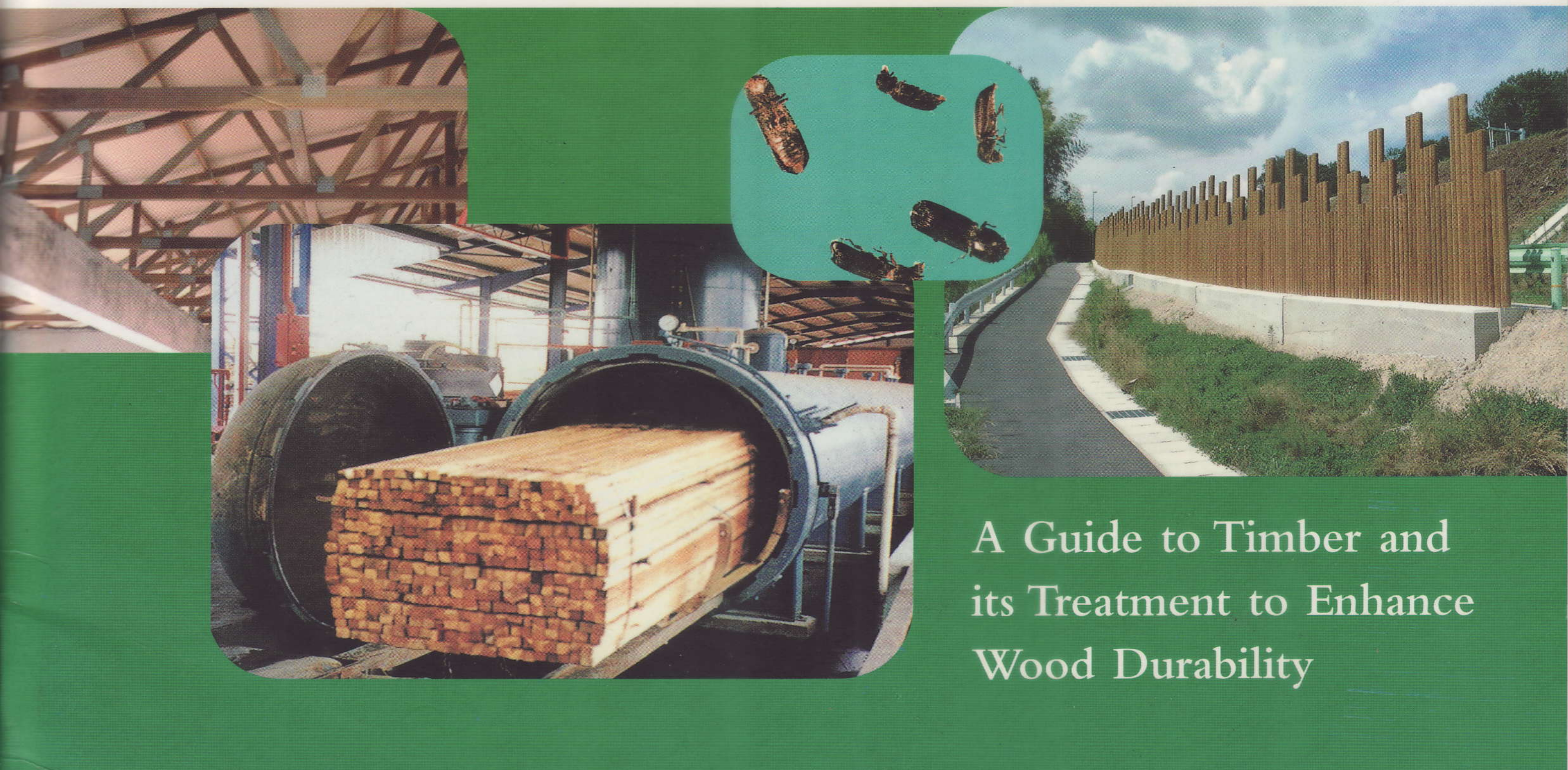
UNDERSTANDING TIMBER PRESERVATION



A Guide to Timber and its Treatment to Enhance Wood Durability

Persatuan Pengawet Kayu Malaysia (reg.no:1249)
(Malaysian Wood Preserving Association)

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This guide book has been prepared by the Standards Committee of MWPA and approved by MWPA Council.

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MWPA is an association comprising timber treaters, suppliers of preservatives, research organisations, and individuals and organisations having an interest in timber treatment and the use of preservative-treated timber.

MWPA promotes the benefits of timber preservation, assists in the establishment of and adherence to standard specifications for preservative treatment of timber, and supports the maintenance of approved and acceptable standards of practices in all sectors of the preservation industry.

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1. INTRODUCTION

The objective of this publication is to provide a general introduction to wood technology and wood preservation. A knowledge of these fundamental subjects is of considerable assistance in gaining an appreciation of the value and importance of timber preservation and the selection of the most appropriate method of preservative treatment.

The growth of the Wood Preservation Industry has been one of the most important technical developments within the forest industry. The wide acceptance of preservation as an integral part of wood processing and utilisation is a significant contribution to maintain the sustainable supply of this renewable resource. Wood preservation promotes the conservation of indigenous forests by making plantation timbers, which aren't naturally durable, into effective substitutes for durable timbers from indigenous forests. It also reduces the volume of wood used by prolonging the service life of wood for many years.

There are timber structures still in existence after hundreds of years of service but there are fence posts, which have rotted after only 18 months service. This is due not only to the great variability in wood properties and the environment but also to the way in which the products are used. Wood suffers minor and gradual physical and chemical changes as a result of age. It is an organic material which can support the life of other organisms if the environment is suited to their growth and this, under certain conditions, leads to rapid breakdown of the wood. What are the circumstances in which wood is likely to be attacked by destructive agents and what measures should be taken to defeat them?

Most people can identify wood when they see it and can give names to the more familiar timbers in general use. However, much is taken for granted and relatively few may know timber in terms of a growing form of plant life or understand what structural variations produce the features characterising species which enable us to name them. The differences which exist between species are sufficient for us to realise that timber is a substance of greater diversity and character than materials such as steel and concrete. To enable the best use to be made of wood and to ensure the correct selection of the type best suited to any application, it is necessary to understand something of its structural form and characteristics and how these vary from species to species.

2. TREES THE SOURCE OF WOOD

Trees have several main parts each with special functions. These are the roots, the stem or trunk, the leaves, branches and bark. Wood is produced from the stems or trunks of trees. The roots anchor the tree in the ground and absorb water containing dissolved mineral salts from the ground. The outside of the trunk is covered by layers of an insulating and protective material known as the bark, guarding the wood from extremes of temperature, drought, biological and mechanical damage. The leaves of the trees are predominantly green because the cells, which make up a leaf contain a green coloured substance called chlorophyll. This material absorbs energy when exposed to daylight. In the presence of daylight this substance catalyses, a process called photosynthesis whereby water derived from the soil and carbon dioxide derived from the atmosphere are combined into food materials called carbohydrates (i.e. plant sugars and starches).

Food materials are transferred through the branches and the trunk to a special layer of tissue just beneath the bark called the cambium where the growth of the tree takes place. The trunk of the tree is composed of two main parts known as the heartwood and sapwood. The heartwood (also called the truewood) is the central portion of the trunk and is surrounded by a zone under the bark known as sapwood. Usually these two zones can be clearly seen, as the heartwood in most species is somewhat darker in colour than the sapwood. The heartwood obtains its colouration from various tannins, resins and other matter, which have been deposited there during its transition from sapwood as the tree grew.

The sapwood is the outer portion of the trunk through which water and dissolved mineral salts are conducted from the roots to the leaves and where food materials are stored, usually as starches. Wood changes from the sapwood to the heartwood condition gradually, through a region of variable width known as the "transition zone". The wood in this zone has intermediate characteristics between both the sapwood and heartwood and it is here that the resins and other deposits which are the distinguishing feature of heartwood first occur in the wood cells:

3. TIMBER CLASSIFICATION

All timbers in the world can be broadly classified into two large groups, each with district botanical features. These are known as hardwoods and softwoods. The hardwood timbers are derived from broad-leaved trees, which bear seeds in seed covers. The softwood or coniferous timbers, on the other hand, are derived from a comparatively small number of cone-bearing species, mostly with evergreen needles or scale-like leaves.

This classification into hardwoods & softwoods is botanical in nature and does not actually refer to the hardness or softness of the timber. For example Balsa (*Ochroma lagopus*) or Jelutong which is a hardwood is exceptionally soft & light while Yew (*Taxus baccata*) is harder than many hardwoods although it is a softwood. Most of the hardwoods are found in the tropical and semi-tropical regions of the world while softwoods are found mainly in the temperate zone.

In Malaysia, basing on record so far, most of the timbers are hardwoods and only a few are softwoods. According to Malaysia Grading Rules (MGR) for sawn Hardwood Timber, 1984 edition, the hardwoods are classified into 3 classes based on the density & natural durability while there is no specific classification for the softwoods. Thus Malaysian timbers are classified broadly into four categories, namely Heavy hardwoods, Medium hardwoods, Light hardwoods and Softwoods.

Heavy Hardwoods

Heavy Hardwoods are heavy or very heavy constructional timbers ranging in density from about 800 to 1120 kg per cu.m at 15 percent moisture content and are naturally durable. Such timbers can be used in most exposed conditions without undergoing preservative treatment. However, the sapwood of these timbers requires preservative treatment as it is not naturally durable.

Some examples are Balau/Selangan Batu (*Shorea* spp.), Chengal (*Neobalanocarpus hemi),* Resak (*Vatica* spp. and *Cotylelobium* spp.);,and Merbau (*Intsia palembanica; Intsia bijuga*).

Medium Hardwoods

Medium Hardwoods are moderately heavy to heavy timbers ranging in density from about 720 to 880 kg per cu.m at 15 percent moisture content. They are usually moderately durable timbers. Some of these timbers (eg. Kempas and Tualang) are heavy and strong enough to be classified as "Heavy Hardwoods" but under tropical conditions they lack sufficient natural durability when exposed to the weather or in contact with the ground unless they are properly treated with preservatives before use.

Kapur (*Dryobalanops* spp); Kempas (*Koompassia malaccensis*); and *Tualang* (*Koompassia excelsa*) are some examples of medium hardwoods.

Light Hardwoods

Light Hardwoods are relatively light with density below 720 kg per cu.m at 15 percent moisture content. These timbers are not naturally durable under the tropical climate (although some are quite durable in temperate regions) and they require preservative treatment to prevent attack and infestation by wood destroying agents such as insects and fungi.

Examples of light hardwoods are Meranti (*Shorea* spp, etc); Ramin (*Gonystylus* spp); and Rubberwood (*Hevea brasiliensis*).

Softwoods

There are very few softwoods of commercial significance in Malaysia and none of these are durable in the tropics.

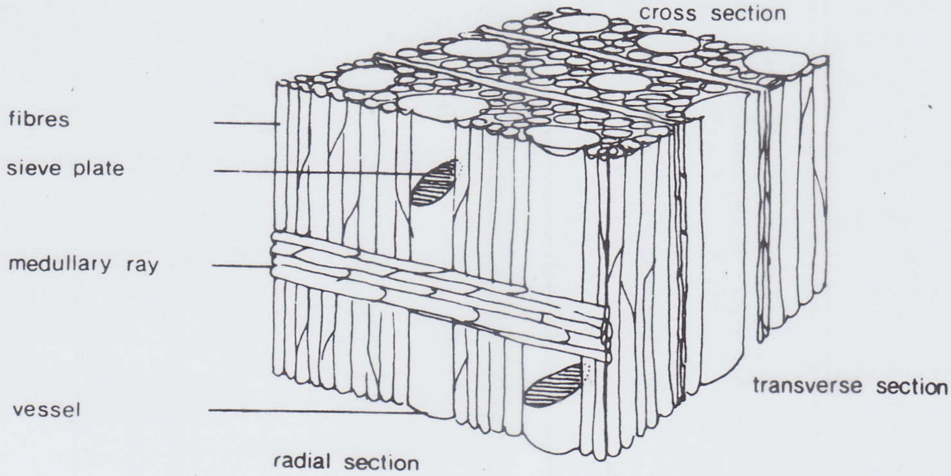
Examples of softwoods are Damar Minyak (*Agathis borneensis*); Podo (*Podocarpus* spp); & Sempilor (*Dacrydium* spp; *Phyllocladus* spp).

4. THE STRUCTURE OF WOOD

Wood, like other materials originating from l..ng matter, is composed of an immense number of hollow individual units known as cells. It has been estimated that there are about 45,000 such cells in an ordinary matchstick.

In hardwoods, the arrangement of the cells is not as simple as that found in softwoods. Very small tubes known as fibres provide strength to the tree. In shape, the fibres are similar to the softwood tracheids, except that their ends are like pencil points rather then wedge shaped. Much larger open tubes known as vessels or pores, pass water from the roots to the leaves. Again, there are masses of radially placed rays, similar in shape to the brick-shaped cells in softwoods which also act as storage containers for surplus food materials.

In hardwoods, many of the large liquid-conducting tubes in the sapwood- the vessels – remain open and allow the free passage of liquids into the trunk. In the truewood (heartwood) of hardwoods however, these tubes are very often blocked in one way or another, making-the passage of liquids along their length-very difficult.



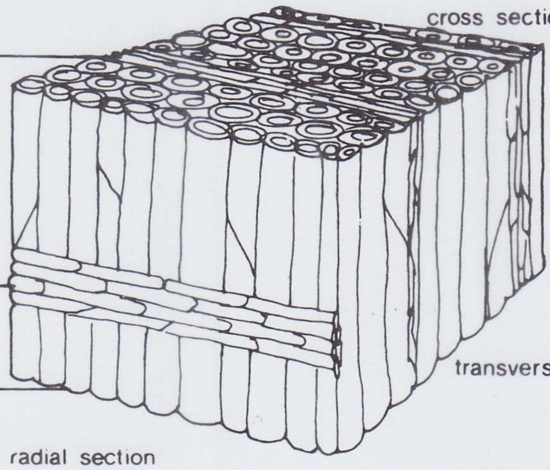
Simplified drawing of a cube of hardwood on the same scale. Cell wall pits omitted.

In softwoods, the cells are shaped like tubes with wedge-shaped ends and a length many times their width. They are rather like drinking straws joined end to end and compressed on all sides to give the appearance of a honeycomb in cross section. These tubes convey liquids between the roots to the leaves and also provide strength to the structure.

The vertical tubes or cells are called tracheids. Passing between them are small bundles of horizontal radial elements composed of brick-shaped cells, known as rays which are essential food storage cells containing plant sugars and starches which are surplus to the growing tree's immediate requirements.

Liquids pass up the length of the tree from cell to cell in the sapwood through numerous valves in their walls. These valves are called pits which are so placed that liquid can be passed from one cell to the next right up the tree. Each valve is divided into two parts by a flexible, permeable membrane. In many softwoods, this membrane has at its centre a thickened pad large enough to cover either opening to the valve. Generally, the membrane and pad are centrally placed, leaving both openings uncovered, thus allowing liquids to pass freely from one cell to another. Under certain circumstances however, the pad moves over and covers either one or the other opening, thus restricting the .movement of liquids through the valve and therefore movement of liquid from one cell to the next throughout the timber. It is this movement of the membrane that may cause the flow of liquid through the sap-wood to be unpredictable.

The moisture movement in the tree occurs in the sapwood, the heartwood playing little, if any part in water conduction. The cells of the heartwood (truewood) are inert, often blocked by gums, resins or other chemical compounds and generally contain a high proportion of valves in which the pad on the membrane has moved to one side closing the opening. Therefore, moisture movement is greatly rested.



Simplified drawing of a cube of softwood magnified. The cell wall pits have been omitted.

5. WOOD PROPERTIES & CHARACTERISTICS

Timber species vary markedly in their structure and chemical constituents. These factors determine the extent to which wood is naturally protected from decay and the ability to penetrate it with protective chemicals.

5.1 Durability

Sapwood, irrespective of species, is of low natural durability. It generally has a lower density than the heartwood, has a high moisture content and high starch content, all of which are conducive to fungal or insect degradation.

Wood that is kept dry and is naturally durable is able to resist invasion by fungi or insects. Factors involved in providing this durability include carbohydrate and chemical makeup.

Heartwood contains cells which have chemical deposits within the cells, little or no carbohydrates and relatively lower moisture content. Heartwood in some species e.g. resak, can be highly durable whilst in others e.g. kempas, durability is low.

Durability may be increased by the addition of chemicals that are toxic to fungi or insects, or which reduce the possibility that the moisture content of wood will increase from the seasoned state. It is the addition of these chemicals that provides the basis of the timber preservation industry:

5.2 Permeability

The ability to penetrate wood with chemicals toxic to insects or fungi is largely dependent on being able to remove moisture, so that the preservative liquid can be added in its place. (Some water soluble chemicals will *move* by diffusion to penetrate the wood sufficiently to protect it.)

Most preservatives will not pass through cell wall membranes by diffusion and require pressure to push them deep into the wood. The depth to which penetration is achieved is dependent on density, chemical inclusions within cells, moisture content, cell type, techniques used, etc.

Generally, light hardwood (Rubberwood, Jelutong),and softwood (*Damai Minyak* and Podo) are more easily penetrated than medium hardwood (Kempas) and heavy hardwoods (Balau). Sapwood is more easily penetrated than heartwood.

6. DETERIORATION OF WOOD

Depending upon the conditions of service, timber may be attacked by one or more agents causing degrade. Proper design, and preservation practice can eliminate or minimise such attack. The principal causes of attack are:

6.1 Fungi (Decay)

Fungi are classified with characteristics of both plants and animals, but differing from plants in that they have no chlorophyll in their structure. They develop from minute spores and when germinated in suitable condition, send out filaments called *hyphae*. These penetrate wood structure and if suitable conditions exist break down the wood tissues into simple chemical compounds on which they feed.

Under favourable conditions, the development of attack can be rapid. Timber which is attacked by fungi is sometimes covered by a mass of intertwined and overlapping hyphae resembling cotton wool, collectively called *mycelium.*

When the fungus is mature and conditions are suitable, it produces fruiting bodies (mushrooms) which are very different from those of normal garden plants. They can be microscopic or relatively large, either in the form of a fleshy plate standing out on edge from the decayed wood, or as a thick, flat skin covering part of the wood. Fungal spores are produced by the fruiting body in vast numbers and may be carried by air currents, animals, birds etc. for considerable distances to another wood where they will germinate, provided conditions are suitable. Conditions necessary for the development of fungi are:

- A moisture content suitable for their development.
- An adequate oxygen supply.
- Suitable temperature for their growth .
- Adequate nutrients.
- Sufficient Time.

Timber preservation, is largely built around the nutrients, i.e. rendering the wood nutrient toxic, unpalatable or uninhabitable. There are two main groups of fungi which can cause decay in timber. Whilst some particular fungi may be representative of both groups, they are usually classified as either wood destroying or wood disfiguring fungi.

6.1.1 Wood Destroying Fungi

These fungi feed on the compounds of the cell wall and consequently can weaken the structure of the wood to such an extent that the wood breaks and crumbles away. Wood destroying fungi can be subdivided into three groups:

(A) ***White rots.*** In the white rot type of fungi, the breakdown of the material forming the cell is more complex, since the cellulose and lignin are both attacked. The affected timber eventually becomes much lighter in colour and weight and loses its strength properties. Badly decayed timber does not crumble in the same way as that which has been attacked by the brown rots. The timber breaks down more in a longitudinal direction with a fibrous appearance and there may be pockets of decayed wood between apparently sound areas. The transverse cracking found in the brown rot attack is generally absent.

(B) ***Soft rots.*** This group is typically found in wet situations such as cooling towers and wood in contact with the ground. The physical and chemical character of the form of wood cell attack caused by the group of fungi responsible for soft rot, differs markedly from that of the decay types described above. Decomposition commonly results from the organism making longitudinal cavities in, and parallel to, the axis of the cell wall. In wet wood, its presence is evident if surface layers are soft and may be readily scraped away. When dry, surfaces will exhibit a profusion of fine cracks and fissures both with and across the grain. Microscopic examination would reveal the characteristic cell wall cavities.

Hardwoods are thought to be naturally more susceptible to this form of degrade than softwoods though no wood is completely resistant.

(C) ***Brown rots.*** In this group, the fungi feed mainly on the lighter coloured cellulose content of the cell wall and leave the darker lignin more or less intact. The timber, after attack, may become dark brown in appearance and as it dries, the surface can become badly broken by deep transverse and longitudinal cracks and generally, apart from the colour and smell, gives the appearance of wood which has been charred in a fire. The decayed timber usually feels very dry and is low in strength, light in weight and burns easily. The most common brown rots are often found attacking softwood timbers and the lighter hardwoods. Brown rots do not appear to be a problem to Malaysian timber.

6.1.2 Wood Disfiguring Fungi

Some wood colonising fungi, whilst having little or no effect on the strength of timber, can reduce the commercial value by adversely affecting its appearance Fungi of this type fall into two categories:

(a) ***Staining Fungi.*** The sapwood of most species of timber is susceptible to fungal staining which can occur in both logs and sawn timber, especially in climatic conditions of warmth and humidity. Although staining fungi may be the only ones present initially, true decay fungal attack may follow unless control is initiated.

One of the most commonly occurring stains is referred to as sapstain or blue stain and usually manifest itself as a blue-black, blue-grey, brownish purplish discolouration of the timber. Freshly felled logs are particularly susceptible and in cases of severe attack, the entire sapwood may be stained.

Staining is generally caused by fungi that depend on sugars and starches present in the wood rays and rarely utilise the lignin or cellulose, as in the case of wood decay fungi.

It should be noted that chemical stains (as opposed to fungal stains) can occur in timber with a high tannin content, when in contact with such metals as iron, copper or copper alloys.

(b) ***Moulds.*** This form of disfigurement is caused by fungi which produce a powdery or woolly mycelial growth and masses of spores at the timber surface. The most common colours of these surface moulds are black, shades of green, brown and occasionally orange.

The moulds that cause disfigurement are most severe on sapwood, particularly that with a high carbohydrate content. Mould fungi are very similar in all other important aspects to staining fungi, i.e. colonisation, proliferation, nutrient requirements and limited or no capacity to utilise the cellulose and lignin content of the timber, thus having negligible effect on the strength of the timber. As with fungal stains, the activities of moulds may increase the permeability of woods to fluids. Obviously, the consequence of this is that the affected timber absorbs moisture more rapidly and favours the development of fungal decay.

Generally, mould fungi are more tolerant to preservative chemicals than staining or decay fungi, which is why moulds sometimes appear on treated timber. Nevertheless, most of the chemicals used for stain control will deal adequately with moulds also. Since moulds are usually superficial, they can be readily removed by brushing or planing, though shallow spot staining on some hardwood commodities such as plywood face veneers, may occur.

6.2 Wood Borers (mainly Beetles)

Practically all timbers, under certain conditions, may be attacked by wood borers of one sort or another. Infestation by some wood borers may be of little or no significance, whereas attack by other borers may be serious and necessitate remedial action. Wood borers are mainly beetles (the order Coleoptera) which at some stage of their life cycle bore into wood for food or shelter. These beetles are the powder-post beetles (Lyctid and Bostrychid borers), ambrosia beetles or bark beetles (pinhole or short-hole borers), and longhorn beetles (Cerambycid borers). Beetles pass through four distinct stages of development: egg, larva, pupa and adult. With the majority of wood borers, the major damage to wood material is done by larvae which actively tunnel in the timber from which they derive their nourishment. With some exceptions, the only damage they cause as adult beetles is the cutting of a flight or emergence hole through the surface of the timber as they escape from it. After emergence, they usually live for only a few weeks. After mating, the females may re-infest the timber from which they emerged.

The other tropical wood-boring insects, carpenter bees and other groups of insects, are omitted as these are minor timber pests or little is known about their biology.

6.2.1 Powder Post Beetles

Powder post beetles can attack softwood and hardwood, both in the green and seasoned condition, during and after seasoning or storage (Findlay 1985). Symptoms are surface holes with digested wood as a fine flour-like powder. The infestation is confined to the sapwood containing starch that constitutes the most vital ingredient in the diet of powder post beetles (Hickin, 1975 & Iwata, 1988). The infestation can cause structural damage to timber containing a high proportion of sapwood. The most troublesome powder post beetles attacking timber belong to the Lyctidae and the Bostrychidae families.

6.2.1.1 The Lyctid Borers

Lyctid borers infest the sapwood of susceptible hardwood timbers at between 8 and 25 per cent moisture content, but not the heartwood. The susceptibility of the various species of hardwood is determined by two factors - starch content and pore (vessel) size.

Female Lyctid beetles lay their eggs beneath the surface of the wood, by inserting their ovipositor into the pores. Any species in which the pores are too small to accommodate the ovipositor will be immuned from attack. Likewise susceptible timbers that contain insufficient starch, will have little or no larval development and that particular piece may be less damaged.

Only the dry sapwood of certain hardwoods with high starch contents is susceptible to Lyctid attack. Because heartwood is never attacked, structural weakening can be caused only to those building timbers that have a large sapwood content e.g. Kempas. Where timbers, often with a very wide band of Lyctid-susceptible sapwood are used for building, Lyctid attack can be serious.

In the tropics, the Genus *Minthea* of the Lyctidae family was reported to be very common and is distributed throughout tropical Asia, East Africa and Northern Australia (Abood et al, 1992). The Mintheas are generally found in high rainfall areas. *Minthea rugicollis* is small in size about 2 – 3 mm long. The female Minthea beetle can insert its eggs into timber with smaller pores due to its smaller size and it does not bore through the wood to lay its eggs. Another common insect *Minthea reticulata*, is often misidentified as *M. Rugicollis*. Another borer, *Lyctus brunneus* is seldom found to be widespread in Malaysia.

6.2.1.2 The Bostrychid Beetles

The Bostrychids vary in size from 4 mm to about 11 mm long (Bravery, et al, 1987). Bostrychids bore into the wood to lay their eggs and so they can infest wood with large or small pores (Findlay, 1985). Infestation of these powder post beetles in woods cause the formation of entry and exit holes with fine powdery dusts being exuded from them and numerous tunnels within the sapwood. They prefer seasoned and partially seasoned sapwoods with high starch contents. The common wood infesting insect of this group is *Heterobostrychus aequalis*. Two common bamboo borers are, *Dinoderus minutus* and *D. bifoveolatus*, both rarely attacking timbers (reported on Rubberwood and Jelutong). Another rare timber pest is the Bostrychid beetle *Xylothrips flavipes* that attacks green timber (reported on Rubberwood, Yellow Meranti, Merbau, Mersawa, Rubberwood and Tualang). Others also of relatively rare occurrence on timber are *Sinoxylon conigerum* and *S. anale*.

6.2.2 Ambrosia (Bark) Beetles

Ambrosia beetles are prevalent in the tropics and invade fresh-felled wood rapidly sometimes within an hour of tree felling. These insects are members of the Platypodidae and Scolytidae. Ambrosia beetles require moisture for development since they depend on fungi for food. The damage caused by these beetles are the characteristic pinholes or shortholes of 1-3 mm diameter (or <1 mm for some species), but do not occur in seasoned wood. Normally the mechanical properties of the wood are not affected as the tunnels they bore do not extend after the wood is dried. These insects cultivate ambrosia fungi which cause circular black-stains at entry holes, where the fungi are the food of the larvae and the adults. The insects reduce wood into fibrous bore dust but galleries are frass-free. Examples of common ambrosia beetles in Malaysia are the genera *Platypus*, *Xyleborus* and *Arixyleborus*.

6.2.3 Cerambycid Borers

These are also known as longhorn beetles due to their characteristically long antennae, of the order Cerambycidae. Most of the species are forest insects attacking from the bark of fresh-felled logs, logs that are left lying on the ground for many months, and unhealthy trees, while only a few attack timber during seasoning or timber in buildings. The beetles feed on, and lay eggs inside, the bark. The damage is caused when the larva tunnels through the inner bark and when it feeds on the sapwood producing tunnels tightly packed with frass. The frass is a mixture of course wood chips and fibres.

The common Cerambycid beetles in Malaysia are *Hoplocerambyx spinicornis*, *Stromatium longicorne*, and *Batocera rufomaculata*. The larva of *B. rufomaculata* are also called round-headed wood borer presumably due to the almost circular exit hole made by the insect. About 30 timber species are known to be attacked by *B. rufomaculata*, eg. logs of Meranti, Jelutong, *Acacia mangium*, Kasai, Mata Ulat, Mengkulang and Nyatoh.

6.2.4 Buprestid Borers

These insects are the Jewel/Metallic beetles of the order Buprestidae, which also invade the bark of trees and logs, and then the larvae feed on the sapwood beneath the bark. The exit holes are oval-to-rectangular shaped. Tunnels are packed with sawdust-like borings. The adults appear boat-shaped, are frequently beautiful insects and brilliantly coloured. There appears to be relatively little information about this group of beetles in Malaysia, as these insects may be secondary pests of timber. An example of this group is *Catoxantha opulenta*.

6.3 Marine Borers

The destruction of wood in contact with sea water and brackish water is mainly due to the activity of marine borers of which there are two main classifications: the bivalve molluscs (Shipworms) and the crustaceans (Gribble). There are also marine fungi which can cause slow superficial (soft rot) decay but these are of minor importance, although they are precursors of marine borer attack. Marine borers are distributed along the Malaysian coastline and are found all over the world. They can be most active in the warm waters of the tropic zones, particularly in large river estuaries where the lower salinity is more conducive to their growth. None of the naturally durable Malaysian timber species appears to be resistant to marine borers, while exceptionally high preservative loading in wood may be necessary for protection against these organisms.

6.3.1 The Bivalve Molluscs

The group Teredinids are commonly known as shipworms because of their wormlike appearance, while the Pholads are clam-like. The molluscs produce eggs which hatch in the sea and attach themselves to a piece of wood. Mollusc attack is recognised by the very long round tunnels which riddle the inside of the timbers, (often leaving the surface intact) and by the smooth, shell-like coating in the tunnels. They bore into it leaving only a tiny hole on the surface, growing larger as they feed and, therefore, boring larger tunnels. If a mass of molluscs attack a wooden pile which is of a susceptible species and has not been preservative treated, it may be completely eaten away within three months.

The Teredinids of the genera *Teredo* and *Bankia* are the most prevalent and destructive species in Malaysian waters and will attack most timbers. These groups have a wider distribution. Their attacks are usually confined to the larval stage when the organism is free-swimming. They penetrate the wood at right angles to the grain and subsequently burrow in a longitudinal direction in the wood. The size of the adult varies considerably with the environment. The borer may attain a length ranging from a few centimeters to 12 centimeters or more.

The Pholads of the genus *Martesia* are also prevalent in Malaysian waters, but have a relatively restricted distribution. The Pholads have their body encased in a bivalve shell and appear clam-like. The young organisms are free-swimming. They penetrate the wood as pear-like boring holes under the wood surface and do not extend deep into the wood. The common species is *Martesia striata*.

6.3.2 Crustacea

Commonly known as "gribbles", Crustacea in Malaysian waters includes the genera *Limnoria* and *Sphaeroma,* the latter resembling the wood louse or slater. The crustaceans however, are not regarded as serious pests in Malaysian waters compared to the molluscs.

The crustaceans are not as prevalent and do not attack as rapidly as the shipworms. Their attack is similar to that of dry-wood borers, with irregular holes or galleries in the wood and the damage is not concealed like that of the molluscs. Their burrows are mainly on the wood surface. This superficial attack causes the surface to weaken and hastens erosion, exposing fresh surface to attack. They work mostly between high and low water mark, often eating the pile away until an "hourglass" appearance develops. They breed irregularly, the female laying eggs in the wood and the larvae attacking the wood in which they occur, very rarely travelling very far form it.

6.4 Termites

Termite (white ant) damage is accepted as a significant risk to building and other structural timbers in most parts of Malaysia. Wherever there is a risk of termite attack, it is wise to take some precautions.-For buildings, these precautions usually take the form of chemically treated-soil barriers or physical barriers and the use of proper preserved timber.

There are many varieties of termites encountered in various localities and there is no reason to assume that the areas affected are not spreading. Like bees and some ants, termites are social insects living in colonies which with some species, in a mature colony, may contain several million individuals but in other species numbers seldom exceed more than a few hundred.

6.4.1 Subterranean Termites

Subterranean termites are soft-bodied insects, by nature ill-equipped to survive in the open because they lose moisture and die from desiccation. They conserve their moisture by working within a self-contained, enclosed gallery system. Typically, with the species which commonly attack timber in service, the nest from which the attack originates will be in a tree or a partially decayed piece of wood buried or half-buried in the ground. From the nest, foraging galleries will be tunneled through the surrounding soil to useful food sources. The interior of susceptible timber will be eaten out, without perforating the surface layers and exposing the termites to the atmosphere. Sometimes the excavated wood is replaced by a honey-comb structure of digested matter, through which the insects can move quite freely. Alternatively and notably; in timbers with welt-defined annual rings, the termites might eat out the early wood, leaving concentric rings of the denser late wood more or less untouched. When lightly tapped, infested wood often has a "papery" sound. If probed, the thin surface is easily broken to expose the gallery system beneath. Obviously, the presence of live termites in a freshly exposed gallery indicates active attack. A deserted gallery could mean old attack from a colony which might or might not still be active, or a foraging area which has been disturbed to such an extent that it has been (temporarily or permanently) abandoned by an active colony.

6.4.2 Dry Wood Termites

Dry wood termites occur throughout the tropics and the sub-tropics of the world and a few species extend into the warmer temperate regions. Some live in dry, sound wood; some live in the dead wood of living trees, apparently depending upon moisture from the living portions; and some live in damp wood. Those species which live in dry wood, or at least, in wood not especially moist, are spoken of collectively as dry wood termites. Those of greatest known economic importance belong to the genus ***Cryptotermes***, populary known as powder-post termites.

6.5 Fire

Wood is naturally consumed by fire. Its use as a fuel and as a source of charcoal is well known. This does not mean that wood is an unsafe building material, rather the reverse is true. Wood is a good insulator, hence fire is a surface phenomenon. The core of wooden beams maintains a low temperature, sustaining the natural strength of wood. Large beams and structures while burning, will continue to hold up a building during a fire. Compare this with steel which becomes hot, loses strength, sags and collapses suddenly.

Wood has a well known char rate typically 0.6mm/min, hence design for fire can. be accommodated. Fire retardants can inhibit the ignition of wood by fire and can inhibit or slow down the spread of flames. Improved fire resistance and fire retardancy are valid wood preservation processes.

6.5.1 Fire Retardants

A fire started when wood, a combustible material ignites in the presence of air and high temperature. In this process flammable gases are produced which will further induce flame spread.

Fire-retardant chemicals react with the combustible gases and tar that are normally produced by wood exposed to high heat. These chemicals convert the combustible tars to harmless carbon dioxide and water vapor, rendering them for the most part nonflammable. The built-up of carbon tar acts as thermal insulation, slowing down the rate at which the cross section of exposed wood is reduced by fire and thereby allowing the wood structures to maintain their structural integrity longer. Fire subsequently ceased when the flame source is extinguished.

Most building codes and standards will approve pressure-impregnated fire-retardant chemicals whereby the treatment process can be controlled. Intumescent or brush-on products has no process control and are non-standard/building code applications.

Fire-retardant treated timber is rated by a flamespread and fire propagation index. The flamespread rating and fire propagation index are determined by tests conducted in accordance to BS476, Part 7 and Part 6 respectively. In Malaysia, both the tests are often required to determine fire rating conformance.

Due to the problems of hygroscopicity (moisture absorbency), corrosion and heat degradation (strength loss due to heat) especially in Malaysia, new generation fire-retardants have been developed. The AWPA Standard has also been re-written to subdivide fire-retardants into Type A and B that meet different humidity ranges. Type A is for relative humidity at 92 percent and Type B for humidity in excess of 75 percent.

Fire-retardants are mainly inorganic water-base formulations and are pressure impregnated by the full cell 'Bethell' process. The fire retardant treated timber (FRTW) or plywood is colourless. Loading in determined by thickness and species.

6.6 Weathering

Timber is liable to breakdown by weathering. Ultraviolet radiation present in sunlight has a strong, degrading effect on the wood substance, particularly in the presence of moisture. This effect is responsible for the familiar grey discolouration to which exposed timbers are subjected. However, since ultra- violet radiation cannot penetrate timbers to any depth, this is purely a surface effect mainly of aesthetic significance.

More serious breakdown is caused by the periodic movement of moisture into and out of the timber. As the cell wall takes up and releases moisture, it swells and shrinks, and continuous repetition may cause the bonds between the wood fibres to weaken so that minute checks or cracks are formed. Unless the process of swelling and shrinking is inhibited by some form of protection, these cracks may enlarge until the timber becomes both visually unattractive and perhaps structurally unsound.

The greatest danger of weathering is that the persistent presence of moisture may promote decay.

7. WOOD PRESERVATION

Essentially, the science of wood preservation is the treatment of wood to give extended service life. This involves the placement, within the wood microstructure, of preservative chemicals which are antagonistic to wood destroying agencies. The major factors which bear on the effectiveness of biological preservation systems are:

(a) The biological hazard to which the wood will be subjected in service.

(b) The toxicity of the preservative chemical to the particular wood destroying organisms which will be encountered. Also, the permanence of the preservative chemical under given conditions of hazard following treatment of the wood.

(c) The penetration and retention of preservative chemical, i.e. the extent of the penetration of the preservative chemical into the cross section of the timber and the amount retained in the penetrated zone per cubic metre of the wood.

A similar set of factors determine the effectiveness of preservative treatments against weathering and fire.

Other relevant factors include:

(a) natural durability of the wood,

(b) the presence or absence of sapwood,

(c) variability within and between pieces and species,

(d) preservative distribution gradient.

7.1 The Hazards Defined

The hazard to which wood material will be subjected has an enormous bearing on the extent to which wood preservation will be effective. A piece of wood kept continually dry inside a building is subject to a much lower hazard than a piece embedded in the ground.

A typical hazard chart appears in the Appendix. Its broad categories, ranging from low to high hazard, are as follows:

(a) Interior timbers (i.e. indoors - framing, linings, joinery, etc.)

(b) Exterior timbers (i.e. outdoors above ground - cladding, barge boards, window joinery, palings, rails, bridge decking, etc.).

(c) Ground Contact (i.e. posts, foundation piles, poles, house stumps, crib walls, landscape timbers, playground equipment, bridge and wharf timbers, etc.).

(d) Timber used in fresh water or heavy wet soil (i.e. poles for livestock pens, piling, jetties etc)

(e) Marine Timbers (marine piles, sea walls, etc.).

The hazard level determines the required intensity of the key wood preservation factors, namely the toxicity of the preservative chemical, its fixing characteristics, the penetration required and the retention required. For example interior timbers may only require:

1. Protection only against wood borers, necessitating a simple borer-specific, unfixed chemical like boron.

2. Penetration only in the sapwood.

3. Retention level of a very low order.

However, for ground contact hazard, a heavy duty preservative such as a CCA is required with continuous penetration to a significant depth and with relatively high retentions.

7.2 Wood Preservative Chemicals

Wood preservatives may be divided into three main groups

(a) Water-borne (CCA and Borate)

(b) Oil-borne (Creosote)

(c) Light Organic Solvent borne.

7.2.1 Water-borne Preservatives

The water-borne preservatives are traditionally inorganic chemicals which are dissolved in water, the water acting as a carrier in the treatment process. The water- borne preservatives leave the treated wood odourless, clean to the touch, sometimes imparting a colouration. They wet the timber during the treatment process, often causing dimensional variation, but once the carrier water has dried out, they have no effect on moisture content of the wood. There are two main types of water-borne preservatives commonly used in Malaysia.

(a) Non-fixed, such as the borate compound which is subject to water leaching.

(b) Fixed, such as the copper-chrome-arsenic (CCA) which is highly leach resistant.

7.2.1.1 Borate Compounds

Borate products are available as inorganic borates and has been applied to treat rubberwood by vacuum pressure impregnation process. Treated wood is not coloured and, when it is dry, can be painted, glued or stained. The chemical remains water soluble in the wood and should be used only for dry interior applications where leaching does not occur.

This preservative can be applied as a dip diffusion treatment to green wood. The product has the ability to diffuse deeply into the wood. This process that depends on sufficient time being allowed and on moisture content being maintained, is still commonly used in other parts of the world like Hawaii and USA, but not used in Malaysia.

7.2.1.2 Copper Chrome Arsenic (CCA)

The copper-chrome-arsenic compounds are heavy duty wood preservatives covering a wide biological spectrum without being subject to significant leaching. The copper is a fungicide and the arsenic is an insecticide plus a back-up fungicide. The chrome acts as a fixing agent, reacting in the presence of wood cellulose to render the copper and arsenic chemicals insoluble.

CCA is applied by vacuum pressure impregnation and solution concentration can be varied according to the desired retention.

CCA treated timber is odourless and can be readily painted or stained once dry.

Hot dipped galvanised or stainless steel fasteners are recommended for CCA treated timber.

7.2.1.3 Alkaline Copper Quaternary

Currently this is not an approved preservative in Malaysia. More details can be obtained in the appendix.

7.2.2 Oilborne Preservatives - Creosote

Oil-borne preservatives are applied in open or in vacuum pressure impregnation plants, always at elevated temperatures to lessen viscosity and increase uptake. The concentration of oil-borne preservative chemicals cannot normally be changed in the same way that the water-bornes can. Consequently, required retentions must be met by variation in processing technique.

Creosote is a heavy duty preservative which is toxic to most fungi and insects. It does not alter the dimension of the wood during treatment and is highly water repellent. Creosote treated wood is not subject to water leaching and can be used for ground contact hazard. Its water repellency gives it excellent weathering characteristics. Creosote treated wood usually has a characteristic odour. It is usually black and may through 'bleeding' exhibit black deposits on the wood surface. It cannot be painted.

7.2.3 Light Organic Solvent Preservatives (LOSP)

The term Light Organic Solvent Preservative (LOSP) describes the carrier of the preservative and the LOSPs vary greatly according to the preservative chemicals with which they are formulated. LOSPs are solutions of organic fungicides (such as tributyltin-oxide, TPTO) and or insecticides (synthetic pyrethroids), often containing water repelling agents to develop good weathering characteristics.

Depending on their type and formulation, they may be suitable for interior or for exterior, above-ground hazards such as in housing and other buildings. Effective preservative treatment of wood can only be achieved by impregnation in a vacuum pressure plant.

7.2.4 Insecticide

Insecticides like the synthetic pyrethroids and organic phosphate are applied by dip or spray to provide short term protection for the timber against insect during the seasoning period.

7.2.5 Antisapstains

These are a range of preservatives applied by dip or spray to provide short term protection for the timber against mould, or staining fungi during the seasoning period.

7.3 Penetration and Retention

The primary objective of wood preservation is to achieve, within every piece of timber, a defined retention of preservative chemical within a defined penetrated zone of the cross section, each being predetermined by a number of factors, most particularly the hazard level to which the timber is to be treated.

Retention is closely linked to toxic limit, which is the minimum amount of a particular chemical per volume of wood material that will prevent degrade of the wood. The values vary widely in accordance to the particular chemical, the particular species of fungus, borer, termite, etc. and the particular species of wood.

Below the toxic limit levels, degrade will occur, above the levels it will not. Retention for a particular hazard is set at the highest level likely to be required plus an allowance for variation, plus a factor for safety. (Variation occurs particularly because of different densities of timber and differences in the absorption of the wood preservative in a given parcel of timber in the treatment cylinder.) It is vital that the required retention for a given hazard is achieved in the treated wood, otherwise premature failure may well occur. It is equally vital that the required degree of penetration is achieved in order that an effective zone of treated wood is created.

In summary, the key to wood preservation is the application of a known preservative chemical to a defined zone of penetration at a known required retention.

8. CONDITIONING BEFORE TREATMENT

In order to achieve proper preservation, the timber must be in a suitable condition to absorb the preservative. This involves the following considerations:

8.1 Bark Removal

To ensure adequate penetration, it is essential that all bark, cambium and any foreign matter which might inhibit the entry of liquid into the timber, be completely removed.

8.2 Moisture Content and Drying

Seasoning and drying are two terms used to denote the same process of reducing the water content or moisture content (mc) of wood.

Air passing across the surface of a piece of wet wood is able to pick up moisture and carry it away, thus leaving the surface of the wood slightly drier than it was before. Moisture from the interior moves to the surface and in a continuing fashion, is removed by further dry air flowing over the wood.

When the moisture content has been reduced to the so called "fibre saturation point" of approximately 30 per cent (250 -300g/Kg), all moisture has been removed from the voids in the wood (moisture held within the cell cavity) and the residual moisture is contained in the cell walls only.

Seasoning below the fibre saturation point dries the cell walls and shrinkage may occur. Shrinkage in the tangential direction is considerably greater than in the radial direction. Shrinkage in the length of the timber is so small, relative to the longitudinal dimension, that it can be generally ignored. Commercial methods of drying (seasoning) timber are generally by kiln drying or air drying.

The general method of air drying timber is to stack it in the open on a well drained site exposed to a steady and adequate airflow. All pieces of wood in the stack are separated from each other by small strips of timber to enable the air to move freely over all surfaces.

Commercial kiln drying removes any dependence on the weather. The stacks of timber are placed in an insulated building or kiln and drying conditions are artificially produced by strict control of temperature, humidity and air flow. By practice and research over many years, kiln drying cycles have been developed for the many and varied species. It is now possible to reduce the moisture content of timber to any-predetermined level in the optimum time and with minimal loss through checking, splitting, collapse or deformation.

The moisture content of a piece of wood is always expressed as a percentage of the "dry weight" of that timber. Wood is dried mainly for the following reasons:

(a) To make it more stable. Timber should be dried before it is fabricated, to a moisture content as near as possible to that at which it will be put into service.

(b) To develop maximum strength. Wood that has had its moisture content reduced is much stiffer and stronger than it is in its "green" or unseasoned state.

(c) To make it lighter. It is far easier to handle and more economical to transport when dry.

(d) To reduce susceptibility to fungal attack. Dry wood (i.e. below about 15 per cent MC) will not rot. Starch may also be broken down in the seasoning process, reducing the wood's attractiveness to certain borers.

(e) To prepare it for preservation. Most of the water must be removed from the cell cavity and some from the cell wall before preservative liquids or solutions can be forced under pressure into the timber. Most forms of treatment except diffusion, require the timber to have a moisture content not exceeding 30 per cent. In the case of LOSP treatments it is preferable that the timber be kiln dried to the appropriate moisture content at the time of treatment.

8.3 Machining

It is desirable that all machining processes, including boring, planing, docking, etc. be carried out prior to treatment. Where this cannot be done it is advisable to re-treat any timber exposed by subsequent machining by means of liberal brush application of the appropriate preservative.

8.4 Improved Penetrability

For products produced from difficult-to-treat timber, it is most important that adequate penetration from the lateral faces is achieved. In some timbers it is often impossible to achieve adequate flow of preservative liquids from the end-grain for reasons previously described. By introducing many additional points of entry along the faces of the timbers the distribution and uptake of preservative liquid is improved. This is generally achieved by use of an incising machine which consists of a series of geared rollers carrying blades which make slit-like incisions parallel to the grain of the timber.

9. TIMBER PRESERVING PROCESSES

The effectiveness of all wood preservatives depends on the penetration achieved and the retention of preservative in the penetrated zones. Correct methods in the application of preservatives must be used to cater for the wide variation in timber absorption characteristics. See MS 544 Part 10, MS 360:1991, MS 822:1983 See Appendix for the listing of Malaysian Standards on preservation of timber.

9.1 Brushing or Spraying

Although the simplest and most readily available, these methods are not recommended because the depth of the preservative penetration which is obtained, is only sufficient to give superficial protection to the timber. They are, however, useful where timber needs to be treated in situ and can extend the service life by several years if applied regularly. Organic solvent types of wood preservatives are better suited for this purpose. Good ventilation is essential and skin contact should be avoided.

9.2 Immersion

Immersion treatments require a suitably dimensioned bath of preservative in which the timber can be fully immersed. Cold-dipping can be used for short term protection such as the prevention of blue stain in rubberwood and ramin.

9.3 Hot and Cold Bath

Hot and cold bath treatment in open tanks is a more controlled method of immersion treatment and consists of immersing the timber in the bath, raising the temperature to about 85 deg. C for a predetermined period then allowing the preservative to cool or transferring the timber to an adjacent cold preservative bath until cool. Green, sawn, permeable timber can be immunised in this way with suitable water-borne preservatives but if oil type preservatives such as creosote are used, air seasoning of the sapwood is necessary before treatment.

9.4 Sap Replacement

Sap Replacement can be carried out on freshly felled, debarked, natural round timber, by immersing the butt end in a bath of preservative and allowing the timber to stand vertically until the level of preservative liquid ceases to drop. As the sap evaporates from the top, the preservative is drawn up through the sapwood. An extension of the above method is the Boucherie type process where freshly felled, natural round timbers, usually poles, are laid horizontally and a sealed, tightly fitting cap, designed to hold preservative solution, is fitted to one end. The preservative is then driven along the pole by compressive or natural means, expelling the sap at the other end. In Malaysia this is generally not practised