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TIMBER AS BUILDING MATERIAL IN CENTRAL AMERICA**

by

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INTRODUCTION

The most subtle difference discernible between the primitive cultures of the Old World and American cultures lies in the fact that while the former were born and lived in close contact with the forests and its products, our cultures abandoned and forgot them all too soon.

Just like water, the tree is linked to the nature of man, and we strive to make use of it as far as we can. But with us the potential for doing so efficiently is still very low.

A comparison between on the one hand the possibilities of the Central American region, one of the first in the world as regards area under tree cover and as regards forestry potential, which constitutes a prime characteristic of the region, and on the other hand one of the lowest figures for per capita consumption of timber will induce us to devote greater attention and interest to this ancient material, which would well be able to enhance the quality of the most humble dwellings. Since the building industry is the greatest consumer of primary and secondary timber products, any development of this activity would have a double impact on the life of the region.

This paper is intended to present ideas and general guidelines which might be of value for other studies on timber as a building material and on encouraging its use as a result of an improvement in the techniques for its application.

1. TIMBER AS A BUILDING MATERIAL

The possibilities of using timber for construction purposes can be polarized into three different but associated fields, namely: temporary structures (encampments, shuttering, etc.), permanent structures (timber framing) and auxiliary and ornamental structures (doors, stairways, etc.).

In our milieu, the first and third of the above uses are known, but not the second, due to the operation of a number of factors, both real and imaginary, which hamper its development.

The general outlines of this situation can be defined essentially the following terms: firstly, as indicated above, we have available a guaranteed source of material suitable for building work, namely the timber of our great forests; and secondly, the shortage of low-cost housing and other structures.

We must therefore ask ourselves what the reasons are which have prevented the establishment of the expected logical relationship between the above two facts.

The lack of a tradition rooted in the use of timber will certainly have had a significant effect and is probably one of the main causes, while the almost total ignorance of the properties and potential of timber, the disappearance or the deterioration of good craftsmanship, and certain popular beliefs regarding the liability of timber to destructive agents have, taken together, called into being another adverse factor: the absence of a forest industry able to provide the necessary building materials.

Many of the undesirable characteristics attributed to timber are mere suppositions, with the result that building methods do not take account of the various factors governing the behaviour of this material, and the outcome is thus obviously unfavourable. These apparent difficulties do not mean, however, that our timber is useless as a building material; they mean that it is necessary to eliminate unfavourable factors in order to take advantage of the numerous advantages of timber for building purposes. In this connection it is sufficient to observe what has been achieved with suitable methods which bring out the real nature of this material.

The advantages and characteristics of timber can be summarized as follows:

- Its ability satisfactorily to meet almost all the physical and mechanical requirements arising in architectural work, including its resistance to corrosive substances and vapours;

- Its favourable strength-to-weight ratio, which renders it highly suitable for prefabrication, transport and working processes;

- With modern methods of assembly it is possible to fabricate elements of almost any dimension and shape, limited only by the technical possibilities of erection;

- Its appearance and clean finish;

- The great advantage of having it available in almost all regions (natural and artificial forests), and on a renewable basis;

- The relative simplicity and low cost of the equipment required for processing it.

Other important considerations relate to the varied characteristics of tropical and of temperate forests, and to conifers in tropical areas, a situation which renders necessary greater differentiation between the various groups of species, properties and uses. It would show a lack of judgement to assign precisely the same uses and treatments to conifers and to broad-leafed trees, and to expect equally satisfactory results.

In this connection it is interesting to note that the first aircraft were made of wood, but that this was indeed not Douglas fir.

It is the small and subtle differences which lead to the failure of a particular timber species, when it is called upon to fulfil an unsuitable function. This occurs because, unlike in the case of other materials, all factors are equally important.

A large number of mistakes in the use of timber start with incorrect conversion and seasoning and continue with the action of the climate, which may have an unfavourable effect on dimensional stability and strength.

As has frequently been shown, fire is not a primary cause of destruction, and in fact timber behaves better than metal materials, due to the fact that its low conductivity and high specific heat render it advantageous for many uses.

The susceptibility of certain tree species to action by destructive agents can be reduced by injecting artificial compounds and by appropriate structural treatment; in this connection, future regulations should lay down the reasonable period of time during which a wooden structure should resist the action of each specific harmful agent.

The measures indicated above, apart from making it possible to use many species with a low natural resistance to destructive agents, can break down the popular psychosis resisting the use of timber for dwellings, based on a general fear of all species. This can be done without any significant increase in costs.

Human influence on the final behaviour of timber is decisive, unlike the case of inert materials, and timber suffers the effect of inappropriate and/or untimely handling.

In our virgin forests, the process which it is most important and at the same time easiest to control is the conversion (sawing) of timber. The quality and the final characteristics of constructional timber reflect the methods and forms of conversion to a large degree. We still do not have technical standards adequate for this purpose, except in exceptional cases such as those of timber products for export.

2. TIMBER HOUSING

Timber can be used alone to manufacture all the parts of a dwelling house with the exception of the hearth and chimney. Nevertheless, in the majority of cases wood is combined with other building materials such as clay, lime, cement, stone, iron, plastic, etc., depending on relative convenience, availability and price.

Wood panels constitute the basis of prefabrication in countries where the demand for housing is such that only wood can be relied upon to meet requirements such as one and a half million dwellings per year (US Department of Agriculture Forest Services. M. Publications No. 861).

If we look at the use of timber in countries such as the United States, the Soviet Union, the United Kingdom, New Zealand, Japan, etc., the statistics show that, both in countries with large forestry resources and in those without them, more timber is used per capita and per year in the developed than in the developing countries; and this in spite of the fact that we have the greatest forestry potential in the world.

Here in Latin America an effort is being made to develop the timber industry; Chile, for example, has a well-defined housing policy with regard to the use of wood, taking the form of tax reliefs and government subsidies ranging from tree plantations, primary conversion, the manufacture of prefabricated dwellings to export operations, for example of cultivated conifer timber.

Colombia, for its part, has launched an extensive plan of forestry development aimed at exploiting its very valuable tropical forest resources.

Mention may be made of a number of the advantages associated with using timber for dwelling house construction, positive aspects which have induced governments to introduce clearly defined policies regarding the solution of the housing problem.

(a) Timber is a natural, renewable resource and easy to work.

(b) It does not call for substantial investment for its conversion and for the manufacture of structural components.

(c) Its low weight-to-strength ratio renders it much more economic and easy to transport and deliver to inaccessible sites.

(d) Prefabrication with wood permits installation in a dry state, i.e., there is no need to wait for the structure to dry out, which saves time in erection and use; it also accelerates the turnover of invested capital, thus resulting in a general saving.

(e) Wooden houses can be repaired and adapted at low cost.

On the other hand, for placing dwelling house construction on an industrialized footing, certain general basic requirements exist, such as continuity of demand, standardization and incorporation of the various components of the dwelling, mechanization to a greater or lesser degree depending on the employment policy of the country in question, and ongoing scientific and industrial research.

3. TIMBER STRUCTURES

As a structural material wood may present itself in three forms:

Firstly, in the form of natural timber, sawn from the tree, and constituting roof or floor beams, columns, etc.

Secondly, we have laminated wood, whether nailed or bonded, taking the form of boards 1/2 to 3 inches in thickness, of a certain width, and by means of joints, available in any desired length; these components permit normal spans of 15 to 45 metres, and exceptionally may attain spans of 100 and 120 metres as in the case of laminated arches in France and Germany, and large bridges in the Netherlands.

The third type of structural component is represented by plywood, whose structural properties in comparison with solid material represent yet another advance in the application of technology to nature.

The strength/weight ratio of timber is equal to that of steel. The weight of structural timber is one fifth of that of concrete, and in spite of the fact that in terms of volume it is frequently dearer than concrete, its property of lightness yields savings in transport, erection costs, provision of foundations, reinforcement, etc.

Wood is highly resistant to corrosion, and therefore can be used in environments subject to chemical attack.

It can be worked and cut easily, and joining by means of simple components such as nails is very easy and technically reliable.

Having thus set forth in general outline the great advantages of timber as a building material, there then emerges a preliminary and at first sight convincing argument: if timber is such a good material, why have we used and why do we continue to use steel and concrete in practically all buildings?

The reason lies in the belief widely held by engineers and builders that wood is a unreliable material and in the prevailing ignorance regarding its physical and mechanical properties, together with its features of strength and the structural, mechanical and chemical combinations which are possible.

Above all, variation exists throughout the world, nobody and nothing is the same as the others, and it is science and technology which attempt to create uniformity. In the case of steel of course we produce and fabricate it in accordance with given specifications, and apply science and technology together with a lot of money in the effort to ensure uniformity. But timber is naturally already made for us, and the only way to secure uniformity is by selection, which is just as reasonable a control procedure as are, for example, the controls carried out during steel manufacture.

As regards variation or variability, a civil engineer could well be more alarmed by the variations occurring in reinforced concrete; after all, it is always possible to take a stroll around a wooden structure and, in the light of the presence of knots, cross-graining, etc., to assess the quality and hence the real strength of each timber component; in a reinforced concrete structure, on the other hand, there is the possibility that, for example, a few reinforcement rods have been forgotten. In any case, it is a fact that under normal conditions there are considerable variations in reinforced concrete. Nevertheless it continues to be used for construction work. So I do not believe that we should be frightened of using timber.

What should always be remembered is that timber is a natural material, and that in order to obtain both uniformity and the minimum design values it is necessary to apply the method of selection.

4. COMPARISON OF STEEL AND CONCRETE DESIGNS

4.1 Concrete

For persons familiar with concrete design, it is relatively easy to understand timber design, because the properties of wood are very similar to those of concrete reinforced with straight rods but without transverse reinforcement, with the exception that the weight of wood is one fifth of that of concrete.

The bending, compressive and transverse working stresses are very similar to those of reinforced concrete and, disregarding the effect of weight, it may be said that the dimensions of wooden components are very similar to those in concrete.

Concrete is relatively cheap to produce and, volume for volume, costs less than structural timber and much less, for example, than laminated wood. Hence in terms of cost wood can only compete with concrete where the weight of the structural component has some significance. This obvicusly occurs in the case of roofing - in roof beams but not necessarily in columns. A reinforced concrete column will be cheaper than the same thing in wood.

4.2 Steel

Steel has much greater uniformity and its behaviour in all three directions is uniform compared with the anisotropy of wood; the compressive strength of the latter along the grain may be six to eight times that of the corresponding strength perpendicular to the grain. The cross-sectional strength of wood presents approximately one tenth of the bending stresses. These figures will illustrate the fact that wood has different properties in different directions, and hence persons accustomed to designing steel will have greater difficulties in visualizing the spatial structures and volumes of buildings made of wood.

4.3 Seismic forces

It should not be forgotten that wood is more resistent to short-duration stresses (earthquakes and winds) than permanent stresses, and countries such as Australia, the United Kingdom, the United States etc. accord to wood in their respective Design Codes working stresses some 50 per cent higher for short-duration loadings. The behaviour of constructional joints and assemblies depends on the wood, and hence generally follows the same tendency.

Adding all this to the low weight of timber construction, a wooden building offers advantages as against those of masonry and/or concrete.

A proof of this is the increase in timber construction in Chile (there are at present 25 plants manufacturing wooden houses) and Japan, where almost the whole of dwelling-house roofing is constructed of wood or wood-based materials.

5. TECHNICAL AND LEGAL ASPECTS

In spite of the fact that wood has been used as a building material since time immemorial, it has experienced different rates of progress in different parts of the world. Since in temperate countries and forests wood has always kept pace with technical advances in building and hence continues to form part of the wide range of technical alternatives available to the builder, the technical and legal provisions governing building have developed taking account of this material. But in other countries, particularly in subtropical areas and more specifically in developing countries possessing tropical forest species and timber different from that of the temperate forests, there occurred a technical stagnation in the use and development of timber, and at the beginning of the present century new building materials appeared opening up an entirely new world in the technology of design and construction, accompanied by particular legal standards and regulations and a complete system of financing, manufacture and marketing.

Hence the great difference between those countries using timber as a basic construction material and our countries resides on the one hand in our technological fossilization in traditional methods of timber construction and our interpretation of modernity in terms of new building materials and technologies (concrete, steel, etc.) and on the other hand in the great technical strides achieved in Europe and North America as regards engineering in wood. The result has been that our Design Codes, Building Regulations etc. not only have forgotten to keep timber up to date but have relegated it to a frankly decorative and carpentering role. On the other hand, they have introduced important technical features regarding the new materials, have controlled and regulated their use and abuse, and have assigned the relevant liabilities. This fully meets the legal requirements of the building industry and inspires full financial confidence, thus permitting industry and commerce to develop.

Consequently if we wish to promote timber as a competitive alternative building material, we must regard it as something new for introduction onto the market, with all its technical advantages and above all with elimination of the obstacles which tradition and ignorance have allowed into the present technical and legal provisions governing building.

6. SECTORS CONNECTED WITH TIMBER DEVELOPMENT

6.1 Technical sector

This identifies the material and defines its properties, possibilities and physical and chemical changes. It studies its behaviour under stresses and their transmission to other elements.

It defines the safety and behaviour of timber as a function of time, use, wear and tear and so on, and offers sound design values.

6.2 Legal sector

Standards governing production of the material are issued on the basis of technological, industrial and marketing considerations:

- Dimensioning;
- Strength;
- Types and categories;
- Methods of changing its physical and chemical characteristics.

In the light of the good quality of the material, its maximum parameters, limitations, maintenance requirements and special features, building standards and specifications are issued which taken together form part of the Building Regulations, which in its turn frequently rest or rely on the Codes of Good Practice embodying all available experience in the proper use and care of the material.

6.3 Financial sector

In many places the financing of projects involving new building materials takes an experimental form of moderate scope, once agreement is reached with the legal sector as to the availability of sufficient data to establish the inspections and controls which both the legal and the financial sectors require.

This helps to define appropriate technical specifications which will ensure the recovery of the investment through the correct employment of new material. Similarly, there should be no doubt regarding the permanence of the building (temporary structure), which would require different financial treatment.

The insurance companies play a very important role, because they are the technical agents who evaluate the new product and the new techniques. The various forms of input or contributions should be revised during implementation of the project, if it is a case of prefabrication, and liabilities and profits, completion deadlines and percentages of the total cost must be determined. In a word, all the factors in which the new system differs from the traditional one, so as to secure agreement similar to that existing between the sectors.

6.4 Industrial or production sector

In most cases this sector pioneers the introduction of new techniques and has attempted their introduction before the regulatory provisions emanating from research have appeared.

However, only after sound financing has been assured can one speak of the development of production, and it is then that the new industrial techniques of material conversion and lowering of costs, including quality controls etc., make their appearance - all techniques which the research sector outlined and predicted but had no opportunity to test on an industrial basis.

6.5 Commercial sector

This develops automatically when demand and industrial supply are there, but education is necessary; first by fixing the rules of the game as regards quality, costs and delivery deadlines, and then standardizing the whole operation.

As a result it may be hoped that reliable systems for marketing the new product will be established.

7. DEVELOPMENT OF THE USE OF TIMBER IN BUILDING WORK

If we turn to the annexed diagram we shall see that there is some reference to the subjects mentioned in each sector, but much more is done in the technical, and partly the legal, sectors. The financial sector has not been touched upon apparently because it is normal practice with other materials that the appropriate technical specifications and controls and inspections should be derived from the regulations approved by the competent authorities. Thus, the building regulations are approved, for example, in the Electrical Code, and, basing themselves thereon, the financial sector and its technicians will soon produce their own specifications (very similar) adapted to their requirements.

During the revision, for example, of the building regulations of numerous Latin American countries, it has been observed that timber as a modern building material, with all its characteristics, qualities and problems, has not been included. In some cases there remain traces of the technical regulations dating from the handicraft age, while in other cases the use of the material is limited, dimensions are restricted and on occasion utilization is completely and expressly prohibited.

That is why there has arisen the idea of having a Code of Practice which, at the same time as specifically describing each stage in the design of wooden buildings, lays down very precise directives for calculation and fabrication, providing building guidelines appropriate to the material. All this having the purpose of enlightening and directing the designer, builder, user and the authorities evaluating and controlling good professional practice.

In the case of timber, a number of specific points relating to the following technical aspects of regulations should be mentioned:

(a) Scope and limitations;

(b) Town planning;

(c) Design and structural calculation;

(d) Architectural aspects;

(e) Particular considerations associated with electricity and sanitary aspects;

(f) Recommendations.

Annex 1

TIMBER IN HISTORY

THE EARLIEST TIMES

The use of timber as a building material probably predates that of stone. The nomads of prehistoric times, when they were unable to find caves in which to shelter, seemed to have preferred constructing huts of branches covered with mud or hides to the difficult work of erecting stone walls.

Owing to the relatively poor durability of wood, no remains of these first dwellings have been preserved. However, there is evidence which indirectly makes it possible to reconstruct their general features. In some cases traces have been found of timber components in the ground in which they were inserted; the wood has disappeared but the impression remains.

A study of the dwellings of primitive peoples of the present day assists us to visualize what these ancient structures were like. The slide shows some details of the usual methods of assembly. Such procedures persisted until the development of metallurgy, the invention of the nail, screw and bolt and the first use of metal tools. The only tools available to the ancient builders were hatchets, wedges and knives of stone, possibly saws made of bone, and, for attachment purposes, ropes made of strips of leather or material of plant origin. For cutting wood use was perhaps made of fire.

As peoples became sedentary, their buildings took on a more permanent character. In place of branches logs were used. Nature itself showed the way: the standing tree suggests the column, and the fallen tree the beam. The use of heavy components for walls and roofs resulted in dwellings of rectangular plan. An example from the palaeolithic age is the traces of six rectangular dwellings, 3 metres wide by 12 metres long, discovered in Russia. These structures were sunk into the ground up to a depth of about 3 metres. They were entered via a ramp. The walls were lined with logs and the roof was also formed of logs covered with earth. These structures are estimated to be about 20,000 years old. In Siberia similar dwellings, which are very suitable for cold climates, are still constructed today.

Systems based on horizontal logs predominated in areas where there was an abundance of timber, as was the case over a large part of northern Europe. This led in the Scandinavian countries and other regions to the technique characterized by joining logs at the corners by grooves or slots. This system of construction was simple, as will be readily understood. The roof was normally made of lighter components. The system was introduced into the United States by Scandinavian colonists and was adopted by the pioneers in the West under the well known guise of the "log cabin". One of the reasons for its success was that it did not require nails, the price of which was high until their manufacture was industrialized. Even today recreational buildings in rustic style are still being constructed in this manner.

The systems consisting of wooden post and beam frameworks were common in regions with limited timber resources. The posts were embedded directly into the ground. The spaces between the posts were filled with interwoven branches and mud ("wattle and daub" in English) and, later, with various types of masonry.

An interesting variation is the lake dwelling, constructed on piles or posts over water. The best known example is represented by the remains of a village discovered in the Lake of Zurich in Switzerland. Another lake village was at

Glastonbury in England. Traces of similar structures also exist in Italy and Ireland. The illustration gives an idea of the general features of lake villages. Nowadays similar buildings are found in the salt marshes of Portugal, in Oceania and in some regions of South America and Africa.

In the Mediterranean area and the near East, in spite of the fact that timber was scarcer than in the rest of Europe, wooden frame structures filled with rubble, clay or oven-baked bricks were common from the earliest times. Even where the walls were built exclusively of masonry, the roofs and floors were normally of wood. The illustration reproduces a dwelling of this type at Ur, dating from approximately 2000 BC. The resemblance with constructional systems used until quite recent times both in the Mediterranean area and in Latin America is clearly apparent.

PRE-HISPANIC LATIN AMERICA

Buildings dating from the height of the Teotihuacan civilization employed mainly adobe (sun-baked brick) and masonry. However, wood was used for strengthening walls and columns, just as today ordinary concrete is reinforced with steel. Wood was likewise employed to form flat roofs of beams, round poles and reeds covered with earth.

A distinctive feature of the building systems in the Valle de Méjico was the use of short wooden stakes to form a foundation for heavy structures resting on the yielding clay soils found in the region. Remains of these stakes are still being discovered in excavations carried out in the centre of present-day Mexico City.

Stone is the outstanding material in the large buildings erected by the Mayas. In some cases pieces of hard wood were used to form the lintels of temple entrances. Some of these lintels have been preserved until today.

A notable example of the persistence of a constructional form is represented by the typical Yucatan hut, oval in plan, with whitewashed walls made of beams, intertwined branches and mud, with the pitched roof of straw and palm leaf. Huts of this type, which are still numerous in Yucatan, are similar to those depicted on the freizes and paintings of Maya villages and in the drawings in the Codices.

THE CLASSICAL PERIOD

As in other regions, the first buildings in the Mediterranean countries were of wood. This can be appreciated in the layout of the large stone structures of the golden age of Greece, which reflected the structural components inherent in wooden buildings, particularly the column and the lintel. Although stone was the material preferred for the walls of these buildings, wood continued to be used for the roofs, as in the older buildings, owing to its ability to bridge large spans.

Among the Romans, the structural applications of wood begin to show certain technical refinements. In the age of Augustus, Vitruvius in his Treatise "De Architectura" gave recommendations on the most advantageous uses of the various tree species, on the cutting of wood and on its use in building.

While the Greeks confined themselves to using wood for columns and lintels, the Romans, by an intuitive process, evolved the principle of frame construction, as in the ancient Basilica of San Paolo at Rome, with a span of more than 23 metres.

Timber was an essential material in the military constructions of the Romans. Square-dressed logs were the basic component for the buildings and stockades of their camps and fortifications.

THE MIDDLE AGES

The Middle Ages saw the flowering of the use of wood as a building material. In northern and central Europe, timber was the principal material used in dwellings and lesser structures of all kinds. Stone was reserved for monumental buildings. Even in the Mediterranean region, where there was always less wood available than in the north, wood continued to be used as a reinforcement for walls and for roofing.

However, it was probably in the British Isles that the use of timber reached the highest technical and artistic refinement. Out of the primitive huts of the earliest times there emerged during the Middle Ages various systems of construction.

A first procedure peculiar to England was the "cruck" house. "Crucks" were curved log sections worked to the appropriate shape, with which - by dividing them in the middle - a kind of arch was formed. These arches constituted the main bearing components. For joints hard wood pegs were used. The walls, which might be of reed or branches covered with mud, did not normally contribute to supporting the roof, which was made of thatch or, less frequently, of some other material. This system was employed for centuries both for dwellings and for granaries, stables and similar buildings. Even today some examples survive.

When wood began to be scarce, cruck construction was replaced by post and lintel systems, which required less wood and made it possible to use smaller-section components. This was the origin of the typical mediaeval half-timbered style with wall fillings of brushwood and mud or some type of masonry, which still survives in the old settlements in Great Britain and in a large part of Europe.

In churches and other buildings of importance, it was in the construction of the roofs that stone was combined with timber, and where the inventiveness and artistic sense of the English craftsmen emerged in its clearest form.

Another use of timber during the Middle Ages in England, less spectacular than some of those described above, but of interest none the less, concerned buildings for agricultural purposes. Many of the granaries and stables built in the United States and Canada since the time of the first colonists until our own days show the influence of the old English structures.

NORTHERN EUROPE

In the British Isles, the progessive scarcity of timber placed restrictions on its use as a building material even during the Middle Ages. For ordinary buildings wood was used in combination with masonry for the walls. In churches and palaces the walls were of stone and wood was kept for the roofs. In the northern European countries, where there was no significant shortage of timber, wood continued to be the building material par excellence, even for monumental structures. The most interesting applications are the "stave" churches in the Scandinavian countries and the Russian churches.

The structural system of the Scandinavian churches, which was mainly practised from the 11th to the 14th centuries, was based on the use of vertical load-bearing components stiffened in their upper parts by pieces forming a sort of triangulation. Boards were used for filling in spaces. Generally the posts were placed on stone footings instead of being inserted directly into the ground, as in previous periods, which prolonged their lifetime. A number of churches of this type have survived.

The Russian churches are characterized by their octagonal plan and the bizarre forms of their domes. One of the best known is the Church of the Transfiguration at Kizhi in Karelia, built in 1714.

FROM THE RENAISSANCE TO MODERN TIMES

During the centuries following the Renaissance substantial changes in the use of timber for building can be observed. With Galileo, Coulomb, Euler, Newton, Young, Hooke and others there began to emerge scientific principles for the rational analysis of the behaviour of materials and of structures. In France Buffon tested hundreds of beams for Louis XV's Minister of Marine. In 1792 Belidor published "La Science des Ingénieurs", the first scientifically-based treatise on engineering.

The 19th century was characterized by the mechanization of industrial production, a process which is reflected in the structural applications of timber. The mechanization of nail manufacture, which had previously been conducted by craft methods, meant that nails became readily available at low cost, resulting in considerable simplification for joining pieces of timber. The use of bolts was also expanded. The saw in its various forms tended to replace the axe and a start was made on the mass production of standard-section wood details by mechanized means. As a result of these technical advances, the middle of the 19th century saw the birth of the principle of prefabrication: in 1854 some prefabricated houses capable of being dismantled were shown at the International Exhibition in Paris.

UNITED STATES AND CANADA

Whereas generally speaking the use of timber began to decline in Europe as from the Renaissance, as a consequence of the scarcity of natural resources and the appearance of new building materials, in the United States timber continues to retain considerable importance until our own day, particularly for dwelling-house construction.

The wood frame buildings with masonry or rubble filling constructed by the first inhabitants of the eastern United States reflect the influence of the English systems of construction.

The illustration reproduces an example of a "frame house", with a covering of wooden boards, of the type usual in New England and other parts of the United States. Typical details of coverings are also sho

The "balloon frame" system was developed around 1830. It represents an evolution of the frame houses of New England, whereby the heavy timbers of the latter are replaced by light, standard-section members joined by nails and located relatively short distances apart. It was the introduction of the mass production of nails which governed the success of the balloon frame system. Its simplicity and lightness led to its spreading through all the regions in the north of the continent.

One consequence of the success of the balloon frame house was the development of the prefabricated wooden housing industry. As early as 1860 there existed in the United States a number of firms which shipped by rail prefabricated components for dwelling houses. By 1880 the prefabrication of wooden buildings of various types had become a great industry, whose importance has continued to grow until our own times.

LATIN AMERICA

On their arrival in America the Spaniards found substantial forestry resources at their disposal. Nevertheless, in their country of origin the use of timber, owing to its scarcity, was not so deep-rooted as in England; building work was marked principally by masonry, and the use of timber was restricted to reinforcing walls and making various types of roofing and flooring. At the same time, they encountered a culture in which monumental structures were of stone, while in general timber was limited to more modest dwelling houses. In these conditions it was natural that the buildings erected by the Spanish colonists should reflect the building techniques of their country of origin, both on grounds of tradition and in order to make use of the local inhabitants' experience of building in stone. Thus, the important buildings of the colonial epoch are characterized principally by masonry walls and vaults, while for floors and some roofs use was made of large timber beams supporting various materials. These building systems persisted until well into the 19th century, when steel was introduced as a building material.

In popular architecture, timber acquires some importance in certain regions. A system still much used for roofs and floors is the so-called "Catalan vault" consisting of beams supporting two or more layers of brick joined with gypsum mortar. In some areas timber is used as the main building material, although in a fairly primitive form. For roofs recourse is had to tiles, laminates or shingles. In some regions houses are built of logs with roofs of shingle or laminate.

THE DEVELOPMENT OF WOODEN BRIDGES

Since the earliest times bridges have been one of the areas of structural engineering in which timber has found very interesting applications.

The first bridges consisted of tree trunks felled over a stream or ravine. An interesting variant is the cantilever construction, used by the ancient Gauls and Chinese. In order to cross spans greater than was possible with tree trunks simple trusses were developed. The illustration shows the way in which, in an intuitive manner, the first bridge trusses may have emerged.

The Romans constructed wooden bridges of considerable size. For his invasion of Germany Julius Caesar threw a bridge of trestles and beams across the Rhine, with a total length of about 400 metres, in the short time of 10 days. More interesting from a structural point of view was the bridge built on the Danube by Apolodorus of Damascus in the year 99 A.D., during the reign of the Emperor Trajan. The general features of this bridge were deduced from a relief on the Column of Trajan. Apolodorus made use of the principle of triangulation to construct wooden trusses resting on arches, also of timber. The width of the roadway was about 6.6 metres and the total length of the bridge about 1,200 metres, divided into 20 bays.

During the Renaissance, Palladio, who has already been mentioned in section 3.6 in connection with the use of roof trusses, applied this type of construction to a bridge on the river Cismone, embodying in it characteristics very similar to those of some modern truss bridges.

During the 18th century the Swiss built a series of timber bridges, some of them with considerable spans. For this purpose recourse was had to triangular trusses. Nevertheless, because no very clear idea existed of the principles of triangulation, the trusses were combined with arches, the latter being a proven architectural device thanks to the experience accumulated during centuries of application to the building of masonry structures. Another characteristic of these bridges was the use of roofing for the protection against the weather not only of the users but also of the joints, which were the most vulnerable part of wooden structures. The most outstanding example was the bridge at Schaffhausen built by a carpenter, Ulrich Grubenmann, with a span of more than 120 metres, perhaps one of the greatest ever achieved with a timber bridge.

During the 19th century some wooden bridges were still being built in England, mainly for the railways. I.K. Brunel developed a system of beams supported by fan-shaped structures on masonry piers, and another system based on light trusses.

In the United States, timber continued to be the preferred material for bridge construction, thanks to its abundance, until well into the 19th century. In spite of the fact that the first bridges were designed by empirical methods, the American builders achieved solutions of great ingenuity and spanned substantial distances.

The first American bridges were of beams or arches on wooden trestles. Soon however, the use of triangulated trusses was introduced, combined with arches in some form or other.

Three notable examples of bridges from this period were the "permanent bridge" at Philadelphia, the "Colossus" also at Philadelphia and the "Waterford", built respectively by Timothy Palmer, Lewis Wernwag and Theodore Burr.

As we have seen, the first significant bridge structures combined the principles of the arch and the truss. In 1820 Ithiel Town patented a system in which the arch was dispensed with, thus eliminating horizontal thrust on the abutments. This system consisted of a truss formed by crossed diagonal members for the web and horizontal members for the upper and lower stringers, the whole constituting a sort of lattice. Town trusses, with which he succeeded in crossing spans of up to 60 metres, were very popular, particularly for railroad bridges. Their success was due to their simplicity. The components of the web were of relatively small dimensions, easy to obtain, and could be joined with ordinary nails and bolts. The trusses were placed on either side of the roadway, which was generally roofed over.

Lt.-Col. Long in 1830 patented a bridge truss more like those used in recent times. The members were more robust and further spaced out of those of Town's models.

In 1840 K. Howe patented a system employing wrought iron for the vertical members and wood for the others. Shortly afterwards T. and C. Pratt patented a similar system in which wrought iron was used for the diagonal members.

Like the Swiss bridges of the 17th century, the American bridges had roofs and sides. A number of covered bridges are still in use today.

The 19th century was the railway age. One of the factors making possible the rapid expansion of the rail network was the development of wooden trestle bridges. A famous example was the Portage viaduct, with a height of over 20 metres, built in 1851 within a period of a year. Works of this type are still in use.

In the United States, in spite of the fact that in recent years steel and concrete have become the most popular materials for bridge construction, timber continues to play a significant role. The factors which have helped to keep timber in the position of an economically competitive material have been the development of laminated wood, the improvement of treatment methods for increasing the durability of timber, and the use of prefabrication. In the United States National Parks there are more than 7,500 wooden bridges in service. The total length of the wooden bridges belonging to the railroad companies is over 2,400 kilometres. Bridges normally used for railroads are of the trestle type, overlaid with wooden beams.

The use of laminated wood has made it possible to construct road bridges with spans of the order of 50 metres, such as the Keystone Wye bridge in South Dakota. In Canada the use of wood for bridges is even more widespread.

Annex 2

PRESENT STATUS OF TIMBER CONSTRUCTION

At present, the region disposes of an average-sized forestry industry, mainly grouping producers of sawn wood and of plywood. In both cases the technical level is unsatisfactory, particularly as regards extraction, with the result that the final costs are very high.

There are also basic technical bodies such as the Faculties of Forestry, the Institute of Forestry Research and the Forestry Service, although these are in the initial stages of their activities and their potential is low, particularly in the industrial and production field.

On the other hand there is in being an industry capable of facing the country's building problems, advised by technical and research organizations able satisfactorily to train the human resources required.

However, the necessary links are lacking between these two fields of activity, the situation in this respect being less serious in the private than in the public sector. At official level there do not appear yet to exist even preliminary contacts, much less specific agreements, aimed at achieving integration between the producer and the consumer.

Finally, among the planning or technical regulations governing building in general, the necessary attention has not been paid to timber.

BASIC PROGRAMMES

To achieve an optimum exploitation of forestry wealth, a co-ordinated effort is required between the various bodies at present concerned with them, including proper planning and channelling of decisions.

The fields of activity to be taken into consideration are, in particular:

(a) Research and utilization:

Directed towards determining the systems of construction most suited to the properties of the various timber species or groups of species available. For this purpose it is necessary to co-ordinate the work of bodies dealing essentially with the technology of forest products and those in charge of research into building methods.

(b) Production and construction standards:

Such standards are essential for guaranteeing the manufacture of standardized products, for which purpose it is necessary to co-ordinate research on use and production with practical experiments in both fields, followed by a gradual introduction of standards into the industry.

Construction standards are also the results of research and practical work, they do not exist at present and possibly will not be required at the beginning, when the main task is to achieve rapid introduction [of timber] into all consumer spheres.

It is therefore preferable to start the regulatory process with basic and general standards, with special reference to particular conditions affecting health and general safety. In this way it should be possible to avoid misuse of the characteristics of timber and of its potential.

Once accepted, timber should be protected by standards guaranteeing its use and durability. Present progress in classification techniques justifies hopes for the emergence of practical methods for measuring the physical and mechanical properties of timber in a direct manner.

EXTENSION AND PROMOTIONAL ACTIVITIES

Publicity, in its various forms and at its various levels, is a powerful aid to technology and industry, and particularly so in the present case where changes in popular attitudes are required.

Experience shows that there have been few attempts to promote or implement technical extension work, either on the part of industry or of official bodies; the few programmes launched have been insufficiently technical, and without follow-up or the necessary revision.

It is important to provide means of technical dissemination such as reviews, bulletins and other publications not at present available to architects or engineers, in order to inform them of the achievements of timber technology and of the continuous progress in research.

It will be necessary to launch promotional and publicity programmes, within the framework of a co-ordinated policy aimed at placing and keeping timber in a position of competitiveness vis-à-vis other building materials.

SUMMARY AND RECOMMENDATIONS

The following points merely have the purpose of focusing on the important ideas, i.e. they should not be considered as final conclusions, for obvious reasons.

1. We have available a material which, far from being obsolete, is at present enjoying increased prestige throughout the world, thanks to the introduction of new techniques and the invention of new products based thereon, enabling the qualities of wood to be better exploited and better results obtained in architectural and structural terms, at a competitive cost.

2. Our natural timber resources are sufficient to meet our requirements for a long time, and can be increased with selective forestation and reafforestation programmes.

3. There are in existence the bodies essential for evolving a policy to cover the development of the forestry industry and the use of its products for building purposes.

   We lack only the contacts which could promote co-ordinated plans of work and supplement and reinforce these same bodies.

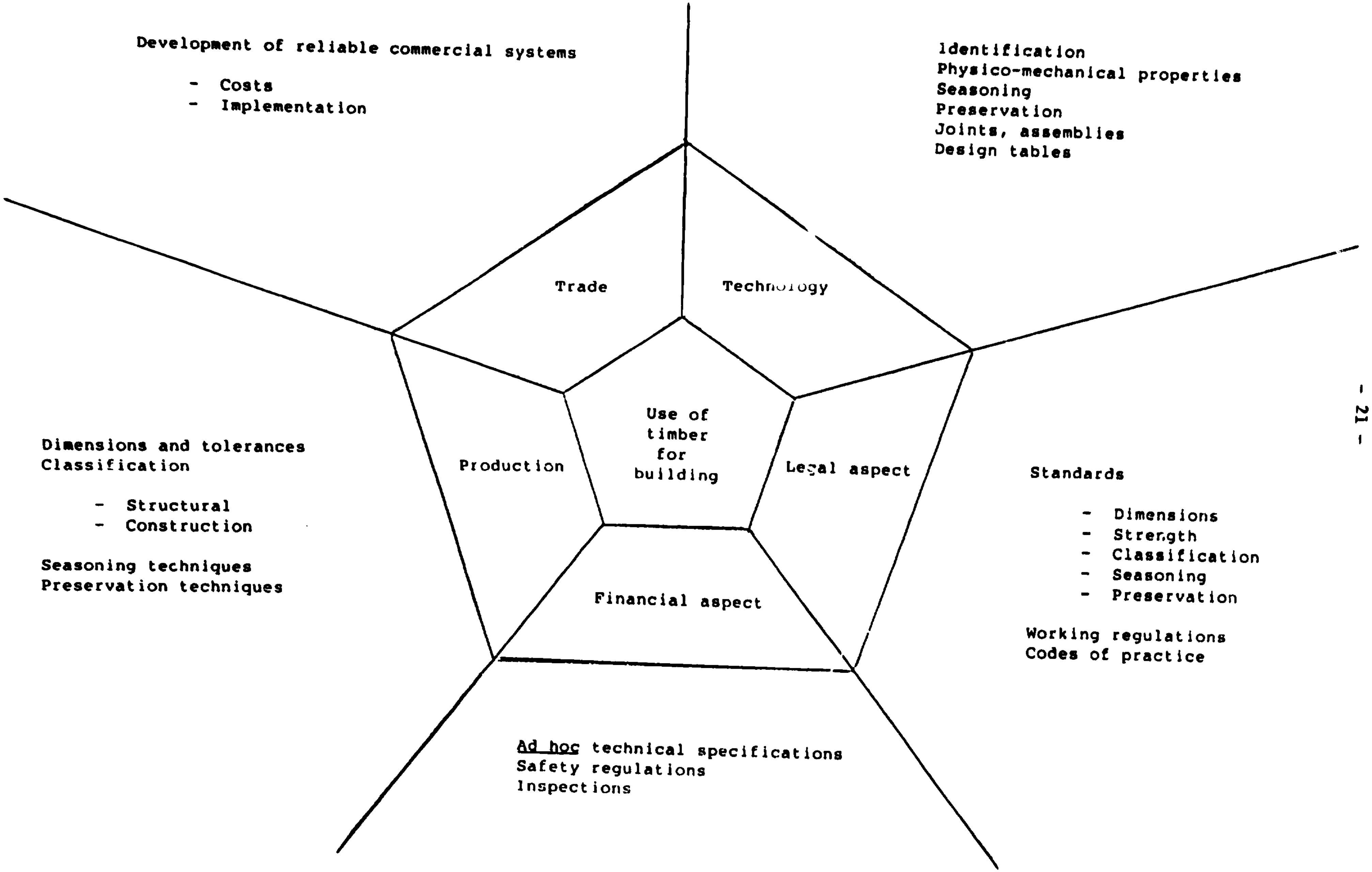
The general policy should reflect the following basic aspects:

(a) Provide facilities for academic and technical bodies enabling them to undertake the study of timber as a building material.

(b) Give initial protection to national forest industries and, at least morally, put pressure on State bodies [to?] use timber products in projects which call for them.

(c) Promote the use of wood at all levels and in all types of building work.

(d) Encourage the training and further training of professional and technical personnel involved in the manufacture of timber products and their use in building activities.


Development of reliable commercial systems
- Costs
- Implementation
Identification
Physico-mechanical properties
Seasoning
Preservation
Joints, assemblies
Design tables
Trade
Technology
Use of timber for building
Production
Legal aspect
Financial aspect
Dimensions and tolerances
Classification
- Structural
- Construction
Seasoning techniques
Preservation techniques
Standards
- Dimensions
- Strength
- Classification
- Seasoning
- Preservation
Working regulations
Codes of practice
Ad hoc technical specifications
Safety regulations
Inspections

Annex 3

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SUMMARY

This document sets out the most widely used systems for timber roof construction in dwellings, farm buildings and industry in a number of developing countries. It describes the use of some of the most widespread jointing arrangements and touches on the use of adhesives in this part of the world.

It includes diagrams of procedures that have been adopted, including a timber consumption index, with subsequent reference to basic cost so that they may be compared with each other and with procedures using other materials.

The document describes some of the most commonly used covering systems and, finally, recommends the production of design aids and technical specifications to increase the use of timber in the most needy areas of developing countries.

1. INTRODUCTION

Timber buildings in developing countries historically recall old-fashioned warehouses and installations in ports, with colonial or republican-style roofs up to the beginning of this century. In farming and rural areas, they are a function of the timber species available locally at the time.

Nevertheless, the advent of concrete and the development of steel welding introduced these new materials in place of timber, stifling its development in most cases.

In general, most developing countries possess forest resources which have been used in some way to solve building problems. The use of such resources was restricted to traditional application for the homes and shelters of people in rural or suburban areas in which one of the main features was the use of a "progressive" approach to obtain a sound construction.

This undoubtedly involved a great waste of material and low-technology jointing methods to achieve a better load distribution.

Rural areas are generally remote from urban centres where technology and specialized labour tend to congregate.

Rural areas lack easy access roads for the transportation of heavy building parts and components.

For instance, it is very difficult to deliver posts for energy transmission or communications to remote areas if they are made of steel or concrete, since transport is frequently only possible using pack animals.

In rural development, the main expenditure item frequently concerns the infrastructure, for example a dessert fruit selection plant requires merely a good roof and some conveyor lines, whereas the main item in a poultry farm is a large shed, which must be strong and durable in order to qualify for funding.

Also, credit agencies must learn to appraise timber constructions, to be able to judge when they are well made, how long they are likely to last, the skill of the builder, etc. They must also be able to estimate costs and to assess ways of monitoring the provision of funding by instalments, etc., something that is very different in the case of timber constructions compared with buildings made of other materials.

Timber technology has advanced greatly in developed countries and knowledge and experience are out of step with the situation in developing areas; the depth of knowledge in both sectors is different, as are the tree species available.

Notwithstanding this, the efforts made and the requirements that have arisen in the marginal, remote and most needy areas of developing countries focus at the point of application. In other words, this is precisely the time to promote the rational use of timber to meet the majority of construction needs in such geographical areas and for such populations.

It is the responsibility of those who understand the significance of the appropriate use of an indigenous resource to disseminate, promote and assist the development of knowledge and technical experience which will help achieve this purpose.

2. TIMBER ROOFING IN DEVELOPING COUNTRIES

2.1 Climatic and loading considerations

The climate in developing countries is generally hot, ranging from tropical to temperate, with moderate rainfall and winds in most cases. Heavy loads, such as snow, rarely occur even in mountain areas. Very rare instances of high-altitude mining construction have to bear the weight of snow.

In many areas, rain is no problem since it is neither intense nor frequent. Similarly, hurricane winds are rare or non-existent. However, there are relatively frequent earthquakes in those areas.

2.2 Roof types

(a) Domestic use

In both urban and rural areas there are roofs for houses, barns and multiple-use buildings for metalworking, woodworking, farming, storage, etc. The roof is typically of baked clay (Spanish tile), palm leaf or straw, with spans of no more than six metres, generally of the traditional type with king post and beam or stringers and lintel. Construction tends to be oversized because of the lack of technical component design and the absence of any proper jointing.

(b) Agricultural use

Semi-urban and rural, generally for poultry, pig and sheep farms.

The problem of spans greater than six metres is traditionally resolved by using a centre post. Imported timber is used for large-volume sheds with, in some cases, steel profiles and, very rarely, concrete columns. Small sheds are built with local roundwood and cane, with very rudimentary joints, sometimes using cords or leather thongs.

In some regions there are prefabricated timber sheds which incorporate modern joints and auxiliary structural components, such as rods and crows feet or diagonal strengtheners.

These systems had to compete with the traditional systems in terms of cost, and there was literal application of the principle of "design to destruction". This means that the safety coefficients are taken to the maximum limit and quality control takes place at the end of construction. If some parts break or bend excessively they are replaced with others.

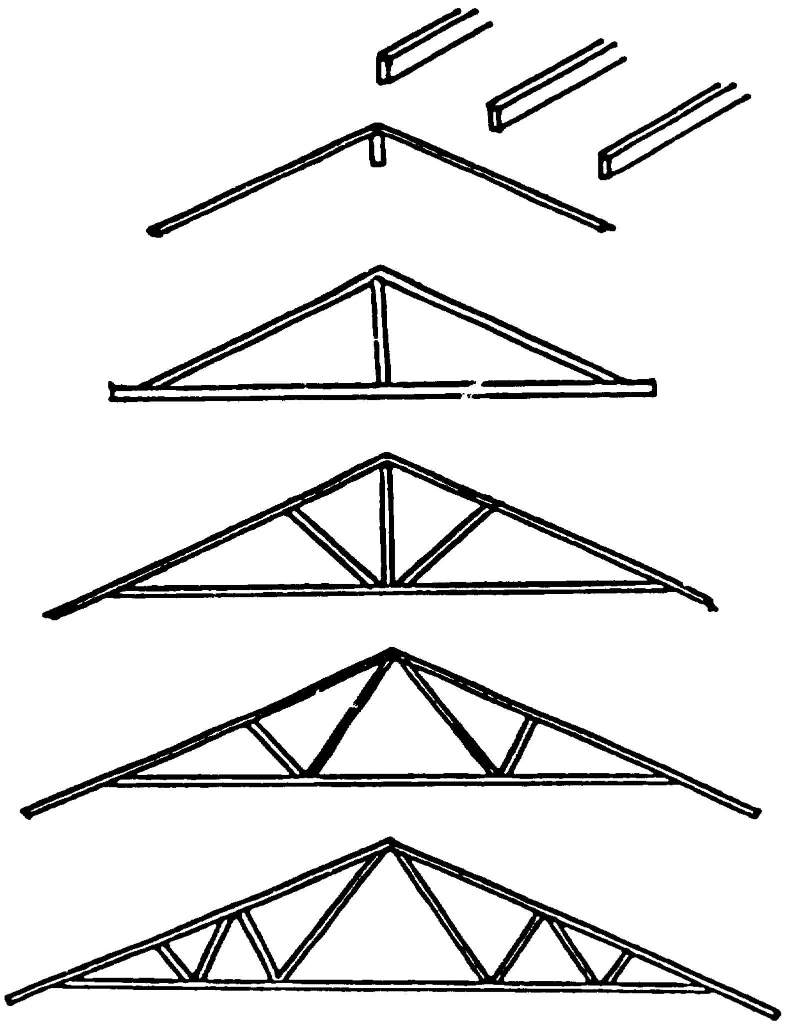
The lack of standard drawings and technical specifications for these purposes is well known among designers, manufacturers and users of agricultural buildings and, in general, all that can be achieved is a vague approach to design suited to the surrounding medium, without it being technically acceptable or economic.

(c) Industrial use

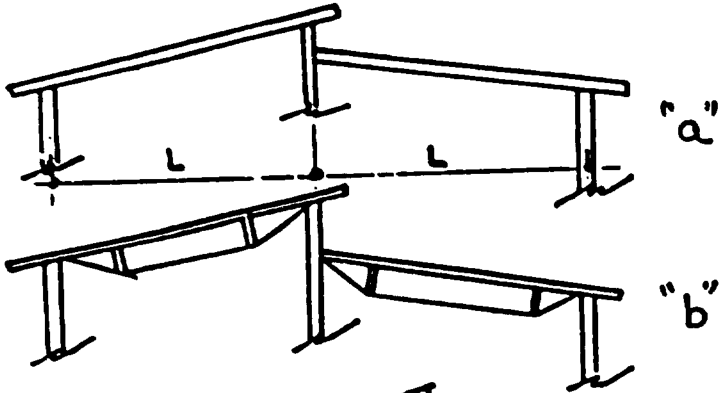
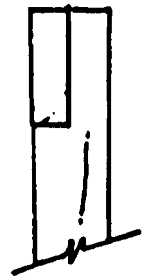
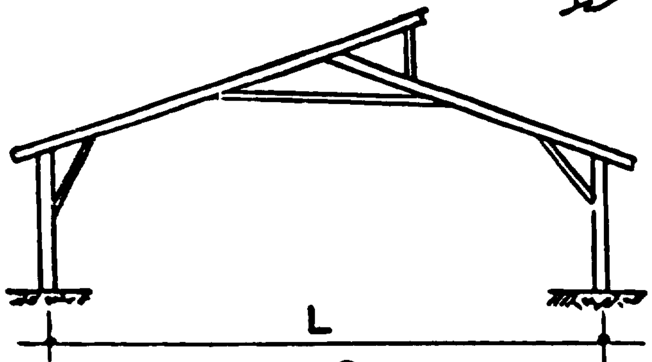
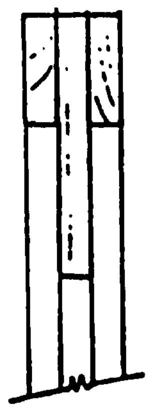
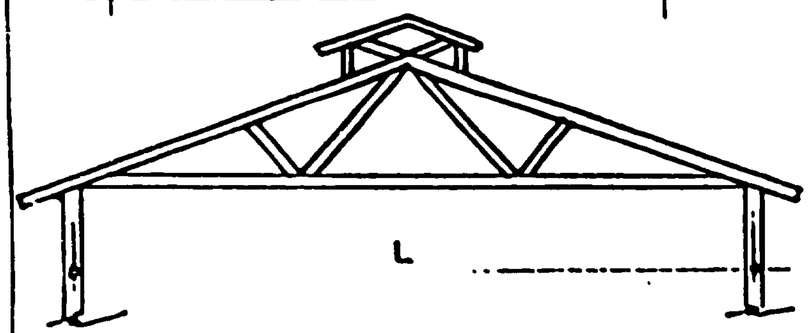
As in the above-mentioned applications, timber ceased to be used with the advent of steel and concrete technology.

None the less, there are still instances of industrial timber buildings making use of designs, structural values and even material that is imported or comes from outside the developing countries.

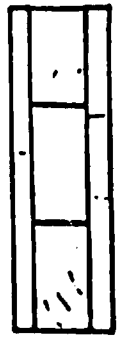
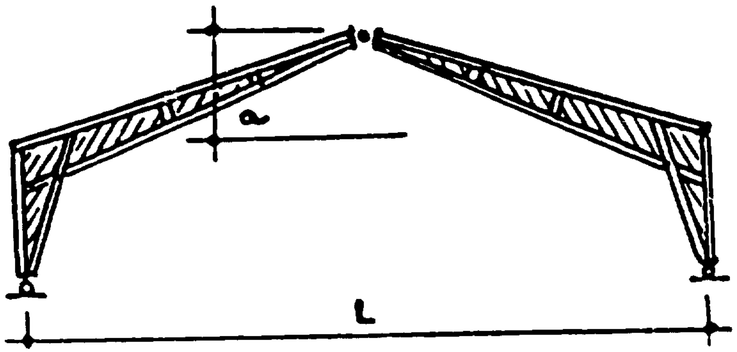
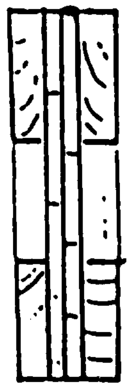
TIMBER ROOFING SYSTEM FOR DOMESTIC USE

TYPE	Cross-section	Span, metres	DESCRIPTION	Quantity of timber b.f./m^2
		3.0	Solid section rafters to support roof planks.	3.0
		4.5	Main beam, rafters and stringers of solid timber.	6.0
		6.0	Rising master truss and rafters. Solid timber and craft joints.	8.0
		7.5	Rising master frame and rafters. Solid timber or compound sections, nailed or bolted joints.	9.0
		12.0	Frame and rafters of compound section. Joints using nails, bolts or gun nails.	10.0
		15.0	Belgian frame and rafters. Compound section. Joints using nails, bolts or gun nails.	12.0

TIMBER ROOF SYSTEMS FOR AGRICULTURAL USE

TYPE	Cross-section	Span, metres	DESCRIPTION	Quantity of timber b.f./m^2
		6.0	Post and beam of simple section and with lightweight rafters; (case "b"), beam section reduced by means of steel stiffeners.	7.5
		12.0	Post and beam of compound section secured with nails. Lightweight rafters, depending on covering material.	6.0
		12.0	Spaced columns of compound section. Standard frame modified for ventiliation lantern at ridge. Lightweight rafters with rabbet to brace the frames.	7.0

TIMBER ROOF SYSTEMS FOR INDUSTRIAL USE

TYPE	Cross-section	Span, metres	DESCRIPTION	Quantity of timber b.f./m²
		12.⁰	Flat beam with parallel cords H = 1/4 span (approx.)	12.⁰
		16.⁰	Pitched beam, variable height Hmin = 1/20 span (approx.)	9.⁰
		18.⁰ 26.⁰	Triple-articulated arches of variable section with simple or laminated and bonded cords. Hmin = 1/30 span a (approx.) = 1/6 span GENERAL: Diagonal-web structures, upper cords boarded, nailed or nailed and bonded, lower cords simple or laminated and bonded.	12.⁰ 15.⁰

Small-scale use of modern techniques started recently in the utilization of native species in modern timber buildings.

Mention should be made of the use of bolts and gun nails in some countries where this is authorized, and the intensive use of nails in diagonal-web beams and arches.

Here again steel has far overtaken traditional methods and the ready availability of high-strength steel rods for reinforced concrete has made it possible to develop very lightweight three-dimensional designs which cut the cost of industrial roofing, perhaps with horizontal tie rod limitations in high arches.

The greatest possible use must be made of timber engineering techniques to rationalize industrial buildings and to be economically competitive.

3. COVERING

Domestic and agricultural buildings in rural or provincial urban areas have generally been covered with local materials manufactured using craft techniques.

To begin with, there is the clay tile, made by the user himself or by a local manufacturer, by shaping the clay and baking it in local artisanal ovens. This produces a very heavy roof, in excess of 50 kg/m^2, which must be nailed to the wooden framework in earthquake zones.

Where there is an abundance of timber and palm, use is made of split and/or sawn timber shingles or sheets, using wood with good natural durability and dimensional stability. The palm leaf is woven in successive layers to produce a waterproof but not very durable roof.

It was not until the advent of corrugated metal and asbestos cement sheets that agricultural and agro-industrial roofing could develop, with a lower cost/lifetime ratio and lighter structures.

In the case of urban industrial roofing, the saving is significant since the sheets make it possible to reduce the frequency of the supporting rafters. There are genuinely lightweight roofs made of timber or of steel which are frequently incapable of bearing the weight of the workers building or repairing them, and such work is done from below, using temporary scaffolding.

4. JOINTING

In former times, hemp ropes and leather thongs, as well as wood and metal fastenings, were used for joining timber and cane constructions. Later on use began to be made of nails, bolts, pins and wood screws, albeit using very rudimentary structural approaches. This contributed notably to the use of oversized load-bearing components.

In recent years, few timber constructions of any size have been erected using design tables and manuals from developed countries, which are not the most appropriate for local timber and conditions.

The structures can be suitable and competitive only when the indices of strength for joints made with local timber are available.

Many developing countries possessing forest resources have sufficient information to design nailed and bolted joints.

A small number of countries have an agent and manufacturer of some possibly under-utilized gun nail system (generally used to avoid cracking in the transverse sections of posts, sleepers or other timber components of large cross-section).

There is not a great deal of experience in the handling and production of assemblies using structural adhesives. As in the case of gun nails, the patented system and the adhesive are imported. But whereas the gun nail system undertakes to supply equipment, technical assistance for manufacture and, in most instances, designs for standard models, in the case of adhesives the technical service available is less comprehensive; this further complicates the possibility of using them and closes the vicious circle of high import prices and low consumption levels which makes it less likely that they will be produced locally to meet a widespread demand and hence at low cost.

The models encountered in some developing countries have shown that it is possible to derive many advantages by using modern design methods involving nailed or bolted joints and the rational use of structural adhesives. Furthermore, the use of epoxy adhesives for small structural joints (scarf joints) in place of bolts and other systems has shown this to be a cheaper option, while maintaining the pleasing appearance of the structure.

5. PREFABRICATION

5.1 Analysis

Considering the limited dissemination of modern timber engineering techniques, the promotion of the use of timber is initially connected with prefabrication, in which necessary quality rules and building standards are respected to ensure the durability of the building. By prefabricating part of the structure and centralizing the technical efforts, it is possible to lay the foundations for economic, functional and reliable building systems.

Even though the investment is not very large, focusing on this idea of prefabrication in a given region could achieve full use of equipment and labour, thus justifying the initial outlay.

Here is an example of the investment and work in a hypothetical region in an economically depressed area.

5.2 Investment and work

HYPOTHESIS

- Population of the area	3 million inhabitants
- Agricultural population	300,000 inhabitants
- Estimated annual income of the agricultural population	$US 36 million

CALCULATIONS

- Minimum investment	$US 360,000
- Equivalent area of agricultural roofing	100 sheds of 500 m^2 each
- Timber input	300,000 b.f. or 600 m^3
- Percentage local timber production (non-timber exporting country)	1.25 per cent

6. COST ANALYSIS

There follows an estimate for the analysis of costs on the following bases:

(a) In a timber building the costs are proportional to the amount of timber used.

(b) The joints and other fixing accessories for lightweight structures represent between 10 and 20 per cent of the total cost.

(c) Provided that the minimum living wage does not exceed $100 per month, the labour cost for manufacture and assembly will not exceed 10 per cent of the total cost.

(d) In each region the costs vary depending on the ease of obtaining materials, distances, fuel costs, etc. The estimates given are therefore only an initial indication and must be rapidly adjusted in each particular case.

K FACTOR FOR DAMP UNPRESERVED SAWN TIMBER

	DOMESTIC	AGRICULTURAL	INDUSTRIAL
Impact of the factor on sawn timber cost	2.0	2.4	2.9

<u>Examples</u> - calculated in US dollars

Domestic roof No. 5

COST = 10 (b.f./m^2) x 0.4 ($/b.f.) x 2.0 (K)

COST ($/$m^2$) = $8/$m^2$

AGRICULTURAL ROOF NO. 8

COST = 6 b.f./m^2 x $0.4/b.f. x 2.4 (K)

COST = $5.8/$m^2$

INDUSTRIAL ROOF NO. 12 - SIMPLE

COST = 12 b.f./m^2 x $0.4/b.f. x 2.9 (K)

COST = $14/$m^2$

7. RECOMMENDATIONS

In order to promote the further use of timber in building we give here a suggested approach to the preparation of standard designs and competitive rational procedures for developing countries.

7.1 Objective

Designs of standard buildings for domestic, agricultural, agro-industrial and industrial use, employing local timber and jointing components.

7.2 Activities

(a) To plan and select carefully the sectors of a country or region where these activities could be initiated - for example industry, agriculture, education, health, building and public works, etc. in order to have an appropriate technical counterpart and, above all, experience, adequate information, interest in the programme and resources to implement it.

(b) To prepare a general document that is valid for different geographical areas, containing a wide range of ideas and possible solutions.

(c) To visit each region or country, taking particular note of the levels, domestic solutions and materials and methods used. It is important to record costs.

(d) To work in conjunction with national designers, adjusting and adapting the solutions in the general document to the conditions observed in the country. To include technical specifications and manufacturing and assembly recommendations.

(e) To prepare typical cost analysis systems in order to compare the various solutions formulated and those existing locally.

(f) To design, manufacture and construct one or more models or examples.

Annex 4

SOME COMMON FALLACIES ABOUT WOOD

by

Forest Products Laboratory, 1/ Forest Service
US Department of Agriculture

In the course of its work the Forest Products Laboratory continues to encounter various false ideas about wood, many of which lead to unnecessary trouble, expense, or dissatisfaction in the use of wood. Some common misconceptions of this kind are the following:

Fallacy 1. That all wood in the course of time "naturally" decays as a result of age.

This fatalistic concept ignores the true cause of decay and may lead the user to neglect the proper precautions against it. Time or age itself has nothing to do with the decay of wood. The White House, when remodelled in 1949, was found to contain sound timers that had been in place since 1816. The Fairbanks house, a wood structure in Dedham, Mass., is standing structurally intact after three centuries. Timbers several hundred years old have been recovered from the ruins of Indian pueblos in Arizona and New Mexico. A part of a Roman emperor's houseboat that sank long ago in Lake Nemi was sound enough nearly 2,000 years later to be identified by the Forest Products Laboratory as spruce. A log seven feet in diameter was found some years ago in a tunnel being dug 150 feet below the bed of the Yakima River in Washington. A piece of it was sent to the Forest Products Laboratory and the wood was identified as an extinct species of sequoia, of an age estimated by geologists at 12 million years. During the progress of thousands or perhaps millions of years wood constantly immersed in water or wet soil gradually undergoes chemical changes (not to be confused with true decay) that result in a loss of some of the original strength. This millenial process that involves only immersed wood, however, has no practical signficance for current structures.

These examples prove that wood does not necessarily decay with age at all. Decay is the result of one thing only, and that is the attack of wood-destroying fungi. In the cases mentioned the wood had been kept free of fungus attack in one of two ways: it had been kept dry, as in weatherproof structures or in a dry climate, or it had been kept thoroughly and permanently saturated. A fungus is a plant. If the wood is too dry for it to grow and spread, decay does not occur. If the wood is thoroughly saturated, the fungus is "drowned out". The range of activity of fungi lies betwee 20 per cent moisture content of the wood and a "soaking wet" condition in which all air is excluded.

Fallacy 2. That some woods never decay, regardless of exposure and service conditions.

Both this fallacy and the first one are answered by the fact that no woods decay when fully protected from fungi, and that any wood will decay when exposed to fungus attack that is severe enough and continued long enough.

The conditions that bring about decay of wood are, briefly, dampness and mild to warm weather. If you have a house, porch, or shed built over damp, poorly drained ground, with the foundations bricked or boarded in, look out for decay.

1/ Maintained at Madison, Wis., in co-operation with the University of Wisconsin.

Sills of untreated wood resting directly on damp ground are sure to rot. Likewise untreated posts and poles seet in the ground are exposed to ideal conditions for fungus attack, and their service will usually be terminated by decay near the ground line, no matter what wood is used.

The sapwood of all species is easily and quickly destroyed by decay. (Sapwood is the outer, light-coloured part of the tree trunk.) But it is a fact that the HEARTWOOD of some species resists decay longer than the heartwood of others. This is the advantage of using for fence posts, and so on, such decay resistant species as cedar, catalpa, chestnut, baldcypress, juniper, black locust, osage-orange or or bois d'arc, and redwood. They may last for years. Do not imagine, however, that the underground parts of the post will remain just as you put them in; in a comparatively short time decay will eat away the sapwood, and the business of holding up the fence will be left to a core of the more resistant heartwood. Of course, by treating the wood with a good preservative you change the picture materially. Most of the preservative goes into the sapwood and protects the part that is most vulnerable to decay.

But to suppose that the use of cypress, cedar, or any other special wood will excuse you from all precautions against decay is a bad mistake. Do not expect too much of Nature. In the first place, remember that only the heartwood is the durable part, and then take care of the service conditions as well as you can. A Laboratory man once went to inspect a floor that was falling in. It happened that the subfloor was of genuine cypress, specifically put there to ward off decay, but alas! It was laid directly over damp ground and was covered with tar paper before laying the upper boards. What the owner had was a high-powered fungus pit for his cypress, and the fungus literally ate up the subfloor and spread to other parts of the building at the owner's expense.

Fallacy 3. That there is such a thing as "dry rot" of wood.

Much has been written or said about "dry rot" in buildings. Any brown, crumbly rot is so called, but the term is a misnomer. No fungus can grow without water. Wood is the food for the wood-destroying fungi, but they cannot use that food unless it contains at least 20 per cent of water (based on the weight of the oven-dry wood). However, the fungi that are responsible for some of the decay in buildings are capable of rotting wood that is apparently much drier, for they produce water-conducting strands which carry water from some source, usually in the ground, up into buildings where the wood normally would be dry. Moreover, some wood-destroying fungi can remain dormant in dry wood for months or even years and then revive and continue their destructive work as soon as moisture becomes available.

Call it dry rot if you wish, the fungi that come sneaking into a house carrying their water supply are bad ones, and should have been kept out by proper precautions when the house was built. The Latin name of the most common one in the United States is Poria incrassata. It is at home in the South, on the Pacific Coast, and at least as far north as Pennsylvania and Nebraska.

Here is an example: a house was completely wrecked by this destroyer in less than 10 years. Investigation showed that some floor joists were allowed to rest on an old stump that happened to be in just the right place - or the wrong place. Do not give this wrecker a chance to get into your home by leaving planks or timbers connecting the structure with the ground. After Poria incrassata gets started it can set up its own connections with the damp ground, an ugly rootlike growth sometimes as big as your finger and thumb.

A good, dry, well-built frame house is in practically no danger from decay if just a few normal precautions are taken. (1) Build on a well-drained site and avoid construction that allows moisture to accumulate in joints or pockets; (2) secure well-seasoned lumber; (3) do not allow the selected material to lie on the ground after it has been delivered on the job; (4) untreated lumber should not be allowed to come in contact with the soil or with foundations or walls which are liable to be damp, and should not be embedded in concrete or masonry without leaving ventilation around the ends of the timbers; (5) wood flooring, unless it has been chemically preserved, should never be laid directly on the soil or on concrete that is in contact with the soil; (6) remember that dry wood will not decay.

Fallacy 4. That wood used in construction is under all conditions more dangerous than steel in case of fire.

It is true that wood when exposed to fire temperatures will burn and be converted to charcoal, whereas steel does not burn under similar exposure condtions. But wood, when used in heavy timber construction, has a tremendous advantage over unprotected steel. Where thick beams constitute the supporting members of a structure, the outside surfaces, on exposure to severe fire conditions, will become charred, while a substantial core of wood, because of its low heat conductivity, remains at low temperature, uncharred and intact, and retains most of its strength for some time. Steel, under the same fire exposure conditions, because of its good heat conduction, will quickly become heated throughout and lose much of its rigidity and load-bearing capacity and thus permit collapse of a structure sooner than timbers of the same initial strength. For structural purposes, the working strength of unprotected wrought iron and steel as reported in Johnson's Materials of Construction, must be regarded as regularly diminishing while the temperature increases, the rate of diminution being about 4 per cent per 100° F increase in temperature.

It is for this reason that steel members are commonly required to be enclosed in concrete or some other protective material.

Fallacy 5. That a fence post will give better service if set in the ground "upside down".

A tradition seems to exist in some quarters that setting posts bottom end up (opposite the position of growth) makes them last longer. There is neither evidence nor theoretical basis to support this idea, so far as we are aware. On the contrary we should expect posts so reversed to rot more quickly than if set upright. They would have less material at the ground line for fungus to rot through, and a greater proportion of that material would be sapwood, which is generally an easy prey to fungus. Furthermore, the less woood a post has at the ground line the weaker it is, like a fishing pole grasped at the small end.

Fallacy 6. That oak, hickory, or other heavy hardwood has a higher fuel value than pine.

This may be true as between a cord of hickory and a cord of pine, as the cord of hickory weighs more; but pound for pound the pine gives off more heat. Resinous woods in general have a higher heat value per pound than non-resinous. What this means is that for a quick, hot fire you would use pine; but for practical home heating or cooking purposes no general means has yet been devised to "tame down" the burning of resinous woods and make them last like a hickory backlog, for instance.

Fallacy 7. That the sap "rises" in a tree in the spring and "goes down" in the late fall.

The difference about sap is that it is moving or circulating actively in the spring and summer. It is always "up" and never "down". By actual weighing, logs are heavier in the winter than in spring, showing that they have more sap in the inactive season. If the sap were "down", no tree could freeze in winter as they often do, with a loud "crack".

Fallacy 8. That trees exposed to storms and rough weather all their lives form stronger and better wood than sheltered trees.

This idea is mere poetic licence, as it never affects the selection of wood in manufacture and actual use. Trees exposed to extra severe conditions are apt to be deformed, gnarly, twisted, stunted, and fit mostly for firewood. Trees grown under normal forest conditions make the best lumber because they are straight and regular in grain. Piece for piece, their wood is as strong if not stronger than that grown under the wildest conditions of exposure.

Fallacy 9. That wood of a given species grown in one State or region is superior to that grown in another State or region.

Examples are "Michigan maple" or "Vermont maple", northern vs. southern ash, etc.

Tests of more than 600,000 specimens at the Forest Laboratoy prove that a tree's location inside or outside certain imaginary geographical lines has nothing at all to do with the strength of its wood. If the tree or species in question is growing within its proper range of climate, it is not affected by its north, south, east, or west location within that range. The immediate influences of its site, such as moisture, drainage, fertility, and exposure have the controlling effect. Properties of the wood in any one State or region will show a wider variation than any general geographic difference. The test of wood quality lies within the piece or the shipment itself, and not in where it came from.

Fallacy 10. That limbs rise higher from the ground as the tree grows older.

This phenomenon would obviously require the stretching of the interior wood where the limb is attached, and trees simply do not grow that way. A new layer of wood is put on every year over the tree as it stands, limbs and all. What goes on this year stays put. If there is a limb 10 feet from the ground now, that is where it will be next year, unless it breaks off or is cut off. Increase of thickness of limbs may diminish the distance between limbs or, in the case of the lowest limb of the clear bole or log length below it. Nevertheless the centre or pith of each limb remains at its original elevation above the ground.

Fallacy 11. That an expert can tell the age of a piece of wood by looking at it.

This question sometimes comes up in the case of a violin purporting to be a "genuine Stradivarius", according to a Latin label stuck on the inside. This label, put into thousands of cheap new violins, means nothing to the trade except that the instrument is shaped like a Strad; but to the owner the discovery of the secret Latin inscription is often wildly exciting. Hence, an urgent call to the wood expert to inspect the wood and see "how old it is".

Except for the "aging" of wood in colour, which may be purely artificial, the expert can determine the age of the wood only by counting the rings in the stump when the tree is cut. Looking at a stray piece of wood only shows a certain number of rings or growth layers, telling how many years the piece took to grow; the growth may have occurred since 1900 or away back in the Middle Ages, so far as anybody can tell from a single piece. (The research of Professor Douglass on timbers from the old pueblos is a different story which we can hardly go into here.)

Fallacy 12. That some woods "breed" bedbugs and cockroaches; meaning, perhaps, that some woods favour the development of such vermin within their cracks and crannies.

The insects in question appear supremely indifferent to the kind of wood of which a house is built; their interest lies in other directions. To blame poor housekeeping on one or another species of wood of which the house is built is grossly unfair to Mother Nature.

Fallacy 13. That lumber on the market today is not what it used to be in the "good old days".

Popular opinion to the contrary notwithstanding, timber cut today is as good as Paul Bunyan ever laid axe to. Lumber is now machined better, graded better, and seasoned better than formerly. In addition, a wider selection of species and items is available. It is true that strong competition between dealers and between materials in some localities has resulted in bringing on the market lumber that is not what it should be with respect to size, grade, and seasoning. However, this does not mean that good lumber is not available at economical prices. It does mean that discrimination is necessary in buying lumber as well as in buying other materials - undoubtedly more necessary today than it was in the past.

Fallacy 14. That wood exposed to very low temperatures is "brittle as glass" and has little strength.

Some people have had the idea that when wood is frozen or exposed to very low temperatures, as in arctic regions, it is seriously damaged and loses most of its strength. There have been reports that a piece of wood dropped on the frozen ground is likely to shatter into small pieces, much as though it were made of glass. Careful investigation has failed to produce any real evidence of such occurrences. Occasionally, a piece of wood of the commonly used species may have natural characteristics, such as knots or slope of grain, that are very severe and damaging to the strength, or the piece may have such low density that it could readily break when dropped or mishandled, even at normal temperatures.

The fact is that tests on wood at temperatures as low as 300^{o} below zero (F.) show that the strength properties of dry wood, including shock resistance, increase as the temperature is reduced. In the case of wood that is saturated with water, the expansion of the water upon freezing may sometimes cause the wood to crack open (see Fallacy 7), but evidence indicates that wet wood also increases in strength when the temperature is reduced.

It is possible that fastenings, such as nails and screws, may tend to loosen somewhat in wood that is repeatedly frozen and thawed, much as they do in wood that is repeatedly wetted and dried. If this does occur, however, it would be a slow process.