of his nature.

Not sawn wood is used as a basic structural material for columns, beams and purlins. Sometimes sawn wood is used as sheathing for walls, ceilings and floors.

It must be noted that in the hot-humid tropical regions the development and growth of trees, palms, grass and other vegetable fibers is rather exhuberant due to the richness of the soil and atmosphere moisture content.

2.6. Palm leaves - Used for roofs and walls, they can be classified in two main groups, since there is a large variety:

a) Those which deteriorate in a period of approximately two years, such as the coconut palm leaves whose fibers dry and crack in a short period, and

b) those which can be used for a period of from five

2.6. (cont'd) to ten years, such as wine palm leaves and guagara palm leaves which have stronger and flexible fibers. The following uses are typical:

Types of shoots:

Covering, walls and structures of white and black wild cane species. The white species is softer than the black ones which can last as long as ten years.

Thatching roofs:

Rice straw and other hard and durable grasses have been developed for roofing which can last ten years or more. Rice straw has a short period of life, but some grasses like the one called "Cortidera" in Panama will last from 5-10 years.

Walls:

They are made of mattes from hard palms, bamboo, half sawn logs and other woods and canes.

Floors:

For one storey houses (mostly used in the very humid areas of the tropical regions) floor mattes of hard palms, or rough sawn logs. Where mattes are made of black palm (chanta) they can outline the house.

2.7. Rocks - Basalt rocks are used for foundations in some areas, river round rock is used for walls, other types of rocks (with a variety of colors) are used also for walls, fences and floors. In some regions of Colombia, there is such an abundance of rock that much has been used for fences in the rural areas.

2.8. Blocks - Cement blocks are being introduced to the rural areas of tropical regions. They are used mostly for bearing walls and interior partitions.

2.9. **Galvanized iron sheets** - They are being utilized largely by the small home owner who has attained some economic prestige. This material is practically substituting the clay tile and palm leave roof in the tropical countries, bringing other problems like high temperature (in many cases 140°F) under such roofs without ceilings. Thermal insulation will have to be provided because otherwise a large population will be affected physiologically by the extreme heat transmitted by such type of roofs.

2.10. **Glass** - It is considered in many cases as a material of economic prestige, and the people who can afford it will place it in the outside walls of their houses to receive natural lighting during the daytime.

3. **Building Materials Commonly Used in Urban Areas**

3.1. **Burnt clay bricks** - They are manufactured in many cases with more precision in industrial plants. The cost is higher than that of the brick produced by traditional methods. Clay tiles for floors and walls are also produced and in some countries the production of more elaborate accessories like toilet bowls, wash bowls, ceramic tiles, etc. has been initiated.

3.2. **Cement blocks** - They are replacing clay bricks in urban areas mainly due to the difference in cost of production and labour for wall construction since generally the cement blocks are larger than the standard bricks. Most of the tropical countries count on natural resources for the production of cement and it is being used in different types of cement products to replace other materials in the building field.

3.3. **Roofing materials** - In tropical areas the roof is one of the most important elements in the total cost of one-storey structures, and a large majority of houses in villages, towns and cities of tropical regions are one storey.

3.3. Roofing materials (cont'd)

This means that most people are sheltered practically under an umbrella, to protect themselves from sun and rain. Walls are built for security, privacy and protection from strong winds.

One of the materials most widely used in tropical regions for roofing is galvanized iron sheets. Different lengths up to 40 feet can be obtained in local markets. Second in place are aluminum sheets. Wood is the predominant material used for the roof struectures. Its flexibility, strength and working facility still predominate over other materials. Clay roof [illegible] used in more expensive housing. Asbestos cement sheets are also being used in the standard size of ,60 x 1.80 x ,90 x 1.20 m. The use of canaletas of asbestos cement has been found to have wide acceptation, because it has lowered the cost of the roof by eliminating practically all the structural elements. The canaleta realizes a double function by acting as a structural member and a cover at the same time.

3.4. Stone and sand - Abundant rock and sand (from mines or seashores) are extracted from local depostis. Basalt rock is used for foundations and as a concrete aggregate when it is triturated and classified. A great variety of rocks in different colors and sizes are also obtained, some have to be elaborated, others can be used directly as they are found in the quarries. The use of rough and elaborated stones for walls and floors is considered for finishing or structural purposes of the more expensive type of buildings due to the cost of extraction and labour.

3.5. Aluminum accessories - In some countries window and door frames are being assembled using different sections. Aluminum window frames and glass louvers are increasing in demand.

3.6. Iron and steel products - Most tropical regions are not in a condition of establishing industrial plants for local consumption. Some exceptions can be noted like in the case of Paz del Rio in Colombia, where all the basic materials required for the production of iron and steel are within a radius of approximately 50 miles. The consumption of steel products in tropical countries is proportional to the increase in the production of concrete buildings, and also to the increase of steel buildings for fast developing industries. There is a general tendency of using prefabricated steel structures for small and large industrial buildings to be assembled at the site.

Steel bar sections are usually manufacture from scrap metal or imported ingots.

3.7. Wood and its derivatives - Wood is used mostly for structural members in ceilings and roofs in one storey buildings. In some countries of tropical regions, especially in the more humid areas, there is a large amount of existing wooden buildings, in some cases up to 50 per cent of the dwellings. Some local fire codes, however, exclude the use of wood for walls and floors in the urban areas, although they are permitted in the outskirts of the cities and in the villages of rural areas.

Rough lumber is also being used in large amounts for scaffolding in the construction of concrete buildings. A large amount of plywood is beingused for the manufacture of doors and built-in-furniture in buildings, as well as for wall finishings. The development of panels made of wood fibers mixed with cement paste has been used increasingly for exteriors and interior walls. The same material is also used for the manufacture of hollow blocks used to form concrete slabs. Panels produced from wood shavings or sawdust have proved to have excellent thermal and acoustical qualities.

4. Causes of Deterioration of Building Materials in the Tropical Regions

As noted by the data shown in tables 1 and 2 of Annex all building materials are exposed to different causes of deterioration. It is therefore advisable that the use and function of every building material be done according to its own characteristics under the action of the elements.

Table A

Characteristic Materials Used in Selected Countries[1/]

Central India and West Pakistan (arid climate)	
Mud dwellings	about 70%
Masonry, including brick, concrete blocks and stone	" 30%
Timber	negligible
	100%
East Pakistan and India ((Assam) humid climate)	
Bamboo dwellings with mud floors	about 60%
Mixed bamboo and timber (incl. all timber)	" 30%
Brick	" 10%
	100%
Burma (predominantly humid climate, heavily forested)	
Bamboo dwellings	about 50%
Timber-bamboo houses	" 35%
All-timber	" 14%
Brick, concrete and stone	" 1%
	100%

The above Table A shows that a majority of dwellings in tropical countries are still using largely indigenous building materials and methods to construct dwellings. This situation should be coupled with improved standards of living, so that the many of the existing dwellings can be remodelled, and new dwellings can be built for the increasing demand of the population by using materials and methods which would accelerate the actual tempo of building.

Organic materials and their development play a more important part than do those of inorganic origin in a majority of the countries under review. Afghanistan, West Pakistan and approximately half of the Indian sub-continent

1/ Bibliography No. ?.

are areas lacking in adequate forests resources. There is a shortage of indigenous timber products in Japan, but the effect of this is modified by the fact that industrial technology in that country is advanced and mass-produced manufactured products utilizing efficiently the resources available compensate the limited locally-grown products.

5. Minimum and Improved Dwellings in Tropical Countries

A minimum dwelling is considered as having a useful area of from 2[illegible] to 50 sq.m.

It includes covered floor space, water supply with one outlet per 8 dwelling units, sanitation with individual waste disposal facilities or water-borne systems.

The Housing Institute of Panama is building a minimum unit with 24 sq.m. concrete floor, pre-stressed concrete columns, steel strusses and a galvanized steel roof.

An improved dwelling would have from 50 to80 sq.m. including one water outlet per unit, water borne waste disposal facilities and electricity.

Table [illegible] below shows the relative cost of these two types of dwellings as built in Africa, Asia and Latin America.

TABLE B [2]

	% of cost	Africa	Asia	L. America
A. Minimum				
Direct labour	30	150	130	240
Domestic mat.	40	200	171	320
Imported	10	50	43	80
Return or capital	10	50	43	80
Administration and overhead	10	50	43	80
	100	500	430	800
B. Improved				
Direct labour	35	270	235	430
Domestic mat.	35	270	235	430
Imported	15	115	100	193
Return or capital	10	77	67	123
Administration and overhead	5	38	33	64
	100	770	670	1230

2/ Bibliography 5, p. 11.

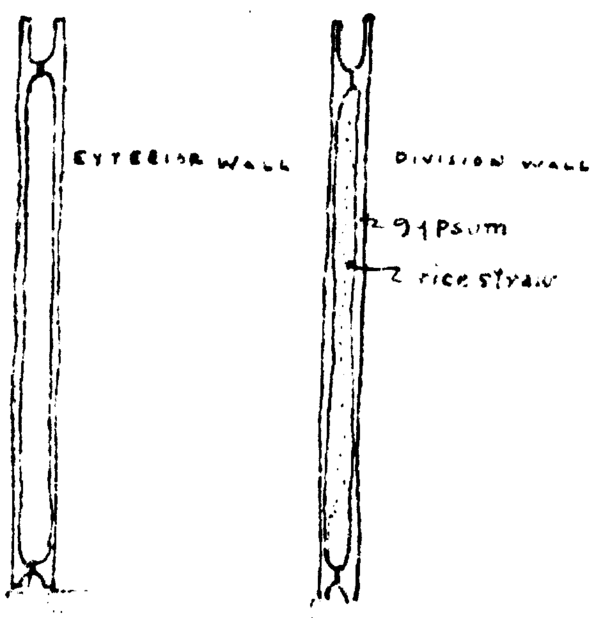
6. **Comparison of low cost housing construction costs utilizing pre-fabricated components in Chile.**[2]

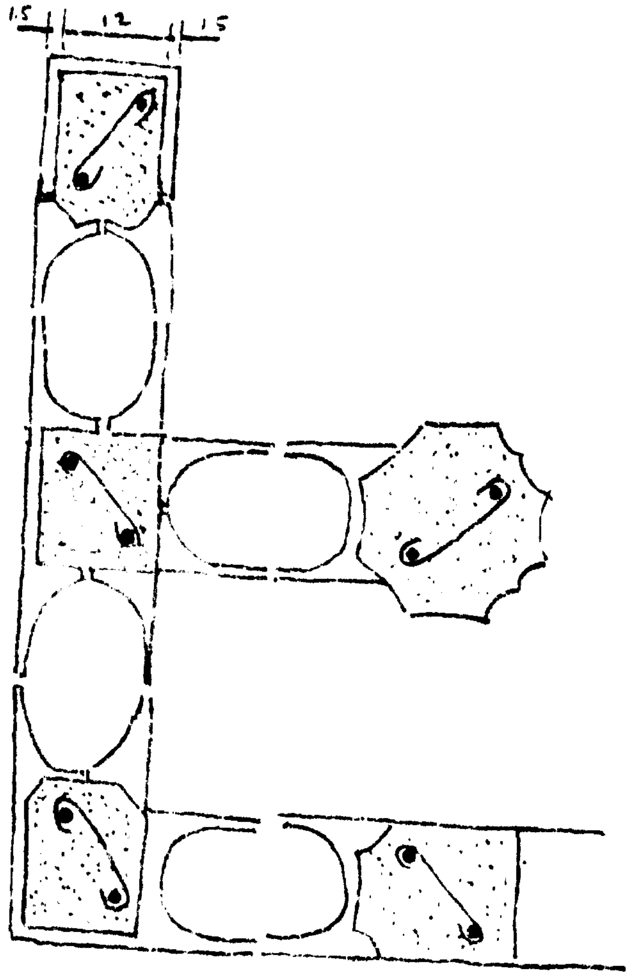
Six different methods of construction and combination of materials were used to evaluate the results of this experiment. The final costs are given in <u>Escudos</u>, the Chilean currency, but for the practical purpose of this work the differences in costs per m^2 is indicated.

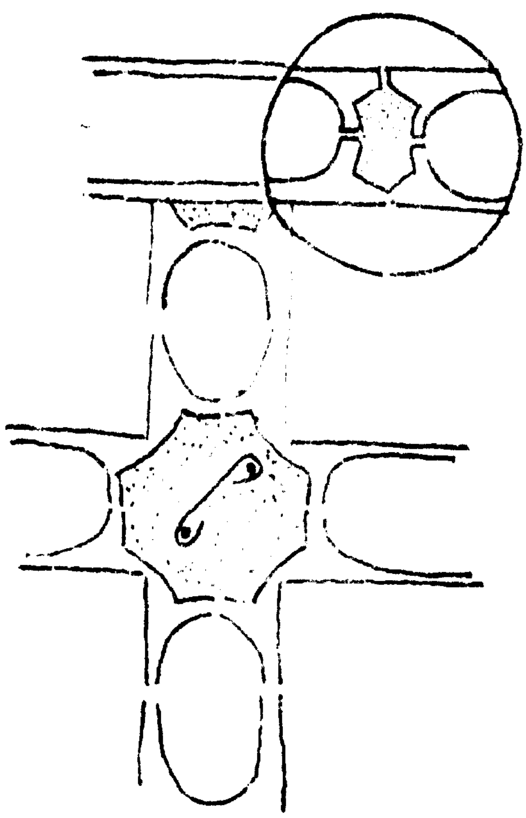
The materials and building methods were applied to a unique design of a selected house type so that a comparison could be made in relation to the cost per m^2.

At the end of the experiment it was noted that cases 3, 4 and 5, which use an all-wood structure turned out to be the lowest in cost.

2/ Construcción y Vivienda, Chile.





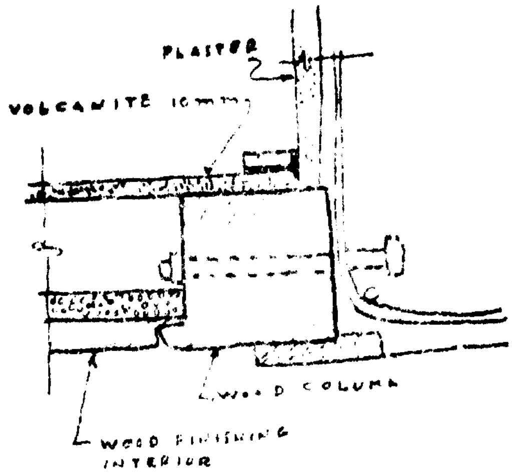


1. BETONIT SYSTEM

- Two vibrated concrete panels placed face to face.
- Panel sizes: 0.[illegible]0 x 2.30 x .015 m.
- Weight of one face: 70 kgs.
- Interior partitions: .0[illegible] m. of gypsum and rice straw insulation.
- House area: [illegible] sq. m.
- Cost per sq. meter = E 2[illegible].6.

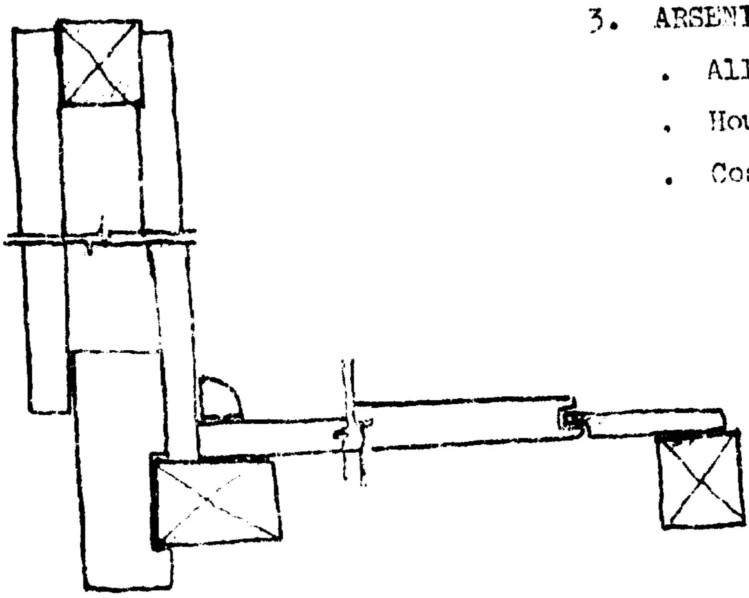
2. CINDEC SYSTEM

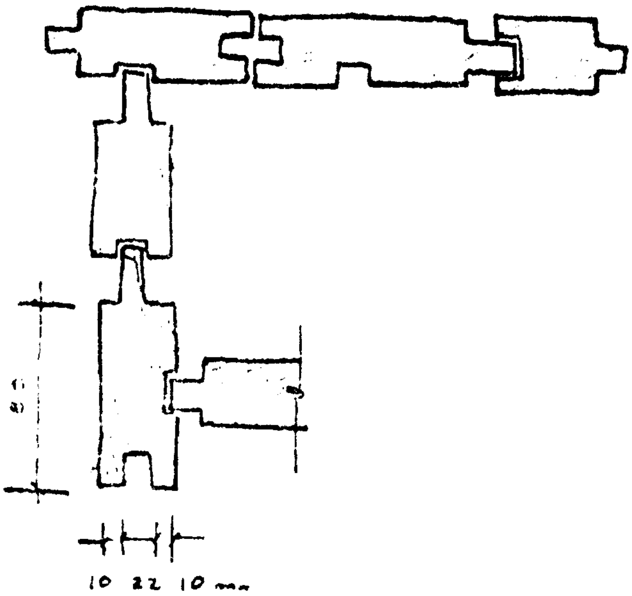
- Volcanite and wood boards in walls.
- House area: 38 sq. m.
- Cost per sq. meter: E 269.15.



3. ARSENIO ALCALDE SYSTEM

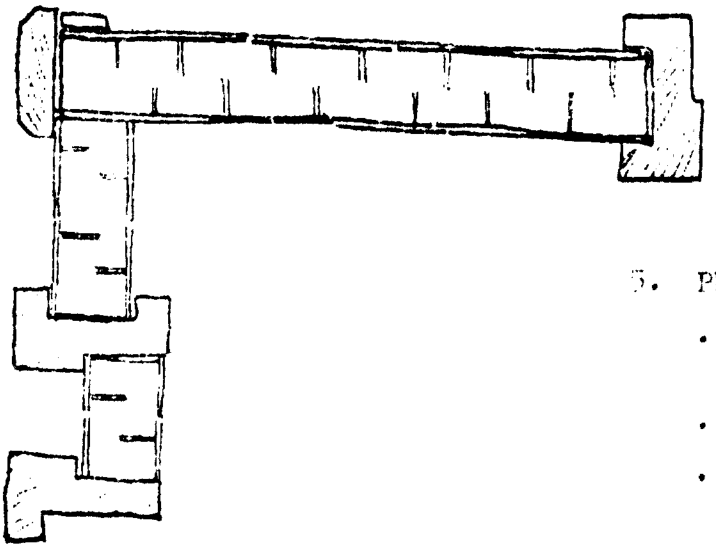
- All wood house.
- House Area: 38 sq.m.
- Cost per sq. meter: E 213.35.





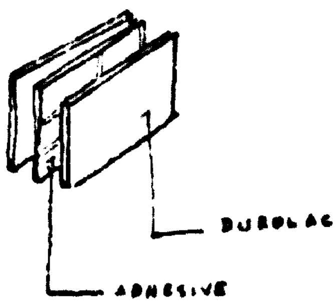
4. PINE HOME SYSTEM

- All wood house
- House area: 40 sq.m.
- Cost per sq. meter: E 2[illegible]8.20



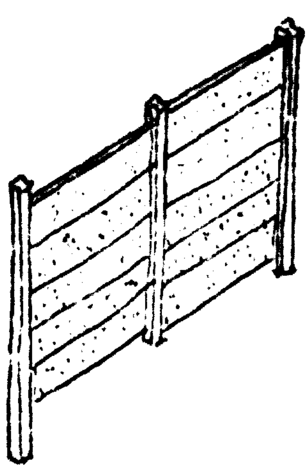
5. PRE[illegible]SONAT SYSTEM

- All wood house, using wooden panels and structure.
- House area: 38 sq.m.
- Cost per sq. meter: E 258.16



6. SIMPLEX SYSTEM

- Standard wood frame.
- .01 m thick particle board sheets glued with acetate of polivynl
- Cost per sq. meter: P 25[illegible].60.



7. DOBAL SYSTEM

- Reinforced concrete panels and stricture.
- Cost per sq. meter: P 255.50.

7. Example of typical dwelling using wood in Honduras.

7.1. Distribution of local and imported materials in a typical dwelling in Honduras built in 1963.[1]

Total construction cost	L. 2,691 = 100%
Building materials	L. 1,806 = 67%
Labour	L. 886 = 33%

Distribution of domestic materials	L	%
Lumber and wood products	552.96	41.70
Common clay burnt brick	197.80	14.91
Clay burnt roofing tiles	172.64	13.02
Portland cement	154.85	11.68
Cement flooring tiles	132.48	10.00
Pine	26.34	1.99
Stone for foundation	25.70	1.91
Gravel, stones	22.31	1.68
Misc. materials	49.87	3.74
	1,326.30	100.00

Imported materials	L	%
Porcelain and sanitary fixtures	97.30	20.34
Electric installation mat.	73.04	15.22
Plate Glass & Putty	56.46	11.77
Asphalt sheets for roofing	47.17	9.83
Plumbing mat	44.77	9.33
Reenforcing steel bars and wires	44.31	9.24
Steel windows	39.31	8.19
Painting mat	33.44	6.97
Hardware	15.36	3.20
Misc. mat.	28.30	5.91
	479.76	100.00

7.2 Distribution of costs of construction of two typical dwelling in Honduras in 1968 utilizing wood intensively.[2]

Structure	One storey: 48 sq.m.		Two storeys: 56 sq. m.	
	Materials	Labour	Materials	Labour
Foundations	25.00	40.00	15.00	37.50
Floors	56.50	40.00	82.00	65.00
Division walls and Panels	326.50	260.00	356.70	300.00
Roof	186.50	15.00	100.65	10.00

1/ Bibliography No. [illegible].

2/ Bibliography No. 34.

Installations	One storey: 48 sq. m. Materials	One storey: 48 sq. m. Labour	Two storeys: 56 sq.m Materials	Two storeys: 56 sq.m Labour
Sanitary	157.50	50.00	157.50	50.00
Electrical	18.00	5.50	5.50	23.50
Carpentry and finishing	22.00	5.00	8.00	2.50
Miscellaneous expenses	100.00		100.00	
TOTAL	1,307.50		1,333.35	

II. Utilization of Wood and Bamboo

Many reasons have given wood a primary construction use through the years in tropical regions, besides its being readily at hand; some advantages over the other building materials have been its stiffness as well as its insulating quality, its strength, workability and ruggedness.

In this chapter the drawbacks and present utilization of wood in tropical countries is shown.

1. Drawbacks of Wood as a Building Material

Like any other material wood is vulnerable to the elements and must be protected accordingly from a group of distinctive agents. The principal causes of wood deterioration and their order of importance are: decay, fire, insects and borers, mechanical wear and breakage, weathering and chemical decomposition.

1.1 Where wood is used in houses under adverse conditions, it may rot for one of four reasons: – (a) The decay fungus becomes established in the wood either in the lumber yard or on the building site, generally because of improper handling;

(b) The wood is located in contact with moist soil;

(c) Water-conducting fungi draw moisture from the soil up to the wood. Such fungi have been known to cause very extensive damage, and

(d) Inadequate ventilation and poor construction practice produce localized moisture conditions favourable for decay fungi.

1.2 Fire: – In the use of wood, or any other combustible, material for house construction, fire hazards are rightly a matter of prime consideration to the builder. Adherence to certain principles of good design is fundamental in reducing these hazards to a minimum and building a safe structure. While fire hazards are not great in the average dwelling, the matter of minimizing such hazards warrants constant attention on the part of the designer and builder.

1.3 **Insects:** Of the various insects that attack wood, two kinds are chiefly responsible for the damage that occurs in dry lumber installed in houses: powderpost beetles and termites.

1.4 **Mechanical wear and breakage:** Wood is a strong material if used properly. Constant hammering with sharp objects or sudden blows in a massive way may deteriorate the resistance of wood.

1.5 **Weathering:** Boards exposed without appropriate protective coverings rapidly become weathered. This may involve change in color, roughening and cracking of the surface.

2. Ways to improve the application of wood in construction and its costs: The developed countries have developed the know how and the technology to obtain the maximum benefits from the purchase of hardwoods from the emerging countries where in turn the material is received as an elaborated product. By this procedure the emerging countries produce a raw material at a low price and receive and elaborated products at a high cost for their standard of living. On the other hand it has been noted that in certain cases some emerging countries which have the necessary demand within their own boundaries for the establishment of an industrial complex have acquired equipment like tractors, trucks, presses, ovens, lithes, rollers, etc. at a price that has caused the final product to cost the same or higher than the imported product. Through this experience and for practical needs and the benefit of the economies of these nations, the lowest investments should be [illegible] in the purchase of sophisticated machinery.

At the same time, architects, engineers and builders are after economy, efficiency, and availability of materials within local markets. It is then necessary to study local market conditions so that local building industries are not confronted with competition of similar imported building materials.

2.1 Aspects to be considered to increase the use of wood for building in tropical countries.

2.1.1 It has been noted that tropical countries do not plan the use of their natural resources. Ecologists say that if man continues to destroy nature at the present rhythm, he will end by destroying himself. It is advisable that in the process of forest exploitation and inventory of the types and volumes of woods available should be done at first, and next the physical qualities of the [illegible] be determined. After exploitation has been initiated, a [illegible] of these raw material must follow having in mind a selection of species that are economically appropriate for the specific region for planting and nursing the seedlings in the areas which will be developed later.

2.1.2 Felling, transportation and sawing of lumber.

Usually, from the moment the tree is cut down most of its natural [illegible] are damaged: the tree is frequently cut by axe and fractured during the fall, next it is rolled down hills or pulled where it can be roughly sawn by hand or taken by truck to a saw mill. It may also be floated down creeks to rivers. When the finished product reaches the consumer, a great amount of waste has been accumulated and the price per board foot at the saw mill has been more than duplicated. An alternative solution worthy of studying is the case when a country with trunk roads and saw mills placed near the raw material supply could find it cheaper to transport the elaborated product to the market using all the waste particles at the mill for production of wood-based materials. Some of these products could be particle and chip boards, embedded fiber boards, etc.

2.2 Aspects to be considered to improve the use of wood in construction.

Through good design and construction, wood should be used rationally in all the aspects of the building. The different types of wood selected should be applied according to the function they are expected to fulfill. Standard sizes and quality control of wood should also provide the building industry with a better product.

This is more important in the tropics where wood has to be protected from the ground, the sun and the rain. Buildings should be protected from three types of humidity: from the ground; vapor moisture proceeding from the interior; and exterior humidity from wind and rain. Therefore, local building codes should include specific provisions to utilize wood that fulfills given requirements such as fire retardance, moisture content and decay.

3. Methods of Preservative Treatment.

The amount of protection given by a good wood preservative depends largely upon the absorption and penetration obtained in the wood. Some methods of applying preservatives, when skilfully handled, assure satisfactory absorption and good penetration of the protective chemicals, while with others such results cannot be obtained. The better treated products are becoming increasingly available. Simple, inexpensive, and often ineffective treatments are being widely used but precautions should be taken when lumber is treated with superficial applications.

3.1 Low-cost methods currently used in tropical countries are the use of creosote as a covering surface (painting) and by submerging the wood in pentachlorophenol for at least three minutes.

3.2 Pressure impregnation procedures: they usually have the advantage over non-pressure methods in that they make it possible to get deeper and more uniform penetration and higher absorption of the preservative and thus they provide greater wood protection.

3.3 Retardant pressure impregnated lumber: it will be influenced by different factors, but in sizes suitable for construction the cost is approximately double the cost of untreated lumber.

3.4 Seasoning of wood is also necessary to obtain a better result from wood. Seasoning can be done naturally or it can be done in a kiln to reduce the moisture content in the wood.

These techniques are widely known and highly advanced and are not being discussed in detail in this paper.

4. **Bamboo**

The rapid growth of bamboo in the humid tropical regions, the flexibility, lightweight, bearing resistance and the many uses that can be given to the material have placed it among the poor Man's resources in Latin America and poor and rich man's resources in Asia and the Far East, where it is used more wisely and artistically. In the tropical countries bamboo has been used in Colombia and Ecuador especially as a building material in very low-cost housing. In Colombia it is used for many purposes, including water throughs in the rural areas. It is noticeable that bamboo has not been given a more prominent utilization in the rural development of tropical countries; its roots are good to protect from erosion the soil close to river banks, it can also grow into vast forests very rapidly, which in a renovating process could maintain a constant supply of basic material to the local markets, as a possible substitute of the harder aglomerates and particle products being used in the panel industry.

4.1 Some uses of bamboo in building.[6]

4.1.1 Foundation

Examples of the use of bamboo posts instead of a conventional foundation for low-cost houses may be found in many tropical countries. However, unless they are treated with some effective fungicidal preservative, such posts are not expected to last more than two or three years on the average, or five years at most under unusually favourable conditions. Until reliable and economical treatments have been developed for preserving bamboo that is frequently wetted or is constantly in contact with damp earth, it is considered better to use some material that is more durable than untreated bamboo for foundations - concrete, for example, or stone, brick, or some durable hard-wood.

When used as supporting posts in low-cost houses, culms should have a fairly large diameter with thick walls and nodes close together to give maximum resistance to bending. Where large

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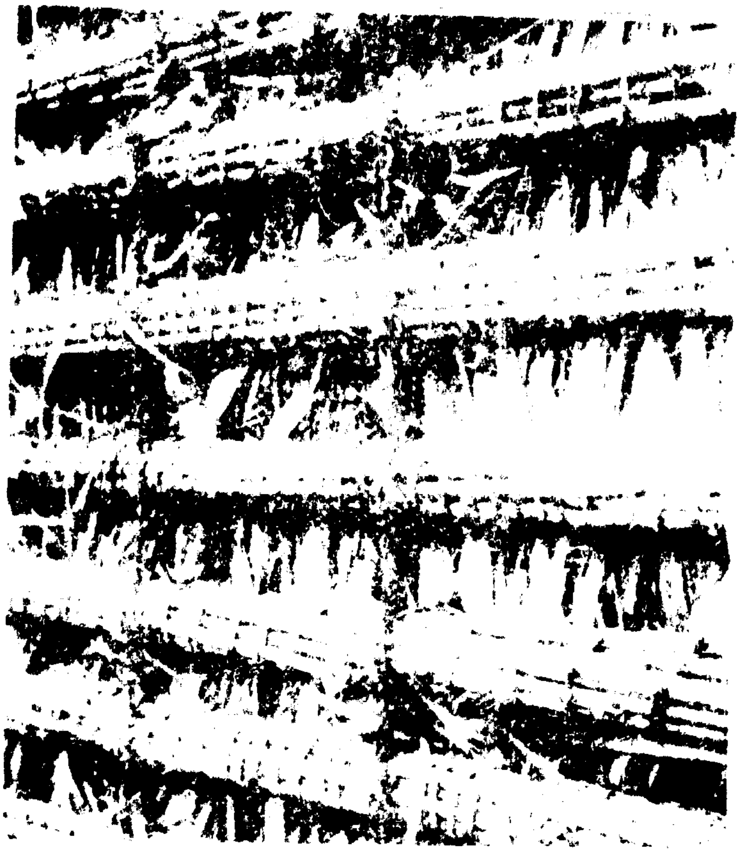
6/ Bibliography No. 34 ([illegible]).

bamboos are not available, smaller bamboos with suitable structural characteristics may be bound together to make composite pillars. (Fig. [illegible] shows the use of bundled bamboo as horizontal members).



5.1.2 Frames

Next to the foundation and the roof covering, the basic frameis the part of a house most often made partly or wholly of materials other than bamboo. In many regions, those who can afford the difference in cost prefer to use some durable hardwood for frames. They do so partly because hardwoods make stiffer joints and more rigid construction than bamboo, partly because a greater prestige is generally attached to hardwoods, and partly because most hardwoods are naturally much more resistant to rot fungi and wood-eating insects than untreated bamboo.

There are certain circumstances, however, under which the superior resiliency of a bamboo frame confers important advantages over a rigid construction. In regions where sharp earth tremors or quakes occur frequently, a bamboo-framed house may survive and remain serviceable longer than any other type.

The individual structural elements that compose the frame of a conventional all-bamboo house correspond closely to those found in an all-timber frame: corner posts, girders or plates, joists, studs, struts or braces, tie beams, king posts, purlins, ridgepoles, rafters, sheating, and so forth. The use of bamboo imposes certain limitations, however. Mortice and tenon joints cannot be used in framing bamboo: any cut, such as notch or mortice, drastically reduces the ultimate strength of a bamboo culm. With the exception of those of certain species of Guadua (notably G. angustifolia) and of Chusquea, the culms of most bamboos will not take nails without splitting. For this reason, the impinging elements are generally lashed to each other at their intersections. In the Far East the wishes used for lashings are commonly split from bamboo, more rarely from rattan. Where the available bamboos yield brittle withes, tough vines or the bark of certain trees and shrubs may be used for lashings. In some areas, soft iron wire, preferably galvanized, is used.

4.1.3 Floors

Serviceable and attractive raised floors may be made entirely of bamboo, given suitable species and a sound structural design. The principal features in conventional design are the supporting beams (part of the basic frame) and the floor covering.

The floor covering may be made of small whole culms, strips, or bamboo boards made by opening and flattening out whole culms. When the floor consists of bamboo boards, it is generally fastened down by the use of thin strips of bamboo secured to the supporting members by thongs, wire lashings, or small nails, according to local preference and the materials available.

4.1.4 Walls, Partitions, Ceilings

The construction of bamboo walls is subject to infinite variation, depending on the strength required (for resistance to natural forces such as hurricanes and earthquakes), the protection desired from rain and ordinary winds and the need for light and ventilation. Either whole culms or longitudinal halves may be used, and they may be applied in either horizontal or vertical array. They function more effectively, however, when they are vertical, and in addition, they are more durable; for any damage quickly [illegible].

A form of wall construction widely favoured in Latin America is made by nailing or lashing bamboo strips or slender culms, horizontally and at close intervals, to both sides of hardwood or, more rarely, bamboo posts. The space between the strips is filled with mud or with mud and stones. During this operation, the bamboo strips are more or less completely covered with mud but in time they become exposed by weathering. This form of construction is relatively massive, though less so than walls made of conventional stone, rammed earth or adobe bricks.

Partitions are commonly of the lightest construction, such as a thin matting supported by a light framework of bamboo poles. In the Philippine Islands, and generally in the Far East, where suitable bamboos are plentiful, the partitions and even the outer walls of houses are generally covered with matting woven from thin strips split from the culms.

The ceiling may be covered with a closely placed series of small unsplit sulms, or by a latticework composed of lathlike strips split from larger culms. Bamboo matting is favoured as a ceiling finish in many areas. In some places the ceiling is omitted altogether, permitting the freer circulation of air welcome in hot, humid seasons.

4.1.5 Doors and Windows

For practical reasons, window and outside door openings are generally kept to a minimum. They may be framed with wood or bamboo. The doors themselves may be wood, or they may be woven bamboo matting stretched on a bamboo frame, a panel of bamboo boards set in a hardwood frame, or a sturdy gatelike barrier constructed of bamboo bars. Doors are side-hinged, and fastenings vary from the traditional latch-string to lock-and-chain.

If window openings are provided, they may be framed with bamboo or wood. Most windows are left unglazed and unscreened. Closure may be provided in the form of a bamboo or wooden frame covered with bamboo matting or palm-leaf thatch. Windows are usually hinged at the top; when open - as they are during most of the daylight hours - they serve to exclude the sun's direct rays or light rainfall.

4.1.6 Roof

Because of their high strength-weight ratio, bamboos are used to excellent advantage for structural elements in roof construction.

In designing the roof, account must be taken of the nature and weight of the roof covering to be used, whether it be grass or palmleaf thatch, halved bamboo culms, bamboo shingles, corrugated sheetmetal, asbestos cement or tile. The dimensions, orientation, and spacing of the individual structural units that support the roof covering are varied to conform to the requirements of the case.

4.1.7 Pipes and Troughs

The culms of certain bamboos, with diaphragms removed, serve admirably for the fabrication of pipes and troughs.

Longitudinal halves of bamboo culms make very satisfactory eave troughs. Where rainfall is light and water must be conserved, they are used to collect rainwater from the roof and send it into a barrel or cistern for storage. Where rainfall is heavy, they are used to carry the water from the roof to a distant point, in order to avoid excessive dampness around the house.

Under certain circumstances wash water from the kitchen may be disposed of through bamboo pipes or troughs. For this purpose a sloping trough is more practical than a pipe since it is more easily prepared and, if clogged, may be cleared with greater facility.

Longitudinal halves of bamboo culms with the diaphragms removed make suitable conduits for bringing water for domestic use from its source to the house by gravity. In Japan, closed-pipe water systems are constructed of bamboo but it is very difficult to make the joints leakproof.

To be suited for the uses just described, the bamboo culms should have a diameter large enough to give the required carrying capacity, and the walls should be thick enough to prevent collapse under use.

III. Production Facilities for Wood Based Building Materials

In 1960, 28 billions board feet of hard wood were sold in the world market. Besides the great industry of sawmills, the plywood industry is rapidly expanding to the degree that it has duplicated its production in 7 years, hardwoods represented approximately 40 per cent of the total production in 1960.

Hardwood grows principally in tropical zones. About ninety-eight per cent of the forests growing in Latin America is of hardwood type and is not being exploited at present. Europe, being the major importer of woods in the world, imported in 1960 3.[illegible] billions of board feet of hardwood and logs. About 85 per cent of that amount was extracted from tropical countries.

1. Extraction of wood raw material

The extraction of timber in tropical countries follows an arduous and long procedure as is explained as follows:

Firstly, the extractor has to select the wood by sections of forest, then he has to comply with government laws. In some cases, a tax must be paid either for each tree that is cut or by hectare of forest to be exploited.

Secondly, procedure used for felling of trees is usually done by axe or gasoline driven saw. Most of the time the labourer is careless while felling, thereby causing heavy damages to adjacent trees. Felling debarkin and lopping is done usually by the same people who do the felling. A group of two persons produce about 70 to 80 cubic feet of timber per day in log form when working by axe.[1/]

The transportation of timber is also difficult in most of the tropical countries due to the lack of roads. In some cases, trees are pulled by tractors to the nearest roads, and then transferred by trucks to the sawmills; in other cases, the logs are thrown down the hills to creeks and rivers to be floated down to the sawmills. However, measures are being taken to improve those conditions as in Gabon where a loan of U.S.$ 112,000,000 for the building of roads in a plywood [illegible].

1/ Bibliography No. 4.

2. Facts about a typical timber producing country: Honduras

Honduras has about 5 million hectares or about 44 per cent of all the national territory is covered with tropical forests of which hardwoods cover about 2.6 million hectares, pine covers [illegible] million hectares and non-resinous hardwoods about [illegible] million of hectares. However, about [illegible] per cent of the wood cut does not reach the mills [illegible] is due to lack of adequate roads and 57 per cent of the final cost of the rough lumber (tree trunks) is devoted to opening of roads and transportation.

A great majority of the sawmills are characterized by their low productivity and high percentage of loss of material due to inadequate methods of operation and lack of efficient machinery.

During the year 1968, Honduras consumed US$ [illegible].417,500 from the wood industry alone.3/ There has been a rapid increase in the amount of wood being exported during the period 1945-1965 (from US$ 425,000 in 1945 to US$ 7,[illegible],500 in 1965) mainly soft woods (pine) to its neighboring countries in the region.

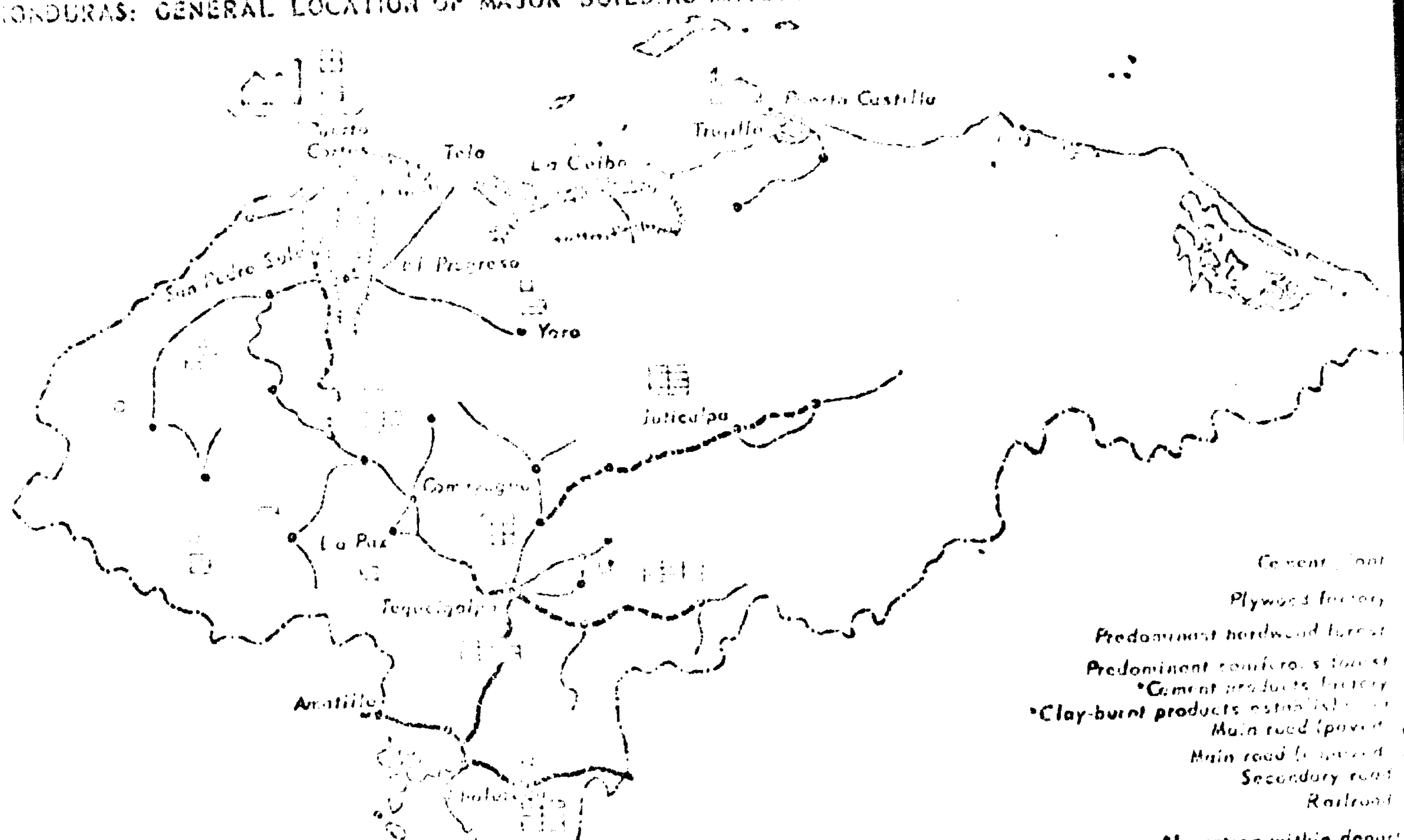
Nevertheless, more than 50 per cent of the houses in the country have adobe walls or bahareque and clay tile roofs with a timber structure. Although Honduras has large reserves of forests, wood has not been used more intensively due to a lack of normalized products suitably treated for their conservation. The use of industrially processed wood is limited to the production of doors, windows, and roof components which respond to a fluctuating demand. Furthermore, a lack of adequate technology and research in the building field has created a gap between the existence of resources and their application in the construction industry. This situation has restricted a major development of the rational utilization of wood.

3/ Bibliography No. 23.

The map below illustrates the existence of hardwood and softwoods forests in Honduras and the location of main building materials industries.

Figure 2.

HONDURAS: GENERAL LOCATION OF MAJOR BUILDING MATERIALS INDUSTRIES AND TIMBER RESOURCES, 19



Source: Housing data collection, Dept. of Social Affairs, Pan American Union.

Factors affecting the strength of wood

Perhaps the factor most readily recognized is that of defects in the material itself, such as knots, shakes, and cross grain. The strength of clear wood free from defects is also affected, however, by such factors as moisture content, density, and rate of growth. In addition, while it is popularly believed that certain other factors have an influence on strength, reliable data have indicated many of these beliefs to be false. The influence of certain of these factors will be discussed briefly in this section.

3.1 Effect of Density on Strength

The density or specific gravity of a piece of wood is an excellent index of the amount of wood substance contained in the piece, and hence of the strength of the piece. In general, a species of high density is higher in most strength properties than a species of lower density. Differences in the structural arrangement of the fibers or in the amount of resins, gums, or other extractives (which add to the weight but do not contribute so much to the strength as would a like amount of wood substance) may cause two species of the same average specific gravity to exhibit different strength characteristics. Likewise, some species of wood are equal in some respects to others of higher density. Departure of a species from the general relationship often indicates some exceptional characteristic which makes this species particularly desirable for certain use requirements.

Density affords a still better index of strength within a species than between species. The heaviest pieces of any species are generally 2 to 3 times as high in density as the lightest, and are correspondingly stronger. This characteristic is recognized in the stress grades by allowing higher working stresses for dense material of certain softwood species.2/

3.2 Strength of Air-dried and Kiln-dried Woods

Claims have been made that air-dried wood is stronger than kiln-dried wood and the reverse. Comparative tests have shown, however, that good air drying and good kiln drying have the same effect on strength. It is important, however, to note that severe kiln conditions may

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2/ Bibliography No. 15.

injure the strength of a piece of wood without producing any visible difference in appearance. Good kiln drying requires the proper application of kiln conditions appropriate to the species, grade, and thickness being dried.

The intelligent selection of species for various uses in prefabricated houses and the proper design of load-carrying members, whether trusses, stressed panels, or sandwiches, requires information on the strength properties of the various wood species. The strength properties to be determined should include bending strength and stiffness, or strength and stiffness as a beam; impact strength, or ability to absorb shocks or sudden blows; compressive strength parallel to grain, or strength as a post; compressive strength perpendicular to grain, or ability to resist loads on the side grain, as at the end of a beam or joist; shearing strength; hardness, or resistance to indentation; cleavage, or resistance to splitting; and tensile strength perpendicular to grain.[10]

4. Types of Lumber

Softwood logs are cut into several types of lumber. Dimension lumber, common boards, finish lumber and pattern lumber are ordinarily used in house construction.

Dimension lumber is 2 or more inches thick.* It must be strong, stiff and uniform in size since it is used for framing -- for joists, rafters, studs. In grading, this type of lumber is classified on the basis of strength as either common dimension lumber or structural dimension lumber. The latter is always four or more inches wide.

Common boards (or merely "boards") are less than 2 inches thick. They have square edges and are planed on one or more sides and edges. Common boards are for general use.

Finish lumber is lumber of select quality. The lowest grades include pieces whose defects normally can be hidden with a coat of paint.

Pattern lumber is special-purpose lumber machined from common boards or finish lumber.

5. Use of wood as a raw material

The wood-based panel industries still account only for about 6 per cent of the world's consumption of industrial wood. The growth of these panel

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* When lumber is 5 inches or more in thickness and width, it is called "timber".

10/ [illegible]

products has markedly improved the efficiency of the utilization of wood as a raw material. One of the basic ideas of board production is the elimination of defects of the raw material through disintegration of small-sized fibres or particles so that the end products become uniform in texture. The industries will tend to utilize lower grade raw materials wherever the price advantage over better grades is of sufficient magnitude.

Wood is widely used for the production of plywood, fibreboard, particle board, wood-wool board. Plywood is the most important of all the wood-based panels. It has many desirable properties and a great increase in consumption. A fibreboard is a sheet of material made from fibres of wood or other ligno-cellulosic material and manufactured by an interfelting of the fibres followed by compacting between rolls or in a platen press. A particle board is a panel manufactured from particles of wood or other lignocellulosic material bonded by the use of an organic binder and one or more agents such as heat pressure, moisture, catalyst, etc . For the manufacture of fibreboard and particle board and of nearly any dimension from a large number of species is being used including silvicultural thinnings and residues from logging operations as well as from sawmilling and other forms of conversion.

The manufacture of wood-wool board is comparatively simple and can be carried out without elaborate equipment. Where large outputs are desired, the process can be mechanized to a considerable extent and heat curing of the binder can be used to speed up production. Wood-wool is made by shredding suitable blocks of wood in a simple machine.

Chemically treated wood fibre is bound with Portland cement and precision-moulded into slabs which are non-inflammable, termite-proof, possess high thermal and sound insulation, and provide a good key for painting and plaster work. In warm and humid regions, apart from its fire resistance and sound and thermal insulation properties, its major advantage lies in its resistance to termites, and vermin. Its immunity to termites has been established by results in Portuguese West Africa. Slabs with soft-wood inserts were laid near a termite colony for a period of six months. After this time, the slabs were unaffected, while the soft-wood inserts were almost completely consumed.

6. **Building Boards, their characteristics and uses in buildings**

Group 1 - Fibre Building Boards, Including Chipboards.

Group 2 - Asbestos Boards

Group 3 - Plaster Boards, Woodwool Slabs and Strawboards

Group 4 - Laminated Plastic Boards

Group 5 - Decorative [illegible] Boards

Group 6 - Veneered Boards

Group 7 - [illegible] Accessories

Building boards are being introduced into the building field according to the new developments in their manufacture. The industrialized countries are using them for ceilings, walls, floors, furniture, etc. In the tropical countries, they have not been used in relation to their quality because most of the countries have to import them, therefore, they prefer to use local materials and methods for building. The cost of these imported materials vary from $U.S. 0.10 per square foot (hardboard 1/4") to $U.S. 0.50 per square foot (laminated plastic board 1/32").

[illegible], we can note the large variety of boards which are [illegible] in Group 1 (Fibre building boards, including chipboards). Some of these boards can be used for the making of furniture, for concrete lining form, for exterior finish, there is an embossed surface board, sound absorbing etc. Group 3 indicates the uses of plaster boards, woodwool slabs and strawboards. The boards indicated in group 3 are the ones most adapted to the practical use and elaboration that can be realized in tropical countries. Most of these boards use as a basic material fibres, straws, etc., which grow rapidly in the tropics. These fibers are compressed and bonded with cement to produce panels or blocks which can be used for walls, ceilings, slabs, etc. Groups 4, 5, 6, and 7 indicate boards which are more sophisticated for finishing and decoration purposes.

7. **Factors which limit the expansion of wood-based products industries in tropical countries**

The following basic obstacles are considered to have prevented the expansion of production and consumption of wood based building materials in tropical countries

They can be eliminated with the technical information and production facilities of today:

(a) Inaccessibility of timber resources; (b) Lack of processing plants; (c) Risk of fire high insurance costs; (d) Risk of other wood-destroying agents (especially termites); (e) Legislation restricting the use of wood in building; (f) Lack of quality control for wooden building material; (g) Lack of technical skill; and (h) Lack of promotional activities.

They can gradually be eliminated through the utilization of adequate production technology and the rational utilization of the finished products.

Plants for processing and elaborating wood products should be accommodated to the market requirements. If products of good quality at a competitive cost can be made available, the building industry would absorb their output and cases of design limitations, building code requirements and insurance limitations can be overcome. It would be advisable that in the development of the wood industries in tropical countries the industrial interests should also undertake the overall process of keeping up with the required raw material, like devising reforestation schemes, selection of species to be planted and assuring the quality of the finished product.

IV. Wood as an Import Substitution Measure for other Building Materials

1. World extraction of forest resources and their utilization

The world extracted from its forests during the year 1960 the amount of 1,731,000,000 m^3 of wood. This quantity originated from approximately 100 countries, including [illegible]75 species. It is estimated that such an amount of wood would be sufficient to stretch around the world on the equatorial line 42 times 1 meter wide and 1 meter thick.[11]

World Extraction in 1960

Millions m^3

Europe	310.7	
USSR	369.0	
North America	407.8	
Central America	35.6	35.6
Africa	155.0	155.0
South Africa	130.2	130.2
Asia	301.2	301.2
Pacific Area	22.0	22.0
	1,731.6 = 100%	644.0 = 37%

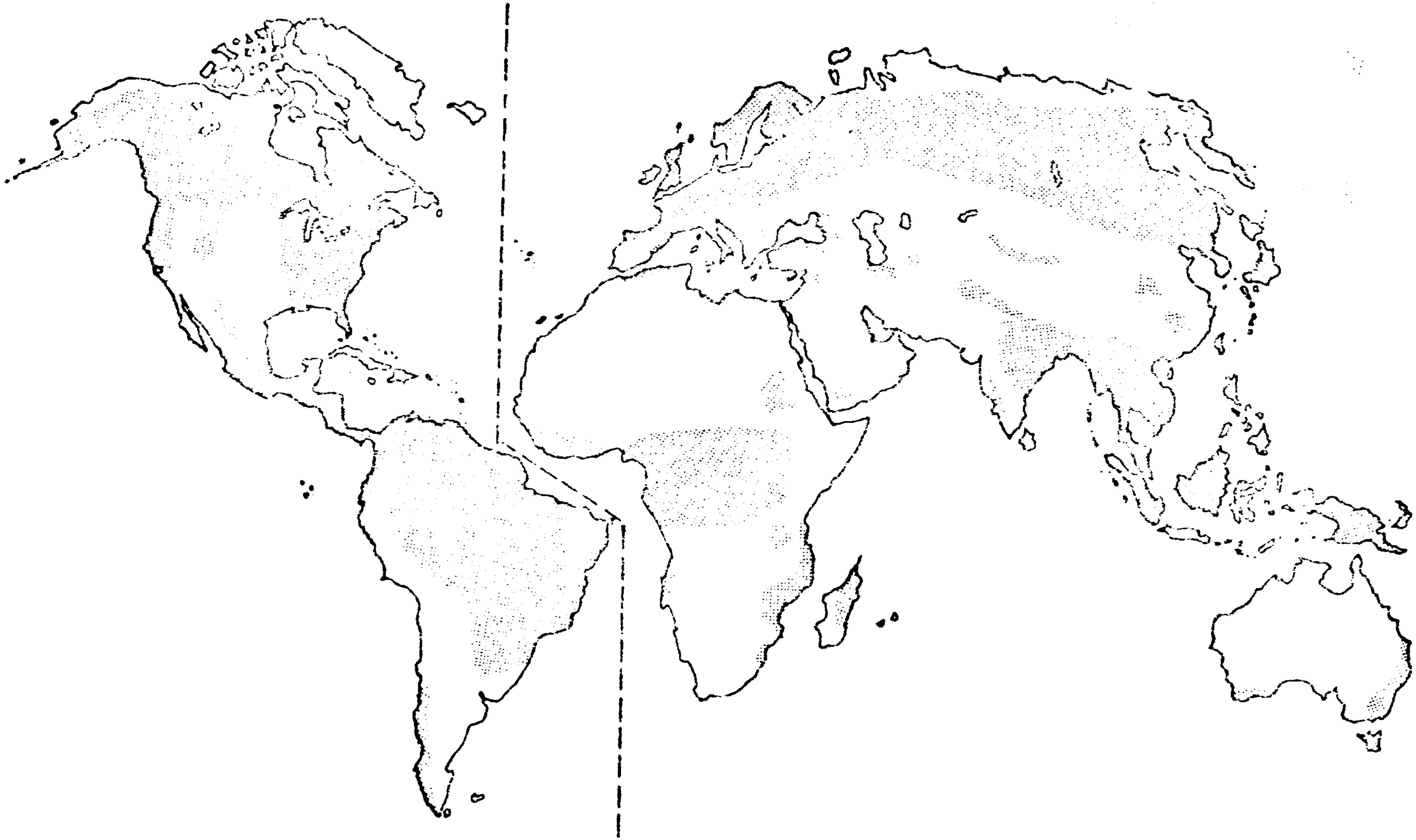
According to the above table during that period the tropical countries extracted from their forests 37 per cent of the world total of wood. Further, the wood so extracted in the world was used as follows:

- 40 % for fuel,
- 38 % for sawn or laminated wood ,
- 12 % for pulp,
- 10 % for posts, beams, others.

A total of 200.7 million m^3 was removed from the forests of Africa. Such an amount was used as follows:

11/ Bibliography No. 32.

Figure [illegible]. WORLD DISTRIBUTION OF FOREST RESOURCES



Data from A. P. Lien, Battelle Memorial Institute, "Plastics as Construction Materials for Developing Countries," United Nations Inter-Regional Conference on the Development of Petrochemical Industries in Developing Countries, Teheran, October 1964.

Sawlogs, veneer logs and logs for sleepers	other round wood	fuel wood	Total
11.0 million m^3	12.8 million m^3	176.9 million m^3	200.7 million m^3

From a total of 200.7 m^3, approximately 88% was used for fuel.

Utilization of the world's production of wood

	Boards		Plywood		Regional, Forestal Zone hardwood
Europe	20%		18%		42%
USSR	32%		9%		20%
North America	30%		58%		25%
Central America	1%)		*		67%
South America	3%)		1%)		81%
Africa	1%)	= 19%	1%)	= 15%	97%
Asia	12%)		12%)		78%
Pacific Area	2%)		1%)		69%

* Less than 1%.

1961 Total Tropical Export of hardwoods.

Central America)	
South America)	12,169,100 cubic meters
Africa)	
Asia)	

2. Use of Building materials in a typical tropical country in Latin America. Example: Panama

In the rural areas a high percentage of the houses have earth floors, second in order they have wooden floors (rough lumber, reeds, mats, etc.). In the urban areas, concrete floors are first in order and they represent about 50 per cent of the total; second in order is the floor made of wood, as a 37 per cent of the rest.

In the rural areas, the walls are made of palm leaves, grass and cane reeds in about 18 per cent and of daub and adobe about 21 per cent. Bricks, concrete blocks and stone walls represent approximately a 23 per cent.[12]

The City of Panama constitutes the major important center for the consumption of building materials in the country. Wood buildings represent 35.3 per cent of the total in the nation with a high percentage of this amount concentrated in the capital. Wood is used in floors, walls, roof structures and ceilings. An account of the use of local and imported building materials used in housing construction is given below to give some figures for further reference.

2.1 Use of local and imported materials

The Public sector Housing Programme indicates an average net cost of US$ 2,300 for a typical 49 sq.m. low-cost dwelling. Of this amount, US$ 1,500 (65 per cent) represents the cost of materials and US$ 800 (35 per cent) of labor and other expenses.

Of the total cost indicated for materials, 68 per cent correspond to materials produced or elaborated locally, the rest is used to buy imported materials. The following tables considers the main building processes and the percentages allocated to each of them.

	Local Materials	Imported Materials	Total
Cement and aggregates	36	0	36
Metals and plastics	9	13	22
Woods and derivates	12	4	16
Equipment and installations	1	7	8
	68	22	100

The use of galvanized iron sheets for roofing represents the bulk in the importation line of metals and plastics. According to 1960 estimates, 44.6 per cent of the total dwellings in the country and 77.4 per cent of the all urban housing had galvanized metal sheets for roofing. Lately the use of aluminum sheets has also been introduced as a substitute.

12/ Bibliography No. 10.

3. The Building Materials Industries in Africa[13/]

It is recognized that the building materials industry plays a key role in the development process, particularly in the development of the industrial sector. From this point of view the present capacity of the African building materials industry is far from satisfactory, as about 50 per cent of the value of the continent's consumption of building materials is imported. This is an average for Africa, indicating that in some of the individual countries the situation is even worse. Recent trends do not indicate any substantial changes in the situation.

The gross national product of the African continent* was estimated to be about US$ 23 billion in 1965. Approximately one-twelfth of this, or almost US$ 2 billion, represented investment in construction, i.e. buildings and other construction works. Generally, about 40 per cent of the gross output of the construction industry is value added and 60 per cent is expenditure on intermediary inputs. In 1965, the expenditure on building materials and components amounted to US$ 1 billion. The share of imported materials has been estimated to be more than 50 per cent, which means that African countries spend annually about US$ 600 million on imported building materials. It is worth noting that in the worst cases, these imports cost four to five times as much as in the country of origin, because of expensive transport, extra handling and profits, premium for insurance to cover breakage or loss, etc.

3.1 Plant size requirements in the building materials industries

In most of the African countries total consumption of building materials is above the minimum capacity of a modern building materials factory. But as the distribution network is often inadequate, centralization of production in one or few factories would create enormous difficulties in supplying the more remote parts of the countries.

Naturally, the problem is very complex and many factors have to be considered before choosing the location and the size of a new plant. Special conditions exist in the land-locked countries where prices of imported building materials are so high that small-scale

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13/ Bibliography No. [illegible].

* Excluding Southern Africa.

factories with their relatively high overheads could be competitive. However, this should not stop governments of these countries from aspiring for optimal solutions through sub-regional co-operation.

Because of the position of raw materials and the size of markets it is necessary for certain industries to base their production capacities on a sub-regional or regional basis. This involves sharing out of industries among different countries within the framework of a programme of sub-regional co-operation in which interchange of products like sheet glass, iron and steel, refractories asbestos cement, etc., could take place.

The common market of Central America which is based on sub-regional co-operation and which aspires to base its production capacity on a regional basis is an initiative which could grow further in the building field especially as to plant size requirements for the manufacture of products which require initial costly investments.

4. Costs of plant installations

Studies made by Fiber Research Inc. of Seattle, Washington, in Panama during 1963, indicate the following initial investment for different processes of wood and plants with different capacities in order of magnitude.

		Board Feet	U.S. Dollars
1.	Small Saw Mill	(20 thousand board ft.)	160,000.00
2.	Medium Size Saw Mill with drying ovens	(50 thousand daily)	1,100,000.00
3.	Laminated Plant with dryer (frames or fill only)	(7 thousand daily)	300,000.00
4.	Plywood plant with hot presses	(50 thousand each period)	2,000,000.00
5.	Waferboard Plant	(25 tons daily)	1,350,000.00
6.	Hardwood Plant	(30 tons daily)	1,730,000.00
7.	Paper Mill	(50 tons daily)	5,600,000.00

Tropical countries have acquired costly experience as to plant sizes installed in relation to the actual demand of elaborated products. It has occurred that large plants have to be installed when there is sufficient demand to work the equipment on an economic production basis. Other cases, unfortunate results have been noted due to the unbalanced relationship between actual demand and production.

5. Consumption of Plywood, Fibreboard and particle board.

It has been noted that some tropical countries are beginning to think of the housing shortage and other social problems not as a national liability, but on the contrary, as a challenge to create new assets for their emerging economies. It is also of special interest to mention that many shortcuts are being applied in the adaptation of technological advances as they aspire to reach higher standards of living.

The consumption of wood based products in Chile is considerable within the context of Latin America region and the world as the following summary shows:

Estimated Consumption of Plywood, Fibreboard and Particle Board 1959/60, kg/capita

	World	Latin America	Chile (a)
Plywood	4.5	0.9	0.66
Fibreboard	1.8	0.6	0.93
Particle Board	0.6	0.2	0.30
Total	6.9	1.7	1.89

6. <u>Estimates on the use of Timber for structural purposes in tropical countries</u>

There is at present an average of 5,000,000 dwellings being built per year in Africa, Asia and Latin America. According to the annual Bulletin of Housing and Building Statistics for Africa, Asia and the Far East and Latin America for 1960-1975, the total housing requirements are estimated to be in the neighbourhood of 390 million dwellings. An annual housing programme which produces 8 to 10 dwellings per 1,000 inhabitants is therefore called for in these regions. We also refer to the Annual Bulletin of Housing and Building Statistics for Europe 1960 which indicates among others that during the year 1960, the U.S. achieved an output of 7.1 dwelling per 1,000 inhabitants and the Union of Soviet Socialist Republics 14.0 dwellings per 1,000 inhabitants.

Regarding the needs of tropical countries, an increase from 2 to 10 dwellings per 1,000 inhabitants in the period 1960-1975 is necessary to cope with the demand. This increase, which has taken from 1.5 to 3 per cent of the gross national product in some countries would have to be stepped up to about 6 per cent to fulfill the housing requirements.

If we assume that fifty per cent of the houses built in Africa, Asia and the Far East and Latin America are one storeyed single dwellings (the others would be in two-story row housing, apartments, etc.), of the 2,500,000 dwellings considered 60 per cent of them may have a timber structure as the present trend shows. Considering that these dwellings are of a minimum improved type with a roof area of 70 sq.m. per unit equivalent to 0.432 cu.m. of structural timber per dwelling, then, the consumption of structural timber for this type of dwelling would be of approximately 648,000 cubic meters. In order to cope with the future required demand, this amount would have to be multiplied by five which gives us a total of 3,240,000 cubic meters of structural timber. To make things more impressive, it must be added that this volume does not include timber used in industrial structures, floors, doors, frames, panels, etc.

6.1 Windows and Window-Frames

The advantages of the wooden frame window over the metal type are mainly its lower initial cost and facility of repair; some of its disadvantages are a higher installation cost and a lower natural lighting area in relation to the total opening. As regards cost, however, a German authority ascribes the wooden window's continued dominance in residential construction to its cheapness. Further, a Belgian estimate gives the price per sq.m. of a window in northern red pine at 625 Belgian francs (530 timber, 95 ordinary window glass) against 1,095 for a metal window (including 275 francs for special glass demanded by the metal frame). The margin, indeed, is sufficient to enable oak and a variety of tropical woods, capable of giving a wide range of decorative effects, to replace pine without surrendering the price advantage. This is apparently not the case in France, however, where the penetration of the metal window has favoured mass production methods and cost reductions, bringing the cost down to the point where it is little dearer than a wooden window.

The comparative maintenance cost is still a matter for contention. A wooden window, whether painted or varnished, needs treatment at intervals of about three years; a metal window is subject to corrosion, and requires annual anti-corrosion treatment. This argument against metal, however, is fast losing its validity. Anti-corrosion treatments already on the market guarantee immunity from oxidation for up to ten years, and current research indicate that it will soon be possible to lengthen this period. This development will help the metal window to gain readier acceptance; some past experience of metal windows, notably in coastal areas where they have been exposed to salt air, has been extremely unsatisfactory.

Corrosion is not a danger in the aluminium or aluminium alloy window, which is now entering the market. In most countries, however, duraluminium window costs from 1,300 to 1,500 francs per m2. The cost of aluminium, however, is continuously falling in relation to timber and steel, and the speed of penetration of aluminium in this field will depend largely on the evolution of this price relation in individual countries. It is significant that aluminium windows have made great progress in recent years in Canada.

There is a general tendency to use metal frames (aluminium alloys or steel in tropical countries due to the inadequate use which has been given to wooden windows. However, in the coastal areas in the tropical countries, due to the exposure to salt air, it has been practically impossible to guarantee any metal from oxydation.

In Central America, the cost of a window of aluminium alloy frame and glass louvers 7/32" thick runs to about US$ 12.00 per square meter.

To reduce costs in the minimum improved dwelling for tropical countries described before, efforts are being made to substitute openings with pre-cast concrete ornamentals, which do not fulfill all the functions required in the tropical countries, but reduce prices effectively in this aspect of the minimum dwelling. Dwellings in the middle and high income bracket generally use the more sophisticated metal (aluminium alloy) window frame with glass louvers or large openings with glass panels and metal frames.

6.2 Doors

No element of joinery has undergone such profound modifications in the course of recent decades as the door. Yet the overwhelming majority are still made of wood in some form or other. Metal and glass doors, though finding increasing application in industrial and commercial premises, still play a negligible role in residential construction.

Thirty years ago the solid panel framed door reigned supreme. Today, the solid wood door is a rarity in many countries and is fast becoming so in others. Its place has been taken by plywood and various hollow-core flush dors which have proved cheaper, lighter and of better dimensional stability.

Plywood first entered door construction as a substitute for the panelling in light solid frame doors. Subsequently, 3-mm. plywood was fixed on either side of a softwood frame, giving rise to the first flush door. The transition from a solid core (utilizing sawnwood or blockboard for the core) to a hollow core door gave a cheaper and lighter door, with no loss of stability. A variety of materials can be utilized for the core, and a hollow fibreboard cellular core on a wood frame with hardboard decks was the next stage in the evolution of the flush door. More recently still, doors with particle-board cores and veneer facing have entered the market; processes have been devised for the pressure moulding of wood frame, core particles and veneer into a finished door unit in a single operation. Thus while the plywood flush door is still important, the hardboard hollow-core flush door and the particle-board door are vigorous challengers. Indeed, in the United Kingdom the great majority of flush doors are already hardboard-faced while in France the hardboard-faced door is likely to overtake the plywood door in the near future.

Some German data are available (table [illegible]) which demonstrate the weight, cost and wood content of three types of flush door:

TABLE [illegible]

Three types of flush door compared

	Unit	Solid panel framed door	Plywood door	Hardboard decks on hollow-space core
Weight	[illegible]/m2	[illegible]	[illegible]	12.[illegible]
Cost of production	DM/m2	[illegible]7.1	13.[illegible]	14.1
Consumption of working material ..	m3/m2	Sawnwood .061	Frames and panels .010 Decks .0[illegible]	Frame and core .011 Decks .008
Consumption of raw material	m3 (r)/m2	Sawlogs .102	Sawlogs .017 Veneer logs .01[illegible]	Sawlogs .01[illegible] Round logs .016
Total		.102	.03[illegible]	.034

Wood required for the manufacture of a flush door (Cubic decimetres)

	Door element: Frame A	Frame B	Core A	Core B	Decks A	Decks B	Complete door A	Complete door B
Solid door (sawnwood only)	-	-	-	-	-		70	125
Plywood flush door	Sandwood [illegible]	16	Sandwood 6	1[illegible]	Plywood 17	[illegible]1	[illegible]	7[illegible]
Fibreboard flush door	Sandwood [illegible]	16	Fibreboard 15	1[illegible]	Fibreboard [illegible]	[illegible]	[illegible]	30
Particle-board flush door	Sandwood [illegible]	16	Particle-board [illegible]0	[illegible]	Veneers [illegible]	21	[illegible]7	82

A. Dm2 of working material   B. Roundwood equivalent in dm3.

6.3 Panels or Partition Walls

One general trend is evident everywhere, though it is proceeding at different paces in different countries - that of getting away from wet plaster work, which seems destined ultimately to play a negligible role in the construction of interior walls. The reasons are of different nature, including cost and shortage of the necessary skilled labour; but the reduction in completion time consequent on the elimination of plastering (which requires drying time and hinders other completion operations) is perhaps the most important factor. Here the recent trend in the USA, where wood-frame construction is almost universal in one-and two-family dwellings, is illuminating. Between 1940 and 1959, dry-wall construction in interior wall surfacing rose from 20 per cent to 70 per cent; gypsum board is currently the dominant dry-wall material, accounting for more than 90 per cent of the drywall potential.

The shift towards dray-wall construction does not automatically expand the market for sawnwood, though it offers opportunities for hardboard and particle-board. But where masonry gives way to lighter constructions, whether pre-fabricated or not, a new demand for framing timber arises. Pre-fabrication, already widespread in many countries, is likely to continue to gain ground. It allows for more economical use of material, factory quality control, and quick erection. Standardized design, usually held to limit consumer choice, may in the long run confer on the dwelling owner or occupant a flexibility which, but a short [illegible] ago, would have been beyond his dreams. It is reported that an experimental house has already been built in Goteborg wherein the only fixed elements are the stairs and the bathroom. The rest of the living space is distributed at will by means of movable pre-fabricated partition walls. In residential construction, this system is still a new concept, though it is encountered increasingly in the design of office and commercial buildings.

It is obvious that if an impact is to be made in relation to this problem the present situation in the building field has to be modified, ways must be opened to new technologies, materials and design approaches. It is not possible to be living in the moon age with the concepts of traditional handicrafts, in

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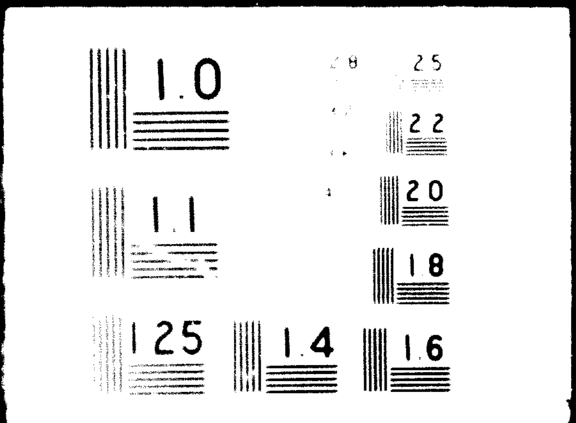

the building field.

7. Steps to increase the use of wood as an import substitution measure in tropical countries

Tropical countries must be conscious of their natural resources and how these can be transformed into building materials, energy, etc. With this knowledge, steps can be taken to increase the use of local natural resources like timber [illegible], palms, fibers, grasses, etc. In the following summaries and drawings, various housing projects developed in Central America with that aim are presented as selected examples.

7.1 In the Valley of Rio Aguán, Honduras, wood is the basic natural material which grows abundantly in the region.14/

An experimental house has been built showing the following costs:

Foundations	3.13 %
Floors	23.59 %
Walls	24.49 %
Roof	38.57 %
Carpentry	10.22 %

On this type of house, the labour represented US$ 66.15 = 14.6 %
and the building materials . . . . US$ 393.43 = 86.2 %

Wood was the basic material used for the structure, floors, walls, doors, stairs and partitions. The cost of board feet treated in autoclave with Swedish salts K-33 was 0.34 ¢ per board foot.

A total of US$ 137.56 was the cost of the treated wood used thus representing about 35% of the total cost of the materials. Materials like nails, bolts, wiremesh, glass louvers, etc. which were not substituted [illegible] amounted to US$ 75.83 or approximately 19.5% of the total cost of materials. A substitution for that amount could have been made by using wood jambs, wooden louvers for windows, etc.

The following figures show construction details of the dwelling.

7.2 Experimental Housing in Honduras. Example of extensive use of wood. 15/

Row Housing with two floors, partly concrete block walls, interior partitions, as well as exterior front and back walls of standardized wood panels. The structure and floor of the second

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14/ Bibliography No. 42.

15/ Bibliography No. 34.

story is also made of wood.

By the use of wood in walls and floors an import substitution was made: there is also a saving in the weight of the building and the handling of materials by using local labour in the manufacture [illegible]

8. <u>Other possibilities of substituting imports by the use of wood in the building industry</u>

In most of the tropical countries, the general tendency of architects is to follow the international pattern in materials and building, especially for industrial, commercial and housing structures.

Due to the lack of basic information like availability and technical properties of locally produced components, sometimes designers and builders prefer to use materials well known in other countries. However, it also may occur on the other hand that in some cases, a product which has been tested under certain conditions of humidity or salinity, will react differently in tropical conditions where relative humidity may be higher throughout the year and constant sea breezes may prevail. In those cases the expected performance of those building materials is altered. As an example, we mention the thin coatings which are usually applied on aluminum alloys which are corroded by constant humidity combined with strong salinity in the air.

Most of the dwellings in tropical countries are one-story and have galvanized iron sheets as covering. A building material to substitute this type of roofing that has the impermeabilization of the galvanized iron and the insulation quality of the wood has been developed in a tropical country. In Brazil, Mr. de Meller has been experimenting with the production of a plywood corrugated sheet 1/4 " thick with a thin aluminum film on top of it 1/500" thick.

Industrial buildings could be designed with wooden trusses of timber and plywood or laminated plywood and thus substitute imported pre-fabricated steel buildings . There is a tendency to use more and more steel and other metals in the tropical countries, without considering the economical implications

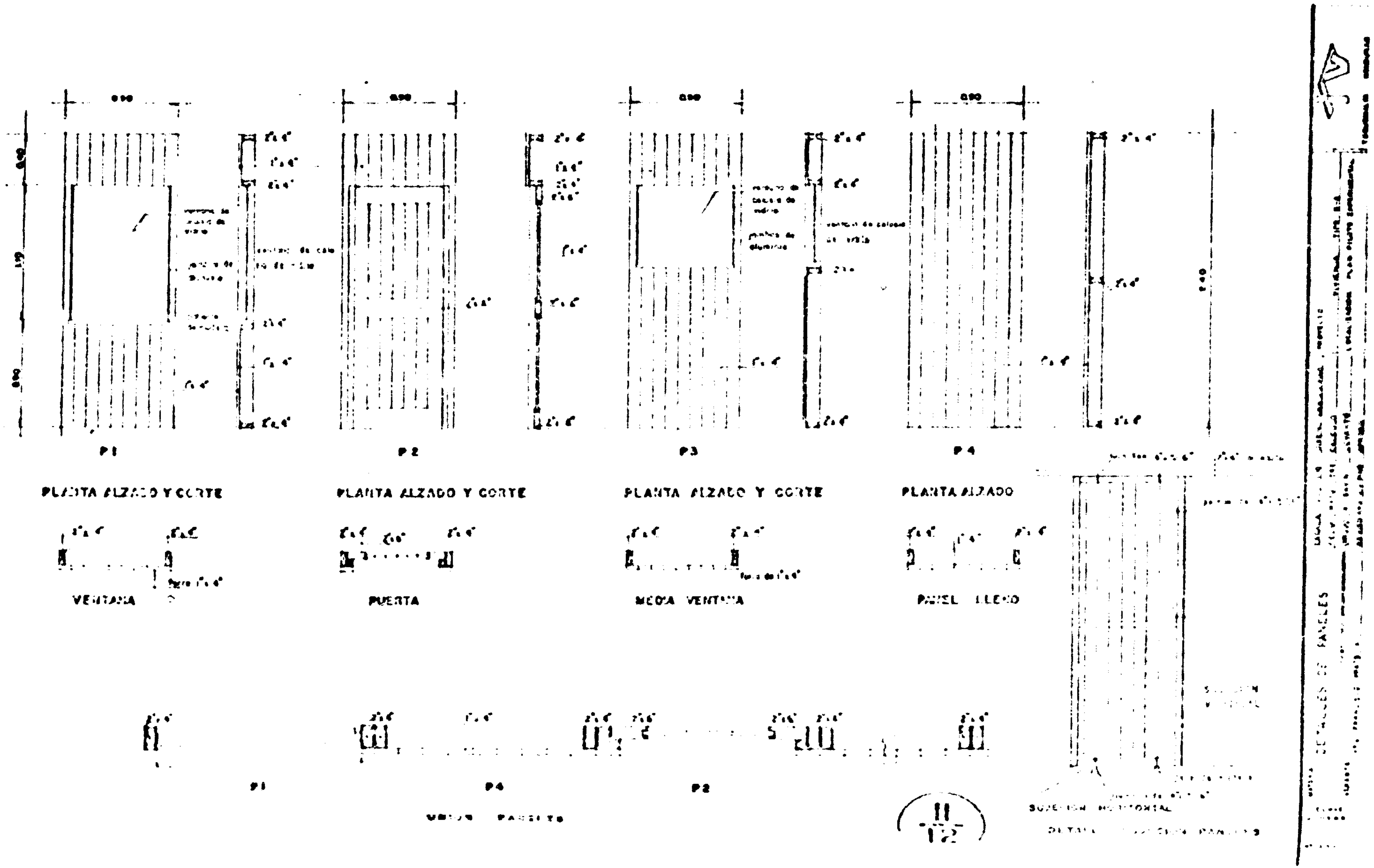


Fig. 4. Honduras, [illegible]. Modular wood panels used for walls in low-cost housing.

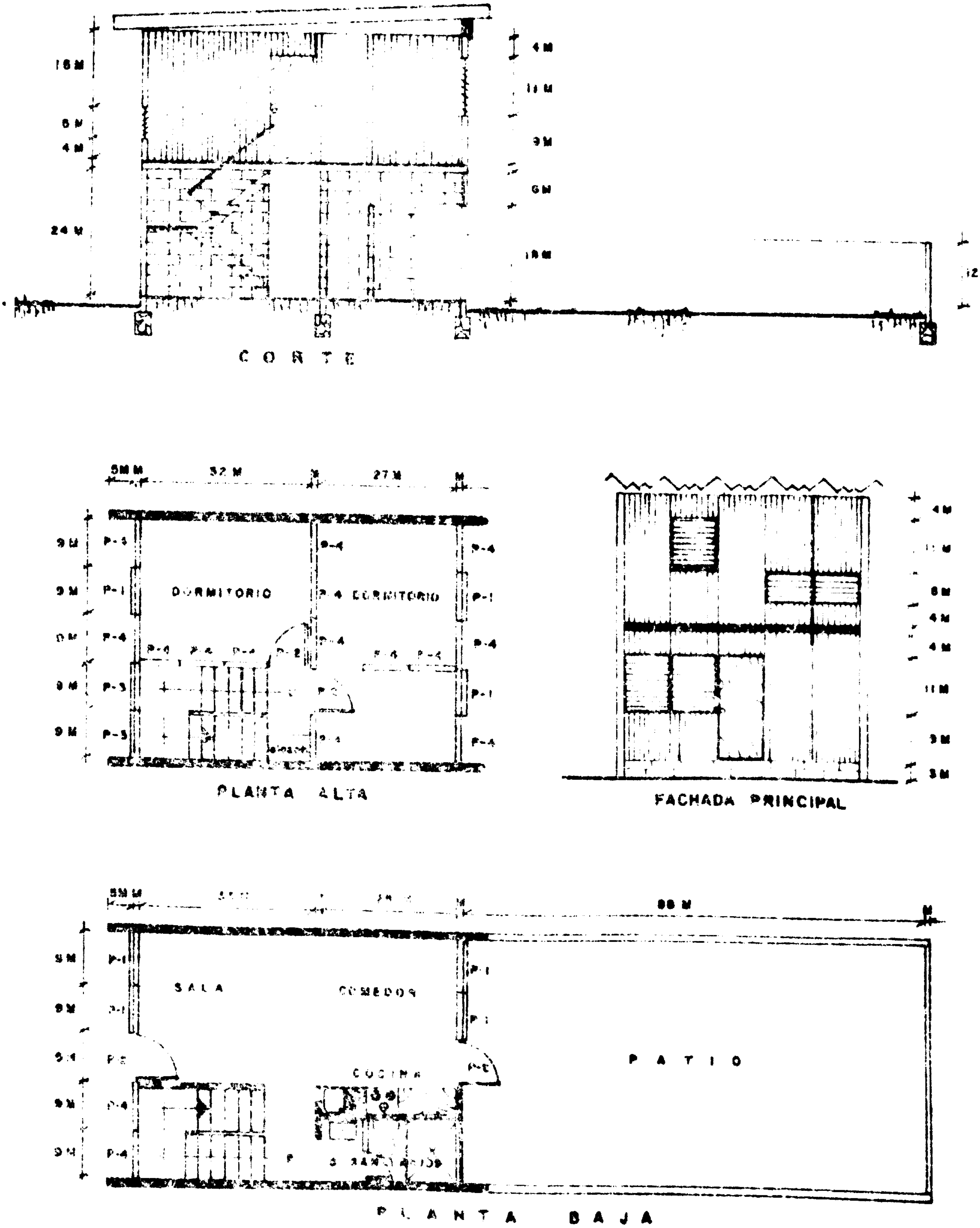
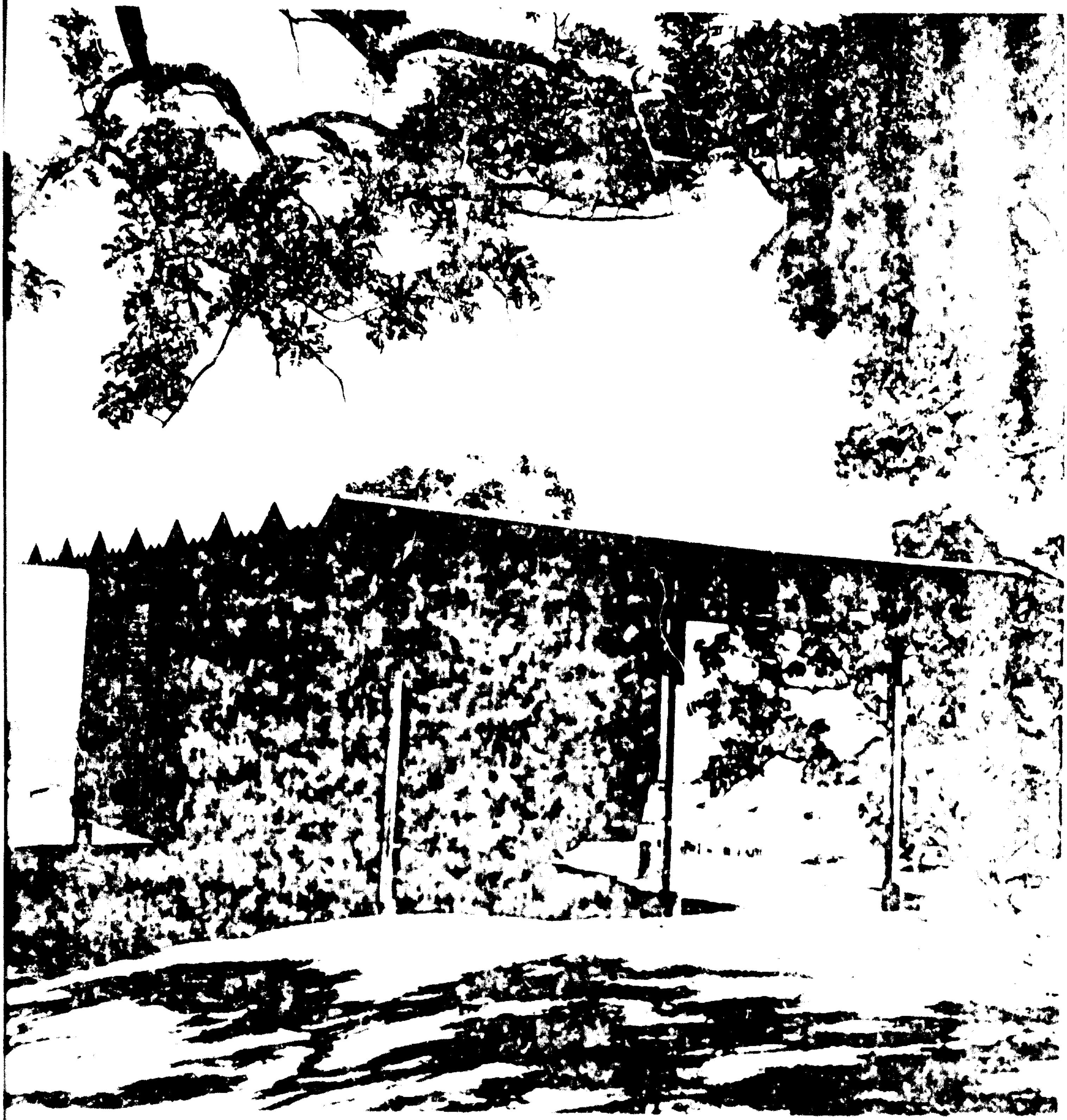


Fig [illegible]. H[illegible], [illegible]. [illegible] wood f[illegible] the second storey floor, the staircase and [illegible] front and back facades, interior partitions and doors.



[illegible] Honduras, 19[illegible]. [illegible]
[illegible] main structure.

and the costly maintenance which these materials require.

Large commercial buildings could reduce weight and cost in the structure by using exterior and interior wood panels instead of concrete, metal or glass divisions which are now being used in many tropical countries.

For one-story and two-story row dwellings, cost, weight and labour could be reduced through rational design and construction, substituting wherever possible the use of aluminium, steel and glass, materials which generally have to be imported to tropical countries.

V. Future Uses of Wood for Building in tropical countries

1. Financing of low cost dwellings and their durability guarantee

Financial requirements for low-cost housing construction demand a specific durability of the structure to guarantee the investment. The dwelling should withstand decay for at least the period set to return the initial investment. For low-cost houses this period has been extended during the last few years from 20 to 30 years to repay capital and interest which varies from 5% to 8% per year. However, low-cost dwellings are being constructed in most cases to withstand a larger period of life using permanent materials like burnt clay bricks for walls, reinforced concrete structures, etc. That is, within this pattern there is no way of using building materials and components of a limited durability but which can be replaced easily by utilizing mass produced type of elements found in the open market. In a way, a similar way of acquiring nowadays units like refrigerators, washing machines, cars, etc. The financial implications of lowering the initial cost of construction by using renewable materials with the possibility of obtaining further financial assistance when those materials are to be replaced should be studied. It might turn out that a larger number of houses could be built with more flexibility for future growth and even a change of the character of whole neighborhoods during periods of time.

2. Factors which affect the use of rough timber and sawnwood for dwelling construction in tropical regions

Fine woods like mahogany, cedar, teak, etc., which used to be used in rural areas as structural members as columns, beams, joists, etc., cannot be obtained at present in sufficient quantities to supply the demand. Such hardwoods have not been replaced with new species in the process of clearing and felling of the trees thus causing the total annihilation of forests as a future construction source. Therefore, we note that in architectural designs a substantial reduction of the use of wood has taken place, especially in low-cost dwellings. At the same time, the materials that are substituting wood are increasing the cost of construction which has forced builders to reduce considerably the size standards of the houses to keep with the same total cost.

On the other hand, due to past experiences with uncontrolled fires that have destroyed complete towns have given ground to construction codes which stipulate that wood shall not be used for structures, floors or walls in urban areas, in several tropical countries.

Therefore, materials like burnt clay bricks and tiles, the development of concrete blocks and prefabricated structural concrete components, coupled with a lack of a steady flow of wood products for construction such as structural members, sheathing, etc. has directed designers towards the search of replacement materials for wood in building in many cases.

3. The building industry in tropical countries and the development of wood products

It is recognized that the building materials industry plays a significant role in economic development, particularly in regards to the industrial sector. However, due to this important position of the construction industry it fluctuates continuously along with the rate of economic growth. This fact affects all the building materials industries which cannot manage to keep up on an increasing growth, when the prevailing conditions of a given economy are not promising. In this connection the wood-based products industries also are affected.

This thought justifies a serious interest and control on the use of forest resources. For example, there is very little control of the types of species being cut and the degree of reforestation measures. Panama as a case, has a law which establishes that for every tree that is cut in the forests, two should be planted. Unfortunately, such a law does not indicate how this procedure should be done and does not allow for provisions to take care of the seedlings. As a whole it is noted that there is a lack of technical know-how in the treatment and use of wood in most tropical countries.

4. The future of wood

One of the most promising natural resources that the tropical countries still have in reserve are the forests coupled with their potentiality to renovate themselves as a natural process. This situation varies from region to region and with different densities of population within the regions. A general tendency in most tropical countries where there is no control in the rural areas is that farmers burn the existing vegetation yearly in order to plant seasonal crops like rice, corn, yuca or beans. When the land fertility is used up they look for a new pieces of virgin land and continue the same process of clearing for agricultural purposes over and over again. In this manner farmers are destroying natural resources which are part of the basic economy of those countries. Very little has been done to control this inefficient and uneconomic system to ruin the land, partly because most of those countries have not been able so far to offer alternate solutions or ways of improving agricultural practices to the farmer or land owner. In countries with low densities in the rural areas there are still large forests which must be tapped until solutions are found to utilize them in the most profitable way.

As shown in the map [illegible] in Latin America, yet local consumption and export of plywood logs are extremely low. For example in the vast Amazon region which has a large variety of wood species no large-scale development of forest industries has taken place to date. The Brazilian plywood industry is located near the consumption centres in the southern part of the country and log supplies originate from the forests in this area. Main wood species used for plywood are paraná pine and cedar. In the states of Espirito Santo and Minas Gerais, the wood species Jequitiba and peroba have attained importance as raw material for plywood.

Argentina and Uruguay cannot meet their raw material needs for plywood from local sources. Both countries import large quantities of logs from Paraguay, where plywood production is only of minor importance; but Uruguay also imports logs from West Africa. Chile mainly uses "Araucaria pine," which is found only in a rather limited area in the middle Andes. There is, however, evidence of other potential sources of wood species suitable for plywood manufacture. Bolivia and Peru produce small quantities of plywood by utilizing locally available material. Colombia has considerably increased production of both peeler logs for home consumption and for export. More than 50,000 m^3 are used for local plywood manufacture, and hardwood log exports - with the exception of Paraguay - are higher than in any other Latin American country. Roundwood is still available for further expansion of the local plywood industry.

Venezuela's plywood mills depend on both local and imported logs and veneers. Among the northeast Latin American countries only Surinam has started to use locally available forest resources for the manufacture of plywood, while the production of plywood logs is of no importance yet in the West Indies.

The Central American countries generally have suitable virgin forest resources which, in step with the development of their infrastructure, should be able to supply plywood logs in the future. In Mexico, several plywood mills are already operating in different forest areas and, although there is no lack of log supplies (pine, mahogany, cedar), plywood marketing problems have become the critical factor for further expansion of this industry.

4.1 New utilization of wood-based products in tropical countries

Through the dry-process, fire proofing in the body of hardboards can be obtained as required for their use in construction. This technological achievement is more spectacular than fungi-and-termite resistance which can, also be done by the wet process, though with complications due to water problems.[10]

The manufacture of mineral-bonded products can be increased with the use of bamboo strands by flaking in a standard flaking machine where they can be separated into narrow and long strands.

Much of the actual waste in the wood industries can be reduced, using it for wood wood boards, cement embedded fibre panels and other materials.

10/ Bibliography No. 43.

Finger joints permit the use of short pieces of lumber. In this process the [illegible] joined lengthwise by gluing interlocking fingers. The finger jointing allows the use of high quality material [illegible] to its full length.

The [illegible] realized by R. De Mello in Brazil for roof coverings [illegible] open new areas of [illegible] the tropical countries. This type of roofing material could substitute the imported galvanized iron and aluminium roofing.

The main application of corrugated plywood lies, without any doubt, chiefly in its utilization as a covering material, especially when provided with an aluminium surface. A 0.050 mm (1/500") thick aluminium film for exterior facing of roofing has been used so far.

A corrugated plywood covering has advantages which no other material is able to give: such great resistance combined with such light weight. One plate of 2.20 m in length is able to sustain the weight of 10 people, notwithstanding the fact that the weight of the plate is no more than [illegible]. The material is not fragile or brittle, hence not liable to breakage during transport, as is the case with ceramic and [illegible] products. Corrugated plywood is very easy to be fixed into the structure of the roof, there being no need for any special fixtures or contrivances, hence the material may be worked by people not possessing particular skills. The "Instituto de Pesquisas Tecnológicas", an official Government Department in São Paulo, Brazil, has undertaken studies with respect to the resistance of corrugated plywood.

The use of bamboo as a building material continues to increase, especially in Asia and the Far East. Based on experience the best species should be recommended to other tropical countries for their development. Africa and Latin America can still produce large amounts of bamboo to substitute the use of hardwoods in the rural areas.

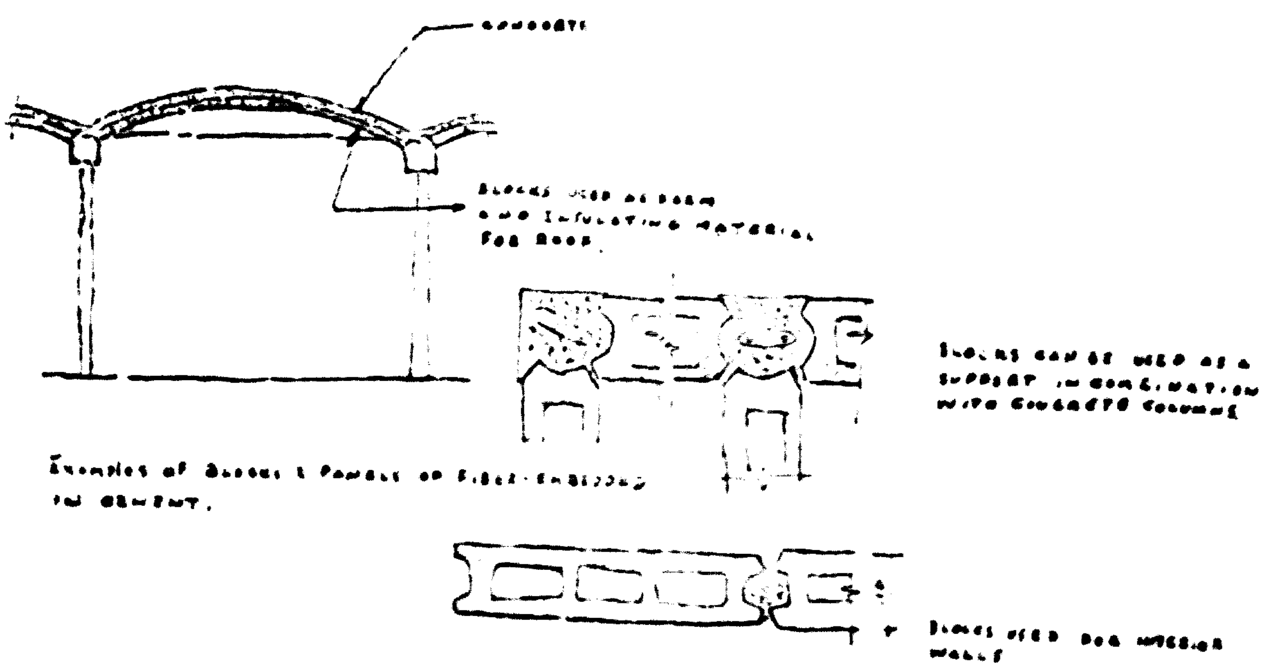
Since soft woods can produce logs in about ten years or less, this would greatly influence the pattern of logs [illegible] in tropical countries if reforestation programmes were taken. The [illegible] and use of balsa wood, as an example, which grows in [illegible] to 4 years, can be stimulated. It can well be used for [illegible] material in panels, as it is being done successfully by several operating plants.

[illegible] Fibre [illegible] and Blocks

At the moment [illegible] type of panel seems to be the most appropriate solution for the tropical countr[illegible] [illegible] the fact that it utilises the basic fibre material as wood [illegible] strands, [illegible] with cement paste. It can be manufactured in different thicknesses, sizes and forms, as thick-hollow panels for walls and roofs, thinner panels for ceilings and non-bearing partitions and it has good acoustical and insulation properties.

The cost of synthetic adhesives [illegible] in the production costs of panels, either made of plywood, particles or fibre [illegible]. [illegible] a study realized in Panama for the production of plywood or wood [illegible] in the production of 14,400,000 ft.[2] ([illegible]" base) per year, the cost of rough [illegible] would be [illegible],320 tons at a total cost of [illegible],776.00, whereas the chemical products in the amount of 720,000 lbs. of adhesives would cost [illegible]. That is, the value of the adhesives was about four times the value of the raw resource (wood).

The above example indicates how costs of production are affected by the use of adhesives which in most cases are manufactured in developed countries. Therefore there is a great need of giving more emphasis to the use of local resources.



Examples of blocks and panels of fibre [illegible] in [illegible]. [illegible] can be used for walls [illegible] [illegible], Palo Alto, California. [illegible] consists of [illegible]

[illegible]

[illegible]

[illegible]

[illegible] requirements and the actual cost of the material in the market.

TABLE

Cause of Deterioration	Possible Effect on Durability in Most Materials
1. Moisture	- Loss in strength with increase in moisture content - Promotion of corrosion and hydration with subsequent change in chemical and physical properties - Dimension change with change in moisture content - Dehydration and splitting under low humidities - Blistering, rotting, etching and removal in solution - Erosion of soft materials by rain, impact damage by hail - Stimulation of biological activity and chemical reactions
2. Solar Radiation	- Embrittlement, crazing, cracking, discoloration and fading by photochemical reactions - Dimensional change and possible deformation and cracking with change in temperature - Embrittlement by vaporisation of volatiles - Softening and flow of semi-solids - Dehydration, recrystallisation with a change in physical properties - often a loss in strength - Stimulation of biological activity, acceleration of reactions
3. Pollution	- Hardening, formation of bloom of carbon dioxide - Erosion and weakening by aqueous solutions of carbon dioxide and sulphur gases - the latter may cause severe spalling and blistering - Discoloration of pigments by sulphur gases - Corrosion, efflorescence promoted by deliquescent particles - Erosion, discoloration by wind-blown dirt - Efflorescence, erosion and spalling by ground salts and waters
4. Biological Attack	- Discoloration, rotting and softening by fungal, algal and bacterial attack - Embrittlement through attack on plasticisers - Etching by biological metabolism - Complete destruction or severe weakening, particularly of cellulosic materials

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TABLE 2

	Asbestos-cement	Asphalt, bitumen	Burnt clay products
Moisture	Continued hydration of cement causes length increase Impact damage by hail	Standing puddles enhance [illegible] Rain removes water-soluble material Felts may blister, can have high moisture movements, felt fibres may rot. Protective granules removed by rain	Movements small - .01-.02 per cent Wetting and drying cause solution and deposition of salts - mostly affects appearance but can cause spalling
Photo-chemical	————	Polymerisation, oxidation intensified by Ultra-violet causes embrittlement, cracking and formation of water soluble compounds	————
Thermal	C (Coefficient of Thermal Expansion) = $7-9 \times 10^{-6}$ per ^{o}C	Loss of volatiles, polymerisation causes embrittlement Expansion of entrapped air or moisture gives blistering Softening and flow with high temperatures	$C = 3-7 \times 10^{-6}$ per ^{o}C
Pollution	Carbon dioxide in presence of small amounts of moisture decreases impact strength and moisture movement, increases transverse strength Carbon dioxide or sulphur gases in rain water removes surfaces layers of hydrated cement	————	Salts derived from ground and by reaction with atmosphere sulphur gases can cause spalling.
Biological	Growth on fibre-held dirt causes surface softening, darkening	Surface growth gives softening and cracking Termites, bacteria can attack	————
General remarks	Combined hydration and carbonation promote warping and cracking	High winds may cause felts to crack and tear Protective granules may be lost	Rain washing reduces salt attack Renderings based on cement can be attacked by products with high sulpha contents.

	Cement	Concrete
Moisture	Premature hydration causes ultimate loss in strength, slow set	Dry shrinkage - Dense concrete .03-.05 per cent Lightweight .03-.35 per cent Moisture movement - Dense .02-.04 per cent. Lightweight .03-.30 per cent.
Photo-chemical	----	----
Thermal	----	$\zeta = 5-13 \times 10^{-6}$ per $^{\circ}C$ Premature evaporation of gauging water gives poor curing
Pollution	Absorption of atmospheric carbon dioxide accelerates set	Acid waters from vegetable decay and sulphate ground waters cause erosion, loss in strength Salts in aggregates and seaspray cause erosion, spalling, particularly with reinforced concrete
Biological	----	Bacteria can attack in particular situations - e.g. sewers
General Remarks	Less in strength under high temperature and humidity conditions by set high alumina cement	Organic impurities in mixing water retard set and hydration

	Lime	Paints	Plastics
Moisture	Premature set of hydraulic limes Slaking of bagged quicklime When very dry conditions prevail, non-hydraulic limes carbonate and harden very slowly	Moisture leads to loss of adhesion, blistering and cracking Condensation on a drying film [illegible] Loss of gloss and inhibition of drying General weakening of the film	Swelling and shrinking can occur with change in moisture content
Photo-chemical	------	Colour change and chalking of pigments Polymerisation and oxidation of vehicle accelerated	Polymerisation and oxidation cause embrittlement, cracking, crazing and discoloration
Thermal	Premature evapoaration of gauging water gives poor hardening of hydraulic limes	Heat polymerisation and loss of plasticisers gives cracking and flaking Movement may cause checking Difficulty in application due to loss of solvent Drying period is shortened	C = 10–250 x 10[illegible] per °C Polymerisation may cause decrease in tensile strength and decrease in elasticity Loss of plasticiser causes warping and embrittlement Permeability to water vapour increased as temperature increases
Pollution	Carbon dioxide causes carbonation - an essential part in the hardening of non-hydraulic limes	Sulphide discoloration of lead pigments Sulphur dioxide in industrial atmospheres attacks certain pigments and promotes attack on metals leading to failure of film Rapid failure in marine atmospheres especially on metal Dirt, grit, dust erode and discolour	Wind-borne grit can etch and abrade, particularly on foamed plastics
Biological	----	Fungal and algal growth on film and surface dirt, particularly when films remain wet - this may cause breakdown of film Termite attack	Growth on organic fillers and plasticisers causes embrittlement Growth also occurs on unfilled plastics and on surface dirt Termite attack

..//

	Lime	Paints	Plastics
General remarks	Storage in wet climates is the chief problem	Importance of substrate - e.g. timber, metal on deterioration	Anti-oxidants and absorbing pigments can improve durability

	Soil	Timber
Moisture	Erosion and loss of strength. Very high movements cause cracking: - wet-dry can exceed 2 per cent for clay soils	High movements cause checking, splitting, warping and raising of the grain
Photo-chemical	-------	-------
Thermal	$C = 12x10^{-6}$ per ^{o}C	Thus thermal movements masked by resulting drying movement
Pollution	Erosion by wind-borne grit may occur but effect is not usually serious	-------
Biological	Damage by termites and rodents	Attacked by many insects and growths, depending on timber type and moisture content
General remarks	Stabilisation - e.g. with cement, aims at increasing strength and resistance to moisture	Rain-washing may leach out poorly formulated preservatives

SUMMARY OF BUILDING MATERIALS IN COMMON USE

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Concrete:	Spread footings or Column pads	C.A	U	Strong, lasting, versatile	Very expensive.	—	—	
	Stumps, bearers, framing posts	C.H	U	Can sometimes be precast; enduring; termite-proof	Expensive; requires form work	—	—	Often found cheaper than first-quality hardwoods
	Blocks, solid or hollow	C.A	U	Can be cast on job in hand-operated machines	Usually more expensive than good bricks	Wider use of block making machines	Development of major industrial production	Have outstripped clay bricks in popularity in Malaya. Extensively used in West Pakistan
Stone:	Boulders or random rubble	A	R	Inexpensive if locally available	Cannot be bonded. Necessitate massive walls	—	—	Widely used in hill regions particularly in India and Pakistan
	Coursed rubble. Ashlar	A	B	Strong and impervious to water erosion. Attractive appearance	Relatively expensive in terms of labour	—	—	Often used in better-class work, where stone is locally available
Clay Bricks:	Machine made	C.A	U	The most versatile and enduring of all inorganic building materials		Better kiln design, rationalization of fuel distribution	Decentralization of industry. Reduction of production costs	Indian Standards Institute is developing a standard specification for bricks in India
	Hand made (Local)	C.A.	B	Locally available. Low cost	Often of poor size, shape and quality	Improved kiln and clamp design		Used in all countries, but most in India and Pakistan
	Sun dried	A	R	Inexpensive. Useful in extremely dry areas	Subject to water and wind erosion	Soil stabilization		In general village use in hot-arid countries
Stabilized soil:	Pisé (monolithic or blocks) Adobe (monolithic or blocks)	C.A.	R	More lasting than sun-dried bricks. Inexpensive. Suited to aided-self-help jobs	Better for walls than for foundations	—	—	Good in foundations only for very dry areas, or with high proportion of stabilizer
Timber:	Framing posts (squared, with or without sole plates)	C.H.	B	Availability, versatility.	Expensive. Must be teak, etc., or impregnated	Chemical treatment of low grade species		Concrete posts or stumps usually preferable where costs are comparable
	Framing posts, round bush poles or jungle or swamp wood)	H	R	Local availability, inexpensive	Not durable unless treated. Aesthetically poor	Treatment with chemicals. (Creosote below ground)	Chemical impregnation	In wide use in rural areas, often in conjunction with bamboo
	Stumps (squared or round)	H	R	Readily termite-proofed. Can be renewed if necessary	—	Fit galv. iron caps for termite-proofing	—	Wider knowledge and application of use of termite caps is desirable in every country
Piling:	Timber or concrete	H	R	Used in made-up ground or swampy or silted areas	Very expensive. Must be impervious	—	—	
Raft Type	Footings, usually of reinforced concrete	H	U	Structural stability on swampy ground	Extremely costly	—	—	Used only in cases of extreme foundation difficulties

a. C: [illegible]
A: [illegible]
H: [illegible]

b. B: Generally in use in both *Urban* and *Rural* areas.
U: Confined mainly to use in *Urban* areas.
R: In general use in *Rural* areas.

FLOORS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Brick:		A	B	Long lasting — impervious — and clean if rendered; cool	Requires firm sub grade must be carefully laid to falls	—	—	For unsuspended floors only - not recommended without topping
Concrete:	Reinforced or otherwise	C	U	As suspended floor in multi-storey building — versatile	Very expensive - Relatively heavy	—	—	—
	Blocks or slabs	C.A.	U	Can be pre cast for solid floors. Cool and clean if rendered	More expensive than brick or screeded ballast	Wider use of small block-making machines	Major industrial production	—
Stone:	Rubble	C.A.	R	Locally available - easily worked	Pervious - must be rendered - for solid floors only	—	—	Commonly used in many areas where suspended floors are not required
	Blocks or paving slabs	A	U	Cool and clean attractive appearance	Heavy to transport and expensive to work	—	—	Used in parts of India as traditional flooring material
Earth:	Rammed	C.A	R	Very inexpensive suitable in very cheap construction if suitably covered	Difficult to keep clean - liable to rising damp, unhygienic	Soil stabilization and/or topping with rendering		The commonest of all floors in Indian and Pakistan villages in dry areas
	Rammed and stabilized	C.A.	R	Cheap - more or less impervious cool underfoot	Surface wears rapidly - needs maintenance	Wider adoption after research	Wider adoption	A marked improvement on unstabilized rammed-earth floors
Timber:	Planks on joists	C	B	Strong, available - clean and versatile	Subject to insect and fungus attack unless 1st grade or treated	Chemical treatment of timbers other than 1st grade		The most generally used suspended floor in urban domestic construction in humid areas
	Palm trunks (e.g. "gaba gaba" etc.)	H	R	Inexpensive locally available	Not very strong; Short-lived	—	—	Not suitable for impregnation
Bamboo:	Whole	C.H.	R	Cheapness, coolness, local availability, light and easily transported, gives good air circulation in suspended floor	Subject to insect attack and can harbour rats when used whole. Shorter life than timber	Chemical impregnation. Better structural details		Means to improve the uses of bamboo rather than to supersede it, are recommended. This is the most abundant organic material available cheaply in humid areas
	Split and flattened (on joists)							
	Woven matting (on joists)	C.H	R					
Tiles:	Concrete (including Terrazzo etc.)	C.A	U	Cool, impervious, easy to clean. Good appearance	Expensive - require firm base	—	—	Usually seen in better class work only
	Clay (glazed or unglazed)	C.A	U	Less expensive than cement tiles	Require firm base and good mortar	—	—	—

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H = More commonly utilized in Humid areas.

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R = In general use in Rural areas.

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Rendering:	Cement-sand	C.A.	U	Enduring can be painted—resists mechanical damage — clean — cool underfoot	Expensive	—	—	Composition rendering preferable except in good class of work, requiring very hard finishes
	Lime Sand Lime Surkhi etc	C.A.	B	Cheaper than cement · more easily worked	Lower strength than cement sand	Increase lime production		More often used than cement in rural works
	Stabilized soil	A	R	Inexpensive better than unstabilized	Wears quickly in floor · difficult to clean	Rendering		—
	Clay and cow dung	A	R	Very inexpensive	Pervious to liquids; unhygienic	—	—	Very widely used in rural work in arid areas
	Bituminous preparations (emulsions etc.)	A	R	Easily applied · seals earth or gravel subgrade	Expensive and seldom available—difficult to clean and maintain	—	—	Not in wide general use
Sheets:	Commercially produced (linoleum, rubber-based etc)	C	U	Cool underfoot, clean	Sometimes expensive and difficult to obtain	Greater local production and cost reduction		Wider use would improve hygienic properties of many suspended floors
Matting:	Various types, fixed (plaited bamboo "Sawali" etc) Various types, movable	C.H	R	Cheap or very cheap cool gives good air circulation · plentiful	Unhygienic unless frequently cleaned and renewed. Subject to attack by borer and termites	Chemical treatment		Very widely used in humid areas in suspended floors, over wood or bamboo joists
WALLS								**WALLS**
Concrete:	Orthodox monolithic	C	U	Enduring — strong — necessary in multi storey buildings	Very expensive. Requires formwork and highly skilled labour and design	Reduction in retail prices of cement	—	Seldom applicable to low-cost projects except multi storey
	Orthodox blocks (various)	C.A.	U	Enduring — strong — may be made on job site	More expensive than bricks · aesthetically inferior unless rendered	Introduction of small hand-operated block-making machines	Industrial mass production	Now used mainly in Malaya, India, Pakistan, Japan and Philippines
	Pre cast slabs and posts	C	U	Enduring · strong high finish and structural standard possible	Expensive · factory made · limit versatility of design	Study of present methods used in Malaya and their applicability to other countries		Factory production initially unsuccessful in India. Good results in Malaya to date
	Lightweight monolithic (Foam concrete or lightweight aggregates)	—	U	Ease of handling high insulation qualities. Earthquake resistant	Expensive except where local light aggregates available nearby	Research into manufacture of expanded aggregates and study of Japanese methods	Factory production, using vermiculite or local light aggregates. Study of use of mineral slags and expanded clays	Now popular in Japan. Aggregates mainly pumice
	Lightweight blocks (Foam concrete or lightweight aggregates)	—	U	Can be made in light machines on job site · strong · earthquake resistant	Expensive except where local light aggregates available nearby			Has a future in countries with good cement supply

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WALLS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Concrete *(Cont'd)*:	Fibre-concrete (bagasse)	H	B	Relatively inexpensive makes good, light blocks. High heat insulation qualities	Confined mainly to areas near sugar factories. Tendency to shrinkage and moisture movement in situ	Utilize waste fibres for building materials instead of for boiler fuel		Successful tests carried out in Indonesia and Philippines. Research on use of rice husks is recommended
	Volcanic ash concrete	H	B	Inexpensive — available in volcanic areas	Trass qualities variable — strength rather low	Improved standards for local manufacture		Mainly in Indonesia to date (trass lime blocks)
Stone:	Boulders or random rubble	A	R	Inexpensive — locally available	Cannot be bonded — require excessive mortar	—	—	Confined mainly to hill areas
	Coursed rubble or ashlar	C	U	Enduring attractive appearance	Fairly expensive — requires skilled labour	—	—	Seldom applicable to low-cost work
	As concrete aggregate	C	U	—	—	—	—	Normal in form of crushed stone or rice, gravel throughout the region
	Coral	H	R	Available in many coastal areas. Light weight. A first-class source of lime and for cement manufacture	Low crushing strength and a tendency to pulverise too readily; large proportion of voids	—	—	Used for footings and road foundations in Borneo and in coastal areas elsewhere
Sheets:	Asbestos-cement (usually corrugated)	C	B	Strong — impervious readily transported — fairly enduring	Breakage common — liable to fungus growth in humid areas. The surface should be washed with dilute ammonia or 1 per cent aqueous solution of zinc silico-fluorite to remove fungus. After this, surface should be painted	Increased local manufacture in conjunction with cement factories		Widely used everywhere. Lasts better in situ than most other sheets, but fractures readily
	Corrugated galvanized iron	C	B	Impervious lightweight — readily transported. Fairly enduring	Only good qualities will withstand oxidization — unsightly. Very hot	Attention to quality		Great quantities exported to region from Japan.
	Corrugated aluminium	C	B	Very light	Expensive — must be fixed with aluminium nails. Contact with iron causes deterioration quickly	—	—	Being fairly widely used in Burma

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WALLS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Sheets (contd.)	Fibrous plaster (Gypsum)		H	Good for internal linings in timber buildings. Could be cheap	Requires high-quality fibres e.g. jute, sisal, etc.	Study Australian production techniques	Manufacture and distribute locally	Recommended for timber houses (internal linings)
	Wallboards, heat or insulating	H	R	Can be cheap if utilizing surplus timber products	Requires machine production and some capital outlay	Increase investment in small production plants	Much wider use as linings and furniture	Desirable project for West Pakistan using reed and grass
	Plywood, waterproof or otherwise	H	R	Light and strong, versatile in building construction	Price at present too high for general adoption	Increase investment in small production plants	Greater use as formwork and wall linings etc.	Major producing country: Japan
	Fibre or Chip boards	H	B	As for wall boards; coconut fibre can be pressed without additional binders	As for wall boards	Increase investment in small plants to process wood chips and coconut fibres in particular	Wider use as wall linings and ceilings etc.	FAO [illegible] valuable [illegible] in Burma, Philippines and Indonesia are processing coconut fibres successfully
Timber.	Framing members	C.H	B	Availability versatility	Short life other than first grade or when preserved	Better grading chemical impregnation	Greater emphasis on machine sawing techniques	Best of all organic construction materials
	Weather boards	H	B	Availability versatility				
	As base for mud plaster As base for "wattle and daub" (sticks and branches)				Used only in the crudest forms of construction. Subject to termite infestation			
	Pandanus and Sago Palm trunks, (gaba gaba) Indonesia Blackpalm	H	R	Inexpensive readily transported by floating - cool walls	Impermanent - better if plastered. Primitive means of construction. Habitat confined to coastal rivers and swamps	—	—	Cannot be readily treated with chemicals
	Gore palm and others							
Bamboo	Whole or split as panelling	C.H	R	Availability versatility - inexpensive. An excellent material at present greatly underrated	Whole sections harbour vermin, shorter life than timber			Emphasis should be on improvement rather than on substitution. Note anti-plague designs in Indonesia
	Woven matting on frames	C.H	R	Gives good cross ventilation. Inexpensive	Impermanence subject to fungus borer and termite infestation	Chemical impregnation and improved construction		Emphasis should be on improvement rather than on substitution
	As base for mud plaster	C.A	R	Cheapness availability	Impermanence termites			

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WALLS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible improvement: In short term	Possible improvement: In long term	Remarks
Bamboo (Cont'd)	Framing members	C H	R	Cheapness availability	Relatively short useful life (2-5 years without some sort of treatment)			Improvement called for rather than substitution
Thatches	Grass or reed	C A	R	Cool walls inexpensive — locally available	Fire risk termite and vermin infestation impermanence			Used more commonly for roofs than for walls
	Sago, nipa, pandanus, coconut fronds etc	H	R	Cool inexpensive — locally available	Fire risk, etc as for grasses reeds			Found only in coastal areas
	Sago-frond midribs "Jajuk" (Java and Sumatra)	H	R	"Jajuk" Lasts longer than most other thatches				
	Tree bark	C A	R	Inexpensive locally available	Fire risk etc, as for grasses, reeds	—	—	A very poor material
	Rammed earth (pise) Puddled earth (adobe) Unstabilized or stabilized	A	R	Cool inexpensive available everywhere		Wider application as an economy measure in all dry areas. This technique could overcome most production problems quickly if widely adopted		[illegible] recommended [illegible] projects
Rendering	Cement-sand, cement-lime-sand etc	C	U	Resistant to moisture hard surface smooth and attractive finishes	Cement expensive and subject to transport and storage problems	Increase production and use of lime		Cement commonly used on better class work
	Mud plaster stabilized	A	R	Better than unstabilized quite inexpensive	—	Introduce in rural work in conjunction with stabilized soil construction pise and adobe		Some [illegible] results in India to date using a slow-breaking bituminous emulsion
	Mud plaster unstabilized	A	R	Very inexpensive unlimited quantities locally available	Unstable — erodes easily soft un-hygienic	Soil stabilization		
Chemical preservatives	Various	C H	B	Prolongs life of organic materials up to 500 per cent	Cost up to 30 per cent of cost of material to be treated	Increased research and wider application of known techniques to timber, bamboo and thatches		Can be used also for fire-proofing
Paints	Oil paints	C	B	External timber preservative improves appearance	Relatively very expensive	—	—	Must be used on external walls in timber other than teak
	Colour washes	C A	B R	Internal and external treatment to walls of inorganic material. Mainly decorative	Needs annual renewal — no protective qualities	Cement-based paints preferable if available cheaply		Normal finish to adobe pise and mud walls
	White wash	C A	R					
	Bituminous, cement-proof synthetic base and other paints	C	B	Give good finish to various surfaces	Mostly expensive	—	—	

a C Common to [illegible] and Humid areas
A [illegible]
H [illegible] areas

b B Generally [illegible] Urban and Rural areas
U Confined [illegible] areas
R In [illegible]

WALL FINISHES (cont'd)
ROOFS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Paper	Machine or hand made	C	R	Inexpensive means of sealing matting ceilings and walls, etc. against dust and draughts	High fire risk, impermanent			Traditionally used throughout the region for wall linings, partitions and sliding panels
Mortars (for jointing)	Cement-sand	C	U	Very strong, impervious to water, necessary in burnt brick jobs, foundations	Very expensive, too strong for many materials, e.g. earth walls, pise, adobe blocks			Used normally for brick or cement block walls only
	Pozzolan cement (mass)		B	Cheaper than cement, available in volcanic areas	Strength varies	Research and wider use in volcanic areas		Commonly used in parts of Indonesia
	Lime-sand volcanic ash	H	B H	Cheaper than cement, available in volcanic areas. Better than Pozzolan cement alone	Low strength in compression	Research and wider use of lime in lieu of Portland cement to reduce expense		See Indonesian "mortars"
	Lime-sand/ lime-surkhi	C A	B	Good mortar for low strength walls	Lime quality frequently variable			Surkhi is commonly used in India, Indonesia and Pakistan
	Mud unstabilized	H	R	Inexpensive, good for earth walls	As for unstabilized walls	Soil stabilization		The most usual mortar in the area
	Mud stabilized	H	R	Inexpensive. Better than mud alone	Insufficient strength for burnt brick and concrete block walls			Best used in conjunction with stabilized blocks

ROOFS

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible Improvement: In short term	Possible Improvement: In long term	Remarks
Tiles	Clay, country tiles, shingle or pan type (pitched roofs)	C	R	Locally available, cheaper than machine made. Good drinking water catchment	Limited by transport problem to areas adjacent to kilns			Widely distributed roofing material throughout the region (Java 90 per cent)
	Arched clay pot type interlocking ("guna")	C	R	Inexpensive, require no centering, easily made by village potters	Limited roof span possible. Suitable only for dry areas	Wider dissemination of knowledge of construction technique		A new development in parts of India where arched roofs are acceptable
	Machine made Mangalore, Marseille, pan, shingle and other patterns	C	B	Strong and impervious, good water catchment, long lasting	Mostly expensive, except near factories. Liable to breakage in transport			
	Concrete, various patterns	C	B	Strong and impervious, good water catchment	More expensive than clay tiles. Very liable to breakage	Greater use in conjunction with expansion of cement production		
	Asbestos-cement shingles	C	U	Good appearance, good water catchment. Easy to maintain[c], strong, impervious	Relatively expensive except where locally produced	Greater production in conjunction with cement factories		Widely used in Korea. Mostly imported into regional countries

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A More common to Arid areas
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c See remarks for asbestos-cement wall sheets re fungus treatment

	Materials	Climatic distribution[a]	Urban or rural utilization[b]	Advantages	Disadvantages	Possible improvement: In short term	Possible improvement: In long term	Remarks
Concrete	Reinforced, monolithic	C A	U	Strong impervious	Very expensive for flat or arched roofs only			Used only in city work or high-class housing
	Precast slabs on joists	C A	U	Can be less expensive and lighter than monolithic				Not widely utilized as yet
	Reinforced inverted hollow blocks, etc.	C A	U	Can be less expensive and lighter than monolithic				
Earth:	Mud over battens and joists, unstabilized	A	R	Very inexpensive easily available cool	For flat roofs only poor water catchment high maintenance	Soil stabilization and impervious rendering		The most common roof in the arid areas
	Mud over battens and joists, stabilized	A	R	Inexpensive				
Stone	Slabbing	A	R	Local availability good water catchment	Very heavy transport costs very high			Commonly used in hill areas
	Slates	A	B R					
Processed sheets:	Corrugated galvanized iron	C	B R	Good catchment light weight impervious	Expensive mostly imported unsightly deteriorates rapidly in salty atmospheres hot	Increased local manufacture. Adoption of ceiling under and air ventilation of ceiling space to reduce heat transmission		Widely imported as substitute for local thatches, etc.
	Corrugated asbestos cement	C	B	Good catchment light impervious	Liable to breakage fungus hot Rather expensive			Lasts longer in situ than CGI
	Corrugated aluminium	C	B	Very light good catchment	Expensive almost entirely imported not as strong as CGI or CAC			
Timber	Wood shingles	H	B U	Local availability [illegible] water catchment good appearance	Fire risk fairly expensive	Chemical impregnation planting of suitable trees in local particularly [illegible]		Commonly used in Indonesia and North Borneo, Sarawak and Brunei
	Ship-lapped planks laid horizontally as weather boards	H	B U		Require first quality timber or impregnation and 45° min roof pitch	Chemical impregnation		Not very common. Only used where timber is abundant and cheap
Bamboo	Long lengths interlocking halves	H	R	Inexpensive versatile locally available	Fire risk not lasting subject to infestation			Forbidden in endemic plague areas of Indonesia as subject to rat infestation
	Halves as shingles	H	R					
Thatches	Tree bark	B H	R	Locally available inexpensive cool				Poor material usually used on temporary or very [illegible] structures
Thatches etc.	Grass and leaves	B A	R		Fire risk not lasting subject to infestation very high maintenance	Chemical impregnation		Widely used in rural areas throughout the region
	Sago, nipa, pandanus coconut etc.	H	R	Inexpensive cool locally available				Used mostly in coastal areas widely distributed use

a C [illegible]
A [illegible]
H [illegible]

b B [illegible] both Urban and Rural areas
U [illegible] Urban areas
R [illegible]

TABLE [illegible] 20/

GROUP 1—FIBRE BUILDING BOARDS, INCLUDING CHIPBOARDS

LAMINATED BOARDS	HOME PRODUCED—ESSEX IMPORTED—Not at present available	Light and inexpensive lining to walls, ceilings and partitions, showcards, display backgrounds
INSULATION BOARDS	HOME PRODUCED— CELOTEX LLOYD SUNDEALA IMPORTED— INSULITE TENTEST TREETEX ATEX L.W. SWAN, etc. HOME PRODUCED— CELOTEX HIGHLIGHT FINISH	Mainly of [illegible] in. thickness which is used for thermal and sound insulation of walls, ceilings and partitions. Thinner boards of [illegible] in. and [illegible] in. thickness for light wall lining. As above but with smooth white finish on one side.
INSULATION BOARD ACOUSTIC TILES	IMPORTED— UNITEX PERTONIT Standard PERTONIT Extra (Hardboard Faced) TENTEST Russell Warren Tiles and Boards	Sound absorbing TILES used in offices, banks, hospitals, telephone booths, etc.
MEDIUM HARD BOARDS	HOME PRODUCED— LLOYD SUNDEALA and SUNDEALA FLAMEPROOF	Interior panelling interior notice boards requiring medium hard surface suitable for oil paint finishes.
PANEL BOARDS	IMPORTED— KRAMFORS L.W. P.V.	A ¼ in. board with a hard smooth surface ideal for panelling, etc.
HARDBOARDS	HOME PRODUCED— CELOTEX LLOYD SUNDEALA IMPORTED— INSULITE KARLIT NOSTEX L.W. MASONITE ROYAL FIBONITE FIBREX, etc.	Hard smooth surface for oil or cellulose paint finishes. For panelling of walls, ceilings and partitions, fixtures, furniture. Properly treated—for exterior signs. Ideal base for veneering exotic woods.
HARDBOARDS PERFORATED	IMPORTED— KARLIT UNITEX	Perforations of various sizes to allow passage of extraneous noise through to an absorbing material behind. Also a popular "peg-board" for display purposes.
HARDBOARDS EMBOSSED SURFACE	IMPORTED— CASTEX HOMANITE LEATHER BOARD	A water resistant board reeded, fluted or reed in check pattern for display work or panelling. Light oak or mahogany finish for panelling, shop interiors, display backgrounds, etc.
SUPER OR ULTRA-HARDBOARDS	HOME PRODUCED— LLOYD Super SUNDEALA Ultra IMPORTED— L.W. Ultra MASONITE Tempered Preswood ROYAL Oil Tempered	Extremely hard throughout thickness and smooth surface. Will do all that HARDBOARDS can PLUS! Ideal for concrete form lining and all forms of exterior work.
RESIN BONDED CHIPBOARDS	HOME PRODUCED— BERBOARD PLIMBERITE WEYROC BERBOARD WATER REPELLENT GRADE	These boards are of solid structure up to [illegible] in. thickness. Suitable for single board partitions. An ideal HARD CORE for veneering bedends, wardrobes, desks, etc. Suitable for temporary shuttering to precast and in situ concrete, its strength saves much supporting timber.
COMPOSITE BOARDS	"K" Panel	PREFABRICATED PARTITION PANEL with insulating filling.

GROUP 2—ASBESTOS BOARDS

ASBESTOS CEMENT PRODUCTS	POILITE FLAT BUILDING SHEET .. FULLY COMPRESSED FLAT SHEET .. FLEXIBLE FLAT SHEET EVERITE 3 in. CORRUGATED SHEET BIGSIX 6 in. .. .. TRAFFORD TILE FLUTED SHEET	[illegible] of [illegible], garages, farm buildings, etc. Skirtings [illegible]—shelving Curved lining work Roofs and verticals of small buildings Roofs and verticals of large buildings Roofs and verticals of large buildings Display backgrounds, shop stall risers, fascias, etc.
ASBESTOS WALLBOARDS	TURNALL ETERNIT "D" KIMOLOBOARD PLUTO Resin bonded HARDBOARD ASBESTOLUX	FIREPROOF wallboards suit[illegible] any kind of paint finish. Ideal for EXHIBITION STANDS [illegible] THEATRES and other jobs where FIRE RESISTANCE IS ESSENTIAL.

20/ As manufactured by C.F. Anderson and Son Ltd., London.

GROUP 3—PLASTER BOARDS WOODWOOL SLABS AND STRAWBOARDS

PLASTER WALL AND CEILING BOARDS	GYPROC PARAMOUNT P. P. G. AND PIONEER	Large size boards of solid plaster core with stout paper both sides. One side suitable for direct paint or distemper finish, other side for using boards as base for plaster finish. Also supplied with alum[illegible] one side for thermal insulation.
PLASTER BASE LATH	THISTLE P. P. G. ROCBOARD GYPROC	[illegible] size plaster core boards for use as base for 1 or 2 coat plaster finish. Similar to above, but with rounded long edges to avoid use of scrim reinforcement of joints.
PLASTER BOARD PLANK	GYPROC PARAMOUNT	Used as solid [illegible] in. core for application of [illegible] in. thickness of plaster either side to form a 2 in. solid partition.
PLASTER BOARD PARTITION	PARAMOUNT DRY PARTITION	Prefabricated partition units consisting of [illegible] in. or [illegible] in. plaster, either side of cellular construction core.
WOODWOOL SLABS	GYPKLITH SUPALITH CENTURY HALCRETE	Woodwool bonded with cement into 6 ft. by 2 ft. slabs 1 in. to 3 in. thick for building up solid partitions and walls for rendering with plaster or cement.
STRAWBOARDS	STRAMIT	Solid board 2 in. thick with compressed straw core and paper facing and edging. Suitable for speedy erection of partitions using minimum of framing support. In standard sizes or cut to special requirements.

GROUP 4—LAMINATED PLASTIC BOARDS

LAMINATED PLASTIC BOARDS **Commercial grade**	DELARON HOLOPLAST PANAPLEX PANAX	Smooth hard surfaces both sides and of very dense substance. For panelling, fitments, signs, cut-outs, display work, etc. In two colours Brown and Black. Thicknesses [illegible] in. upwards and sizes up to 9 ft. by 4 ft.
	HOLOPLAST STRUCTURAL PANELS CORROPLAST CORRUGATED SHEET	[illegible] in. and 1[illegible] in. thickness. Used in all types of partitioning Laminated plastic light weight roofing and side sheeting.

Other Decorative types of Laminated Plastic Boards will be found in Group 5

GROUP 5—DECORATIVE AND DECORATED BOARDS

DECORATIVE PLASTIC BOARDS	FORMICA. WARERITE	DECORATIVE colours and patterns incorporated during manufacture. A hard smooth abrasion resistant surface impervious to water, alcohol and cannot be stained by ink, fruit juices, etc. Standard size boards in stock or special sizes cut to order.
DECORATED BOARDS	LACONITE & PANALAC on PLASTIC and HARDBOARD	Stove enamel finishes on plastic and hardboards. Plain colours, marbles and wood grain reproductions. Also supplied with tile pattern on hardboard.
DECORATIVE ASBESTOS	GRANITE TURNALL MARBLE & STIPPLE GLAZE	Smooth hard surface in various mottled colours Various marble effects on a smooth hard surface.

GROUP 6—VENEERED BOARDS

VENEERED HARDBOARDS	AVODIRE, OAK, MAHOGANY, WALNUT, SYCAMORE and other Decorative Veneers on Surface with balancing Veneer on reverse	These veneered boards provide a high class wood surface panelling suitable for lining walls of offices, shops and showrooms, restaurants and hotels. Also used for furniture, fitments, etc.
VENEERED CHIPBOARDS	As above	Chipboards up to [illegible] in. thickness [illegible] veneered with decorative veneers to provide solid panelling for jobs where structural strength is important.

GROUP 7—WALL BOARD ACCESSORIES

JOINT COVERINGS	PAPER FACED LINEN TAPE	Covering insulation board joints.
	COTTON SCRIM	Covering plaster and insulation joints.
	HESSIAN SCRIM	Reinforcing joints under plaster.
	ANAGLYPTA Corrugated Paper	Decorative covering for joints, allowing for movement.
	INSULATION BOARD STRIPS	Single or double bevel edges for insulation boards.
	HARDBOARD STRIPS	¼ in. thick square edges for all boards.
	FLEXIBLE PLASTIC STRIPS	In various colours of insert and base. **Nails through base only are** unseen when insert fitted.
	RIGID PLASTIC SECTIONS	To fix plastic or hardboards up to ¼ in. thick.
	RIGID ALUMINIUM SECTIONS	do. do. do.
	do. do. do.	Table edging with coloured plastic insert.
PRIMERS	HARDBOARD PRIMER	To seal surface of hardboard for painting.
	ANTIZORB PRIMER	To seal lime content in asbestos cement.
	TEMPRIMA	To seal surface of resin bonded chipboards.
ADHESIVES	BOSCOTEX PRIMER and BOSCOPRENE ADHESIVE	To stick laminated plastic or metals to wood, fibre board or chipboard.
	SYNTHAPRUFE	Liquid bituminous adhesive.
	FORTIL	Liquid cement for sticking various boards.
	AEROLITE 306 and HARDENER GU.X	Bonding laminated plastic to wood.
	BOSTIK "C" and BONDASTIK	Bonding insulation board tiles, etc., to concrete or wood.
NAILS	RUSTPROOFED	All types and sizes for various boards.
BRACKET FIXING SCREWS	RAWLANCHORS, TOGGLE BOLTS and RAWLNUTS	For fixing articles, brackets, etc., to various boards having a cavity behind.
WALLBOARD TOOLS	JIFFY CUTTER	For cutting, bevelling or "V" grooving insulation boards.
	LACO CUTTER	Hand cutter for asbestos cement sheets.
	FLUTING TOOL	Fluting tile and other patterns on hardboards.
ANCILLARY MATERIALS	CABOT'S QUILT	Insulating blanket for cavity partitions.
	FIBREGLASS	do. do. do.
	ARDOR Aluminium Foil	Additional thermal insulation under roofs.
	SISALKRAFT	Waterproof building paper for roof insulation.
	INSULEX	Mineral loose fill for thermal insulation.

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9 · 8 . 72