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THE ADVANTAGES OF WOOD AS A CONSTRUCTION MATERIAL 1/

by

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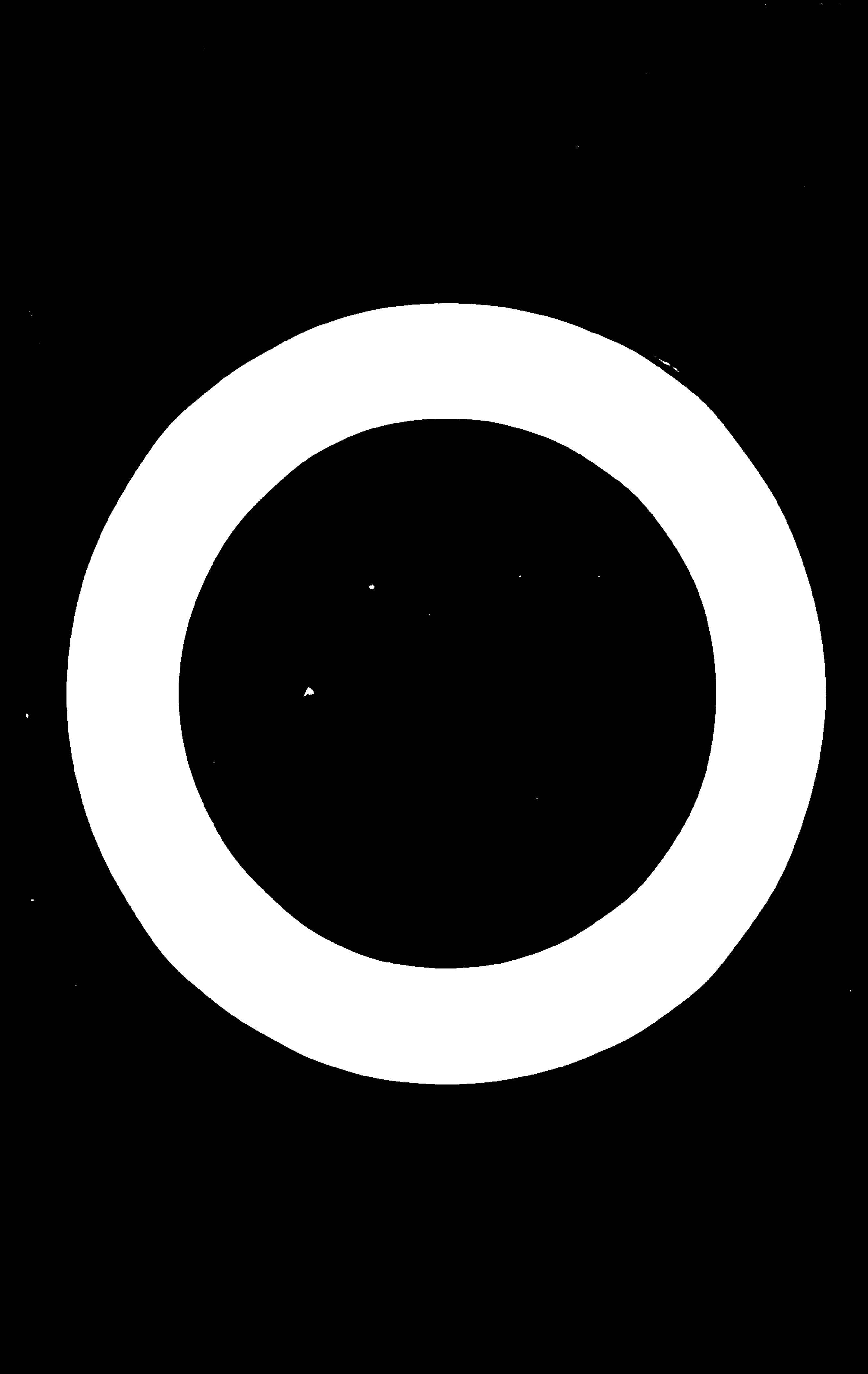

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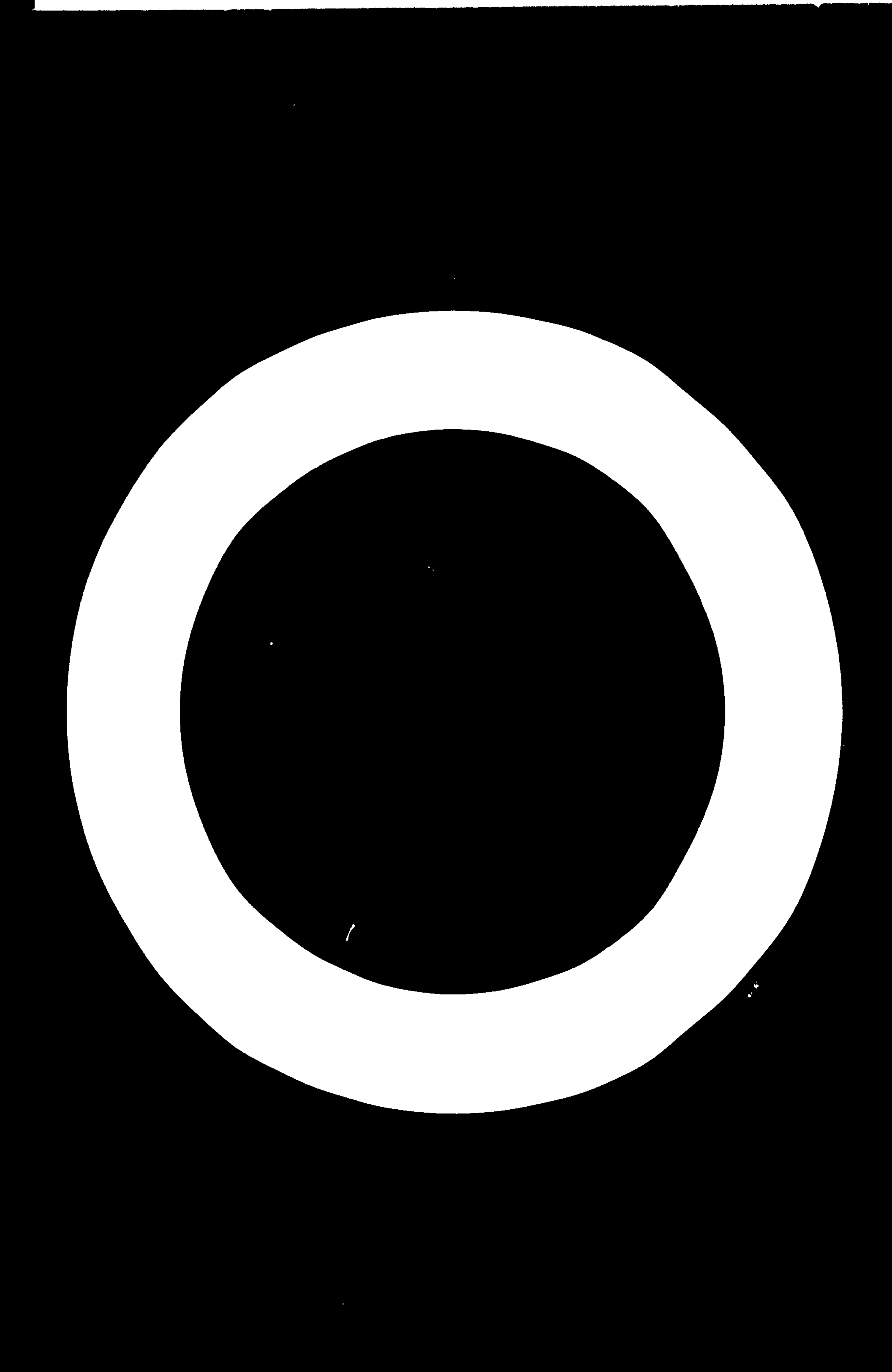


THE ADVANTAGE OF WOOD AS A CONSTRUCTION MATERIAL

INTRODUCTION

Since the industrialization of the construction processes and the prefabrication of elements and components for different types of industrial buildings using wood as a main material is reasonnably well known, the emphasis of this paper is on the advantages of wood as a material rather than the method in which it can be used.

Briefly, the industrialization of construction methods using wood as a main material is best accomplished by the production of two dimensional structural components such as wall panels, roof trusses and roof panels as opposed to three dimensional elements such as box type components, total room elements etc.

The prefabrication of wall panels and roof trusses has been widely developed with the majority of such systems utilizing fully engineered designs showing the minimum sections of wood with the maximum strength possible and all joints being fastened together with gang nail galvanized steel connector plates pressed in. This type prefabrication varies from the primitive drop hammer which requires only electricity or air as power to the highly sophisticated fully automated systems involving computerized controls of massive hydraulic presses etc.

For developing countries, the elementary type of equipment which can be operated by un-skilled workers, coupled with the use of native timber produce prefabricated elements which require only semi-skilled laborers to erect at the construction site and offer economy, use of native materials, ease of erection and fast fabrication in the plant and fast erection in the field.

For centuries wood has rendered unique and ubiquitous service to man. It has a range of qualities in strength-for-weight, workability and natural beauty which no alternative material has been able to challenge.

Only in its lack of long term durability and its vulnerability to fire does untreated timber have drawbacks. But man has developed preservation treatments to overcome these problems. These chemical treatments, methods of application and the designs of the treatment plants take over where nature left off.

The enemies of untreated timber can be broadly identified as fungi, insects, weather and fire.

FUNGI - which live by breaking down the cellulose, starch and sugar in wood. Fungi need moisture for their growth, so their activity in wood tends to be concentrated where timber is in contact with the ground, or where moisture can penetrate or condense. the so-called Dry Rot fungus penetrates a building through a damp patch and then has the capacity to carry water into dry timber.

INSECTS - in temperate zones, insects attack is largely confined to damage caused by the larvae of insects such as Woodworm, the Powder Post beetle, the Death Watch beetle and the Longhorn beetle. These larvae live for months or even years in timber and over a period of time can cause serious loss of strength, lending to collapse. In regions of termite activity huge numbers of adult insects can destroy timber very rapidly.

WEATHER - Untreated timber, absorbing moisture during rainfall and then drying out in sunshine, alternately swells and contracts. This sets up stresses which can cause splitting in the timber and distortion in the structure. In temperate zones the problem may manifest itself as a window which is draughty or resists being opened, but in the tropics it can be much more severe.

Moreover the absorption of water creates the ideal conditions for fungi to germinate and flourish.

FIRE - The vulnerability of untreated timber to fire is in some respects its most serious shortcoming - the hazard which gives least warning of attack and which carries with it a serious risk of human life.

The widespread use of inept misleading terms to describe the fire characteristics of various materials and types of buildings is responsible for misconceptions regarding fire problems. For example, the word "fire-proof" should be dropped from fire language as there is no such condition. The term has gained wide acceptance for reasons of brevity to describe construction with a high degree of fire resistance but this device is not justified. The technical concept of this word is better described by the term "fully protectad", as fire resistance is often confused with non-combustibility. Although most metals are non-combustible in terms of the standard definition, they soften and collapse at fire temperatures and therefore cannot be considered to be "fire resisting" because of the early structural failure which occurs with rising temperatures. A much more basic misunderstanding is the mistaken belief that most fire problems can be solved or at least sufficiently mitigated by use of fire resistant construction. This misconception has caused an ovar-developed interest in fire resistance ratings rather than a critical assessment of the fire hazards involved.

High fire resistance ratings are too frequently required in circumstances where a low rating would suffice or fire resistance is not a limiting design consideration.

All engineers are aware that steel softens and loses a considerable amount of its original strength even if it is raised to only a moderately high temperature. Nevertheless, this does not prevent steel being used for all sorts of structures and yet timber, although superior to unprotected steel in its ability to carry its load during fire is regarded as unsuitable, if not outright dangerous, for permanent structures because it burns. In recent years however, it has been forcibly demonstrated that the combustibility or otherwise of the materials forming the structure of the building bear little relation to fire safety with regard to protection of human life or the contents of the building itself.

The best known example of the fallacy of relying on incombustibility for high fire resistance is the 1953 fire which swept through the General Motors transmission plant at Livonia Michigan, U.S.A. and collapsed the 34 acre steel building in a matter of minutes. Before 3.40 p.m. on 12 August, 1953, nobody even suspected that a fire like this could happen. It was a non combustible building with non-combustible machinery using non-combustible raw materials, and the end product was non-combustible. Yet the building burned, resulting in a 28 million dollar loss.

World wide experience and fire records show that buildings containing engineered or solid timber components perform extremely well in fire and have excellent fire resisting qualities. As mentioned previously, unlike unprotected metals timber does not lose its strength suddenly in conditions of extreme heat.

Because all structural materials are affected by fire, the important consideration is the fire endurance, which may be defined as the period for which structural components will sustain their load when subjected to intense heat. For high fire endurance the materials used must of course be resistant to fire damage but the construction details play a major part. The times to failure for small structural elements of several materials in a fire in which a temperature above 600°C was reached after 5 minutes and 900°C was reached after 35 minutes is as follows. (Assuming that failure occured when the strength of the material was reduced to 25% of its original value.) For timber the rate of charring was assumed to be 1" per 40 minutes and the calculated times to failure were:

i) Aluminium alloy : about 3 minutes
ii) Mild Steel : about 6 1/2 minutes
iii) 2" x 4" softwood : about 25 minutes

Steel loses strength rapidly as its temperatura is raised above 250° C and at about 550°C, it has little less than half its original breaking strength. At about 750° C it retains only about 10% of its original strength.

Most aluminium alloys start losing strength immediately the temperature is raised. They are reduced to about half their strength at 300° C and melt at about 600° C. These temperatures are significant when it is realized that ordinary building fires attain temperatures of between 700°C and 900°C.

Wood does not lose its strength in the same way. In fact its unit strength may increase with the increase in temperature owing to the reduction of moisture content. A wood member loses strength by reason of the material lost through the charring of the surface and it does not normally ignite until a temperature of about 250° C is obtained. These figures make it apparent that even a light timber truss can be expected to have advantage over a steel truss as far as fire endurance is concerned. In addition, non-combustible treatment can now render timber fire resistant and fire retardent and thereby acceptable as an alternative for non-combustible building materials.

It is clear that to protect wood against fungi and insects it must be made unpalatable to the attacking organism. Similarly, immunity to the weather must depend on the degree to which the timber can be waterproofed. Rendering timber fire resistant is concerned with more complex principles but, simply stated, the problem is to ensure that localized combustion is not transmitted across the surface of the wood by flame.

If pre-treatment of timber is to be effective not only must the preservative be carefully chosen with reference to the way the timber will be used and the hazards it will encounter but the method of treatment must be accurately specified and controlled. To effect a permanent solution the processes all involve treatment in a closed vessel. This also provides that accurate measurement of the solution can be achieved. In the case of some of the preservatives, the concentration of the treating solution is adjusted to suit the hazard that timber will encounter to give the degree of penetration desired.

A wide range of preservatives is available, that whatever the production problem or special hazard, it is unlikely that it has not been encountered or anticipated by the research and development laboratories of the various commercial treating companies in the world. To be effectual, the preservative should be permanent and insoluable in water so that it cannot be washed out of the wood by the most severe conditions.

Thus, wood preservation treatment is now available to protect wood from its enemies: fungi, insects, weather and fire and it is practical, not just theoretical. It can be applied economically by simple processes not requiring highly skilled personnal.

No Building is Completely Fireproof

because the contents can burn

The contents of most buildings are combustible and it is the combustible contents, not the building, which is the potential fire hazard to both life and property.

The burning contents of a building can create conditions that are untenable to human life without starting the building to burn. Experience and tests have shown that, if adequate fire protective measures are not incorporated, smoke from burning contents can make a building untenable in 2 to 6 minutes. Temperatures of 150 F may be reached in 5 to 11 minutes. This temperature has been established as the limit for unimpeded evacuation of people through a building in which there is a fire. At such low temperatures, wood and other structural building materials would not be ignited.

Many studies have been made of building fires in which human lives have been lost. When all the facts are known, it is usually found that inadequate fire detection and protection devices, inadequate exits with regard to number and disposition, or other design deficiencies entirely unrelated to the primary structural support are at fault. This being the case, the first consideration in any building — human safety — is to provide for prompt detection and alarm, and adequate exit facilities. The only safety is out.

After the occupants are safely out of a building in which there is a fire, the next most important consideration is to save the building and protect surrounding properties. This not only requires timely and effective fire fighting, but depends on the fire safety measures included in the building design, rather than on the combustibility or non-combustibility of the construction materials.

Why Engineered Timber Construction is *SAFER*

Buildings using suitably engineered laminated and sawn timber construction perform extremely well in a fire and have excellent fire resistive qualities when fire safety provisions, required by modern building codes, are followed. While timber will burn, it retains its strength under fire longer than unprotected metals which are rated non-combustible. The myth of non-combustibility as proof against fire was destroyed at Livonia.

Steel loses strength rapidly as its temperature is raised above about 250 C (482 F); at about 550 C (1022 F) it has little less than half its original breaking strength and loses 90% of its strength at about 750 C (1382 F). Most aluminum alloys start losing strength immediately the temperature is raised; they are reduced to about half their strength at 300 C (572 F) and melt at about 600 C (1112 F). These temperatures are significant when [illegible] building fire [illegible] temperatures of from 700 C (1292 F) to 900 C (1652 F). Wood does not lose strength in the same way; in fact its unit strength may increase with increase in temperature, owing to the reduction in moisture content. A wood member loses strength by reason of the material lost through the charring of the surface. It does not normally ignite until a temperature of about 250 C (482 F) is attained.

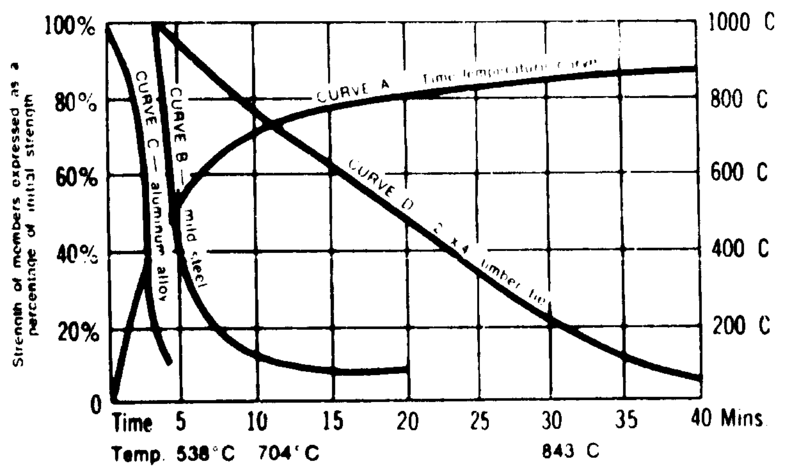
Heavy timber construction is fire resistant because of the slow rate of burning wood in massive form, says the U.S. Forest Products Laboratory in its Wood Handbook.

* Dock and Harbour Authority [illegible]

unprotected metals lose their strength quickly and collapse suddenly under extreme heat.

A graphic portrayal of the value of timber in an intense fire of long duration

Strength of steel, aluminum, and timber in relation to the standard fire test. AITC data.



A graphic presentation of the curves from "Dock and Harbour Authority" showing the strength versus temperature relationship for various materials as related to the standard time-temperature curve for ordinary building fires.

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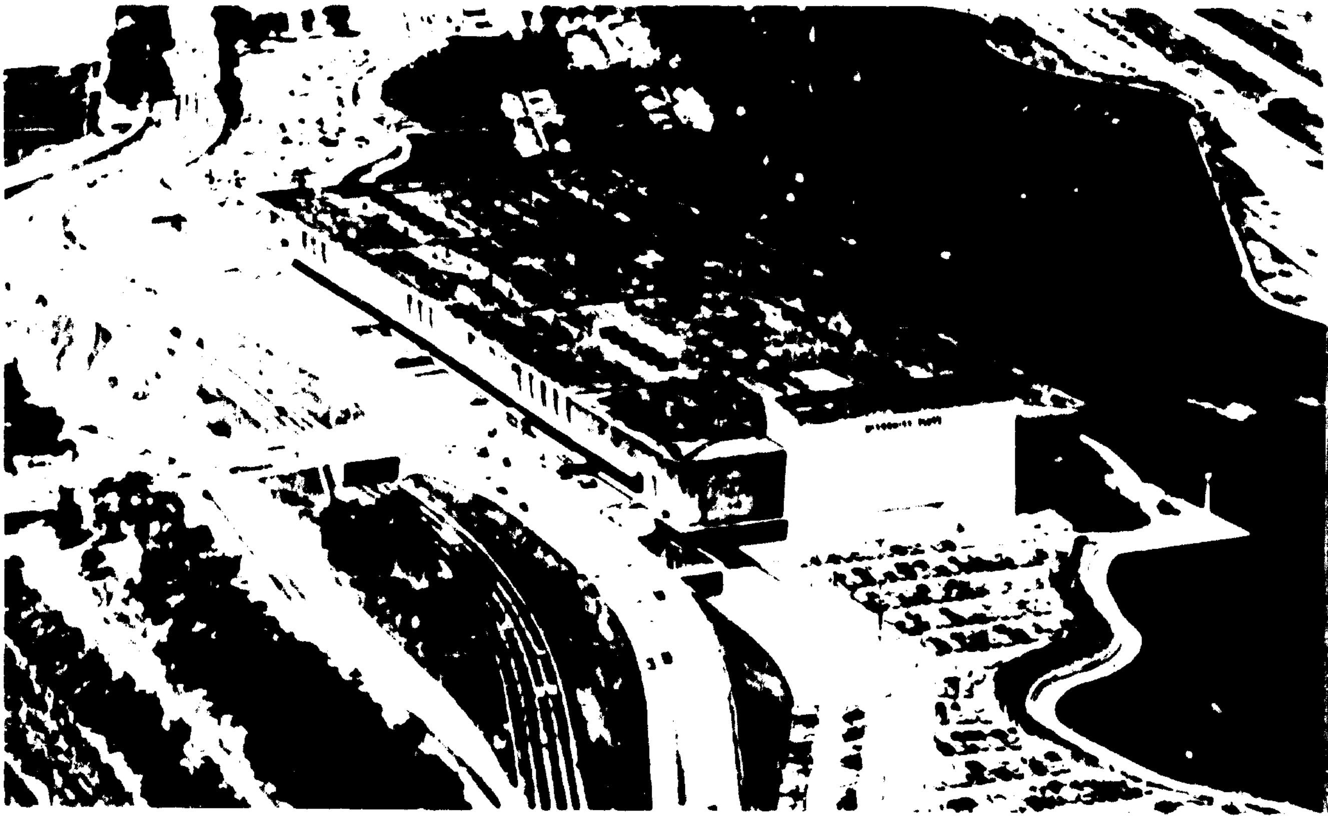

Photo: The Chicago Tribune

Chicago's McCormick Place as it appeared in 1966, 1,089 feet long, 345 feet wide containing 1,119,000 square feet of floor area on 3 levels

"THERE'S NO SUCH THING AS A FIREPROOF BUILDING. THERE ARE DIFFERENT DEGREES OF FIRE RESISTANCE. ALMOST ANY MATERIAL WILL BURN UNDER THE PROPER CONDITIONS." *

Scenes of the most costly single building fire in this nation's history

Many people thought that McCormick Place was a fireproof structure — all of its structural members were non-combustible including its interior and exterior bearing and non-bearing walls. In 1966, 3.55 million visitors poured through the giant exhibition center.

Shortly after 2:00 a.m. on January 16, 1967, a fire broke out in the huge exhibition area where the National Association of Houseware Manufacturers' 1,200 exhibitors were preparing for their semi-annual trade show. Between 12,000 and 15,000 visitors were expected to attend the show scheduled to open a few short hours away.

Edward J. Lee, general manager of McCormick Place, gave the following description of the holocaust that followed: "The furnace-like fire so distorted the structural steel of the building, which in itself, was completely fireproof, that it twisted and buckled the whole structure. Even the southern portion, which is standing erect, and which suffered primarily water and smoke damage rather than fire damage, was twisted and buckled in places as the tremendous heat was transmitted through the structural steel."

Edmund Valique, division fire marshal, gave a similar account: "The flames jumped to the drapes and in a few minutes raced across the ceiling. The heat was so great that — see those girders there — it caused them to expand and contract and pull the whole ceiling down. It fell faster than a wood ceiling would have."

The direct estimated losses for the McCormick Place totaled $150,000,000. The loss on Chicago's economy has been estimated at 3 times that amount.

* Chicago Building Commissioner — Sidney D. Smith.

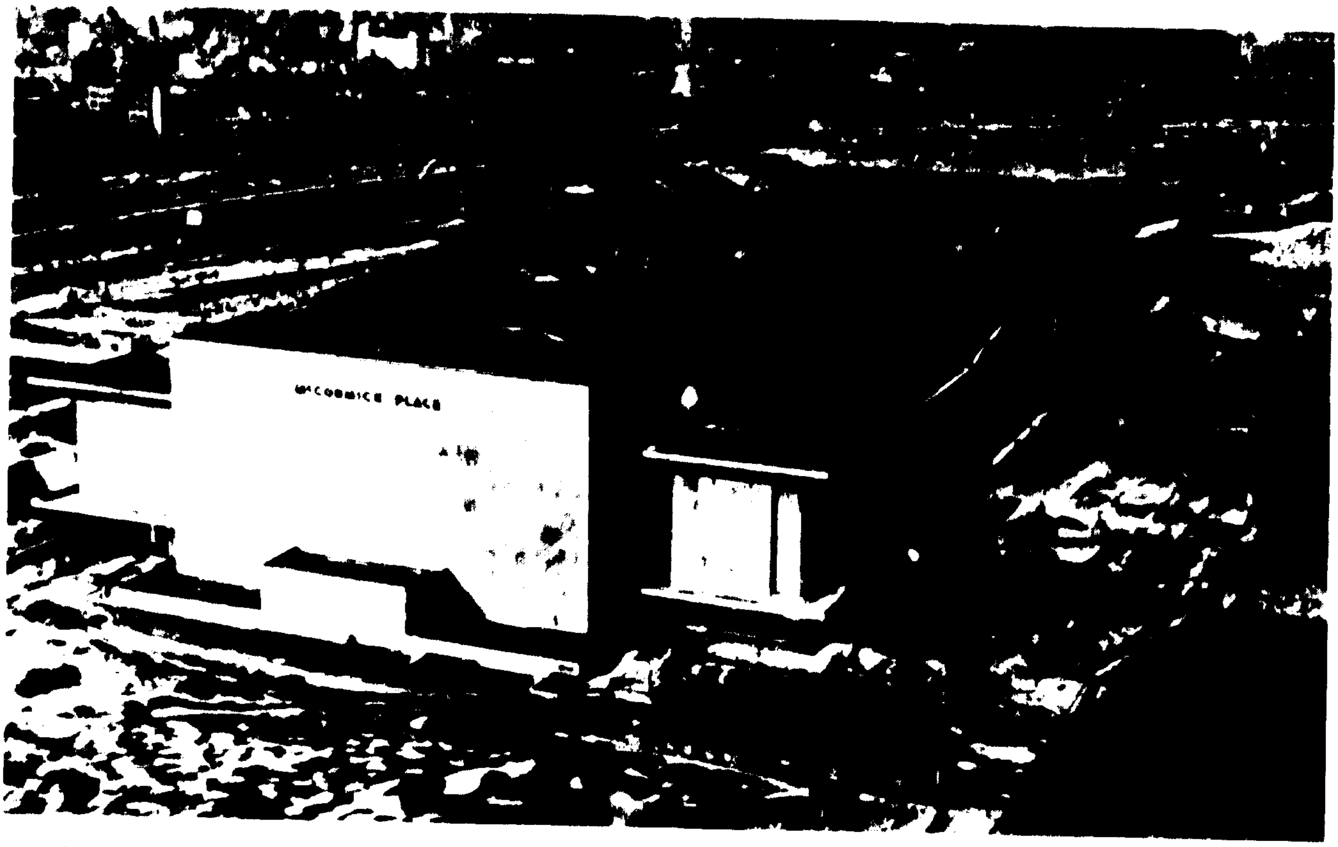

Photo: The Chicago Tribune

McCormick Place the morning after the fire. This "fireproof" structure did not burn but its contents did. Its structural members convulsed as hot flames and icy water combined to expand and contract its beams, girders and trusses and bring about total collapse within 30 minutes after one of the nation's finest fire departments brought every available man and piece of equipment to the scene shortly after 2:11 a.m.

News Bulletin No. 229, National Automatic Sprinkler and Fire Control Association, Inc.

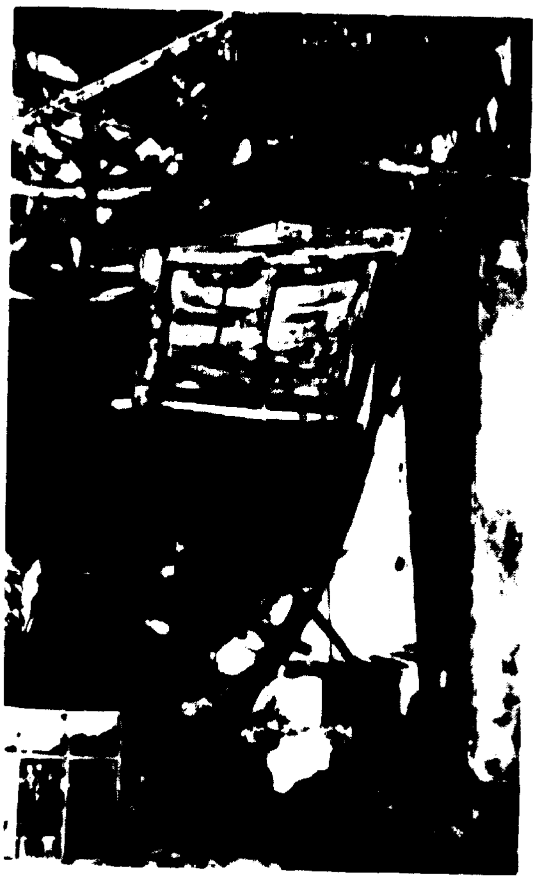

Photo: The Chicago Tribune.

Photo: The Chicago Tribune

This close-up of the fire damage illustrates the destruction involving extensive and costly steel members that collapsed.

There Certainly Is No Such Thing As A Fireproof Building.

STRUCTURAL PROPERTIES

Owing to the very mixed nature of tropical forests, a large number of different timbers are available only in small quantities. Many of them, however, have similar mechanical strength properties. It is common for architects and engineers to specify "all timber shall be Keruing" but there are many timbers as suitable or more suitable than Keruing for structural members. If all suitable timbers were accepted, more complete exploitation of the forest would be possible which would lead to cheaper timber. In conjunction with the stress grading, maximum advantage can be taken of the available timber resources by segregating the available timbers into strength groups and specifying that any timbers of a given group be used instead of specifying timbers by name. In the table given below, the stress range given for each column of the table applies to maximum compressive strength but bending strength has also been considered in deciding the position of each timber. The timbers are arranged in each column approximately in descending orders of strength and a few well known foreign timbers have been added for comparison.

TABLE I
STRENGTH GROUPS

GROUP A	GROUP B	GROUP C	GROUP D
Extremely Strong	Very Strong	Strong	Weakest
Compressive Strength above 8.000 lb.per (1) Sq. In.	Compressive Strength 6.000 - 8.000 lb. (1) per Sq.In.	Compressive Strength 4.000 - 6.000 lb. (1) per Sq. In.	Compressive Strength below 4.000 lb. per Sq.In. (1)
Bitis	Red Balau	Teak	Durian
Keranji	Kempas	Simpoh	Douglas Fir
Chengal	Perupok (Mata Ulat)	Sepetir	Jelutong
Ironbark	Keledang	Machang	Scots Pine
Balau	Merbau	Mempisang	Pulai (3)
Giam	Julim	Ramin (Melawis)	Terentang
Bakau	Resak	Meranti Bakau	Geronggang
	Mengkulang	Jarrah	Damar Minyak
	Rengas	Merawan (4)	
	Keruing (2)	White Meranti	
	Kapur (2)	Nyatoh	
	Tualang (3)	Dark Red Meranti	
	Tembusu (3)	Bintangor	
		Punah	
		Mersawa	
		Yellow Meranti	
		English Oak	
		Light Red Meranti (2)	

1. These figures are the results of standard tests on small clear specimens. They are NOT safe working stresses. Recommended working stresses are given in Table II.

2. For timbers marked thus, some of the species tested showed strengths slightly below the lower limit of the group in which the timber has been placed, although the average strength of the timber is above this limit. This is justified because (i) there is not a wide variation in the species averages for the three timbers concerned, (ii) all are well tried and common timbers and (iii) the method of calculation working stresses is based on the lower limit of strength in each group.

3. These timbers have not yet been tested, and have been allotted low positions in in the table.

4. The various species classed under Merawan vary widely in their strength, some of them would be high in Group C if classified individually. A position on the safe side has been chosen as little is known about the weakest Merawan, and its correct position in Group C is indefinite.

TABLE II
RECOMMENDED WORKING STRESSES

Strength Group	Working Stress in Flexure lb. per Sq. In.			Modulus Of Elasticity 1 000 lb. per Sq. In.	Working Shear Stress Parallel to Grain Lb. Per Sq. In.
	Dry Places Under Cover	Outside Not in Contact with the ground	In Wet Places		
A	2600	2250	2050	2000	180
B	1950	1650	1450	1900	110
C	1300	1100	950	1350	85
D	950	800	750	1150	70

It will be noted that the above recommended working stresses are very conservative because they have been based on the weakest species after making due allowance for all factors which might cause a strength reduction. It is obvious from these figures that significant savings in timber sizes can be achieved if all timber for structural purposes has a known performance which can be specified in engineering calculations. Mechanical stress grading machines are now available and should find an important place in increasing the usage and acceptance of wood having a known strength performance.

Wood structures are generally vastly over-designed because the timber is of uncertain ultimate strength and full allowance has to be made for possible defects such as compression failures, rot etc., which might occur in any piece in the structure. Machine stress grading readily identifies these defects and allows maximum use to be made of all available timber resources irrespective of species. Species identification is of little importance if the strength characteristics of the wood have been defined by mechanical stress grading techniques and the non-durable timbers are made durable by pressure treatment with preservative.

SUMMARY

WOOD IS AVAILABLE

Not only is wood usually available in most countries but it is also self perpetuating in that where forests are properly maintained there is a perpetual source of timber.

WOOD WORKING IS FLEXIBLE

Wood working can be industrialized to any degree required, but industrial processes are not essential. It depends on whether you would rather invest in labour or in capital equipment.

WOOD IS ECONOMICAL

In a timber building, the various functions of the components can be considered separately. Each can be provided for the cheapest and most satisfactory way. Designs can provide optium values without over specification in other respects.

WOOD IS EASILY WORKED

The power required for wood working is small. Wood can be fashioned with simple tools by both professionals and laymen alike. It can be worked by highly industrialized methods as easily as by a craftsman. Excellent workability characteristics also mean that it is easy to modify and additions and alterations are simple. Wood is strong. In comparison to its weight, it is stronger that any other building material. The strength/weight ratio of structural timber in .06 whereas steel is .05 and concrete .02.

WOOD IS LIGHT

The density of wood is approximately 500 kg per cubic meter. Steel is 6 times greater that wood and concrete is 5 times greater. Due to the low density in conjunction with high strength, buildings of timber may be up to eight times lighter than corresponding buildings of brick or concrete. Timber buildings do not need such heavy foundations which is an advantage when subsoil conditions are poor. Transport cost and erection times are proportionally less as well.

WOOD WITHSTANDS MOVEMENT

Uneven settlement may easily cause serious cracking in buildings, in concrete, lightweight concrete and brick. A timber building may absorb differences in settlement from one corner to the other of several centimeters without any visible results and moreover, without damage.

WOOD PROVIDES HEAT INSULATION

The semi-conductivity of concrete is 13 times as great as that of wood and steel is 417 times as great. Because of the good heat insulation capacity of wood, timber structures do not cause "cold bridge" problems relating to condensation and draft sensations.

WOOD IS NOT A FIRE HAZARD

Both, building and fire experts are quite satisfied that low rise buildings in timber do not present any risk in increase fire risks. When fire starts, timber structures continue to retain full strength for long periods. The strength of a timber structure is reduced only gradually, during burning or excessive heat, not suddenly in the case of structures of certain other materials which may collapse very rapidly. Movements are small, which therefore reduces the risk of excessive compressive forces starting fires.

WOOD IS DURABLE

There are timber buildings in existence today which are over 1.000 years old.

IN CONCLUSION, industrialized buildings made of timber, properly designed in respect to use, properly engineered for strength and properly constructed cannot only use native materials and native unskilled laborers but can also save time, save money and the end product can be superior to those utilizing other materials.

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