UK Building Research Establishment

Overseas Building Note

OBN 199

May 1993

Housing and construction information for developing countries

Timber in tropical building

R W Berry

A tropical building making extensive use of timber structural elements and cladding. The design incorporates features such as large roof-overhangs to protect timber cladding against rain and sunlight.

Building Research Establishment

Building Economics and
International Policy Division
Building Research Establishment
Garston, Watford, WD2 7JR, UK
Telephone 0923 894040
Telex 923220 Fax 0923 664010

SUMMARY

Timber is a common material in the construction of buildings in many tropical countries. However, exposure of timber to conditions of high moisture can lead to problems of fungal decay or distortion.

Care in the design of structures will reduce the significance of moisture-related problems and improve the performance of timber under tropical conditions.

If timbers cannot be protected from dampness by design, it will be necessary to apply preservative pre-treatment or to select naturally durable timber species and exclude sapwood, to provide adequate service life.

Insect attack, particularly by termites, can cause serious deterioration of timber in service. Appropriate preventive measures include the selection of timber of high natural durability and the use of preservative chemicals.

The first issue of 'Timber in tropical building' published as OBN 146 in 1972 has now been withdrawn. This revision has been prepared by Roger Berry, drawing upon the experience of his colleagues in the Timber Division of BRE.

CONTENTS

BIOGRAPHICAL NOTES

Roger Berry has worked in timber research for 24 years, initially in the United Kingdom's Forest Products Research Laboratory and later (following the merger of BRE and FPRL) in the Timber Division of BRE. He has worked in both research and advisory capacities, and has been particularly concerned with the biodeterioration and preservation of timber

OVERSEAS BUILDING NOTES

Overseas Building Notes are prepared by the Building Economics and International Policy Division of the Building Research Establishment in order to provide information and advice on housing and construction in developing countries. They are distributed throughout the developing world to a wide range of organisations with a professional interest in building.

Further copies are available to other organisations and individuals with similar interests and can be obtained by writing to:

BRE Bookshop
Building Research Establishment
Garston, Watford, WD2 7JR
United Kingdom
Telephone: (0923) 664444

TIMBER IN TROPICAL BUILDING

by R W Berry

1 INTRODUCTION

Timber has many inherent advantages as a construction material. It can be shaped easily and jointed both in the workshop and on site. It has a high strength-to-weight ratio compared with many other construction materials, and usually good supplies are available locally. As a result, timber has enjoyed a long and successful application in the construction of traditional buildings in almost all climatic regions.

There are, however, many different timber species each with different levels of durability, strength, dimensional stability, paintability and abrasion resistance. Timber for use in a particular construction must be selected for its appropriate combination of such properties, so that it will perform adequately under the conditions that will apply during the life of the construction.

In tropical countries, the climate often presents severe service conditions for timber building components. Particular care in timber specification is therefore needed if the required service life is to be achieved.

Throughout the world, combinations of design and local timbers have been developed to meet local building needs. In tropical countries some traditionally-used local timbers with particularly useful properties (for example high durability) are becoming less readily available, and timbers of less established local performance may need to be substituted. Moreover, increased demand for housing in some countries has resulted in the introduction of alternative designs. They offer the advantage of rapid construction, but may use timber materials or design features which do not have a tradition of successful use in the tropics. In these situations particular care is needed to ensure that departures from well proven specifications will perform satisfactorily.

In addition, designers and specifiers need to take into account changing local attitudes towards performance standards, particularly on the acceptable service life of timber structures. For example, although in the past it might have been acceptable that buildings or components would require replacement or extensive repairs after only 10 to 15 years, nowadays a service life of 20 to 30 years may be expected and indeed desirable to conserve natural resources. The reduced availability of locally grown timbers suitable for replacement or repair can be a factor in inducing these changes in attitude. The consequences of such changes need to be taken into account, especially when considering the durability of timber materials.

This Note gives an outline of the main hazards to timber components in tropical climates, together with guidance on appropriate design and specification of timber structures to prevent deterioration in service.

2 DIMENSIONAL CHANGE

The term 'wood' is used to describe the material of which a piece of timber is composed. It comprises a complex mixture of tube-like cells (Figure 1), which have walls of cellulose and lignin surrounding a cell cavity. This cellular organic structure holds, in the living tree, large quantities of water – up to 200% moisture content (twice the weight of the dry wood component) depending on the timber species. The bulk of this water is held within the cavities of the cells and the remainder is bound within the cell walls themselves.

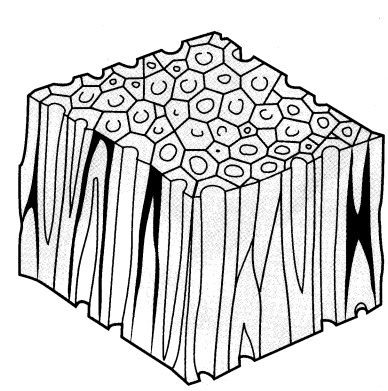

Figure 1 A small cube of wood, much magnified

When freshly felled ('green') timber begins to dry out, the water is lost first from the cell cavities. This process causes no dimensional change in the timber. However, as the timber dries to below about 30% moisture content, water bound within the cell walls is lost. The timber then begins to shrink and continues to shrink until the timber dries to a level at which it is in equilibrium with the surrounding air. If timber that has been dried to a particular moisture content below the 30% threshold is subsequently re-wetted, either by liquid water or by exposure to high humidities, then the shrinkage process is reversed and the wood swells again.

Because of the particular orientation of the cells within the wood structure, this shrinkage and swelling movement does not occur evenly in all directions. In a direction parallel to the original trunk of the tree, any change is usually negligible although a few softwood species such as Caribbean pine can shrink noticeably in length during drying. In a direction tangential to the circumference of the original tree, up to 10% shrinkage can be expected during drying from a green condition. In a radial direction, up to 5% shrinkage can take place (Figure 2). This variation can lead to changes in the overall shape of timber components during drying (Figure 3).

Additional distortion in the form of twisting or bending may occur during drying, particularly with poorer quality timber, because of features such as knots or unusual grain patterns. Rapid drying of large timber sections or poles may result in longitudinal splitting, as the outer portion of the timber dries and contracts more rapidly than the interior.

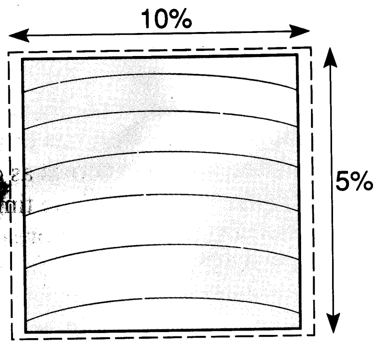

Figure 2 Shrinkage of timber cross-section during drying from a green condition

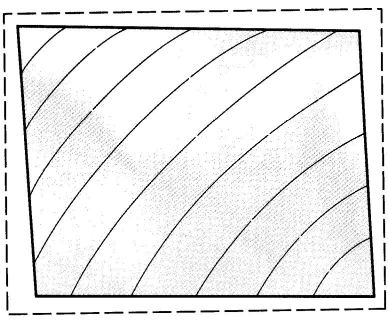

Figure 3 Change in cross-sectional shape of drying timber

These dimensional changes can lead to problems when building with timber in any climate. In tropical climates the problems can be especially severe because of the wide annual ranges of humidity and/or the scarcity of timber-drying facilities.

Use of green timber. Ideally, building timbers should be dried before use to achieve the average moisture content likely to occur in service. This will minimise any dimensional change taking place as the building dries after construction. Depending upon the region and the time of the year, moisture contents of timbers in service in buildings in many tropical conditions can be expected to be about 12% to 15%. However, measurement of the actual moisture content of timbers in existing buildings, using a simple conductivity-type moisture meter, is an alternative and probably more accurate method of estimating the average moisture content likely to be achieved in a new building.

For most timber species and sizes, adequate drying in tropical conditions can normally be achieved by open-stacking under well-ventilated cover for a few months during a dry season. During periods of very high humidity, drying will take a long time.

Timber in tropical countries is often supplied from locally grown sources and put to structural use while it still has a high moisture content. This usually happens where kiln drying is unavailable and the dry season is too short to dry the timber adequately. Additionally, some timbers are easier to cut, drill or nail before drying takes place. Use of such undried timber results in large dimensional changes in timber components as they dry, and traditional designs and construction methods usually accommodate or compensate for the resultant problems.

Where the use of undried timber cannot be avoided, it is important that design details compensate for the inevitable shrinkage.

For example:

- Avoid or minimise the effect of differential movement, select beams to have the same grain orientation as each other, ideally quarter sawn (Figure 4).
- If a deep section beam is used to support one end of floor or flat-roof joists and the other end is supported on masonry (Figure 5), take care that subsequent shrinkage does not result in the roof or floor taking on a slope. Shrinkage could be up to 10% of the depth of the beam. Where such designs cannot be avoided, support the joists at the bottom edge of the beam by means of a ledge or bracket (Figure 6). Shrinkage movement is then restricted to the lower part of the beam only.
- Where undried timber beams are jointed to or abut masonry, steel or concrete, take into account the effects of differential movement on other parts of the construction. For example, where steel beams are used to support floor joists (Figure 7), ensure that there is adequate clearance above the beam to prevent the floor 'humping' over the line of the joist.
- Do not fix skirting boards or other finishing details until the timber structural elements have at least partially dried (Figure 8).

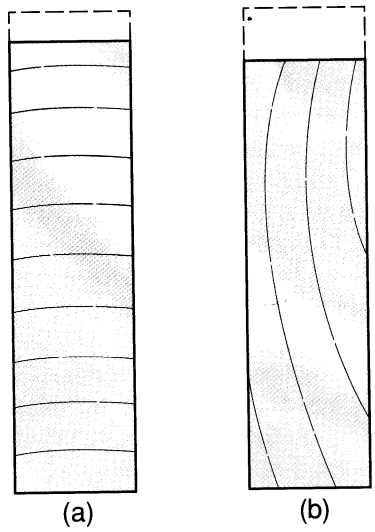

Figure 4 Shrinkage of drying beam (a) Quarter-sawn (b) Flat-sawn

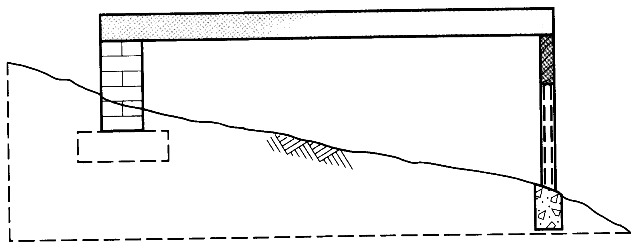

Figure 5 Joists supported at one end only by a timber beam

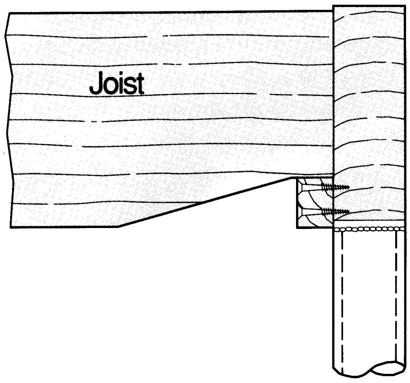

Figure 6 Design to minimise tilting of joists due to shrinkage of a supporting beam. (Note quarter-sawn beam and sloping cut to joist to avoid weakening effect of a notch)

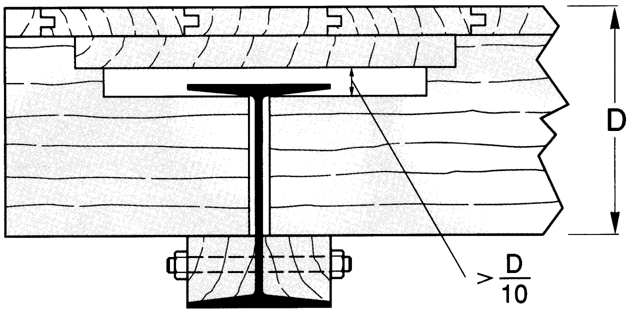

Figure 7 Design to avoid humping of a drying timber floor over a steel beam

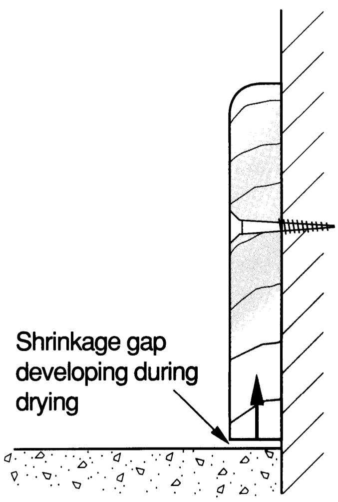

Figure 8 Shrinkage of timber skirtings fitted before they have been fully dried

Fixings to green timber should be designed in such a way that shrinkage of jointed timber components does not exert an excessive stress on fixings between components.

For example:

- In trussed rafters with green timbers over 100 mm depth, nail plywood gusset plates or steel flitch plates as close to the centre lines of the members as is permissible (Figure 9). In this way the shrinkage of the greater part of the depth of each member is unrestrained and therefore imposes less strain on the fastenings or the surrounding timber.
- When connecting rafters and purlins or joists and binders, fix cleats or other fastenings as close to the contact faces as possible to avoid the timbers separating as they shrink and therefore over-stressing the fixings (Figure 10). Alternatively, use sheet-galvanised metal hangers (Figure 11). Avoid nailing timber fastenings such as cleats across the width of large timber beams, as the stress imposed by shrinkage of the beam may cause splitting of the cleat as the nails move closer together.

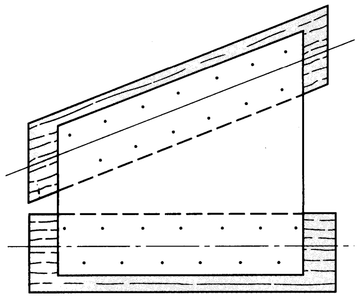

Figure 9 Nailing of plywood gusset plates or flitch plates to minimise strain on fastenings

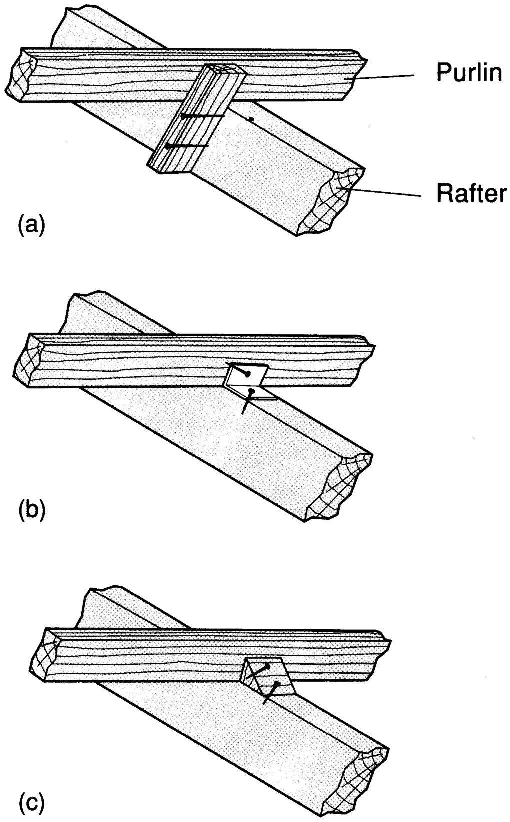

Figure 10 Minimising strain on purlin and rafter fixings
(a) Cleat fixed too near centre of rafter and purlin
(b) and (c) Alternative fixings to reduce effects of shrinkage

Do not use undried timber for the manufacture of components where fine jointing tolerances are required, for example window joinery or other framing. Subsequent drying will cause unsightly distortion of the joints (Figure 12).

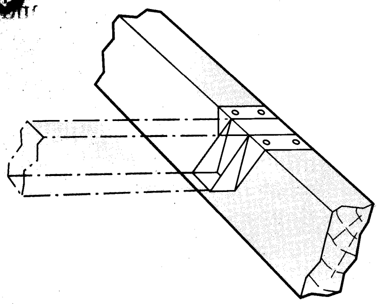

Figure 11 Use of a joist hanger to avoid shrinkage stress on fixings

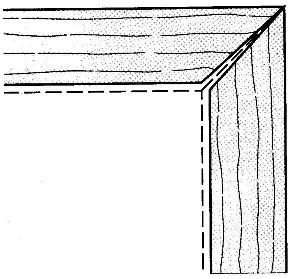

Figure 12 Example of shrinkage effects on a mitred joint

Seasonal climate variation. The range of external air humidities to which tropical buildings are exposed throughout the year may be considerable, particularly in monsoon or savannah-type regions. Wood is hygroscopic, absorbing and evaporating moisture depending on the moisture content of surrounding air. This large humidity range will therefore result in considerably more swelling and shrinkage of timber components in service than is normal in temperate climates. This phenomenon will be apparent both in timber which has been thoroughly air- or kiln-dried before use and in timber which has been installed green and then subsequently allowed to dry.

Although movement of dry timber due to changes in humidity is small compared with the shrinkage of green timber, measures to accommodate such movement are still required if the performance of a timber component relies on close tolerance of joints.

For example:

- Give consideration during assembly to the likely subsequent movement of closely abutting components such as framed panels or cladding boards and floor boarding (Figure 13). If fixed during the dry part of an annual climate cycle, then future swelling can be expected. Therefore the components should not be tightly butted but assembled with some clearance allowed. Where this is not provided, timbers may take on a permanent compression set and areas of panelling may buckle. Conversely, components assembled during the wet part of a cycle (or installed green) can be expected to shrink and therefore should be butted as tightly as possible.
- Form tongues and grooves in panelling, or use cover plates and other means of accommodating movement, to provide as much clearance between components as is practical (Figure 14).
- Construct framed assemblies in such a way as to distribute movement in preferred planes. Vertical movement is the normally preferred option as it gives fewer problems than horizontal movement where the timber assemblies are fixed to rigid non-timber components such as concrete bases (Figure 15).

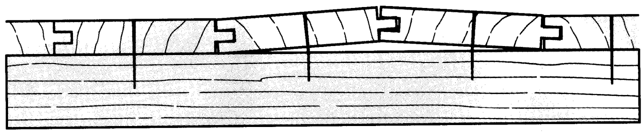

Figure 13 Effect of swelling on closely butted floorboards

Figure 14 Design and fixing of cladding to avoid problems of shrinkage or swelling

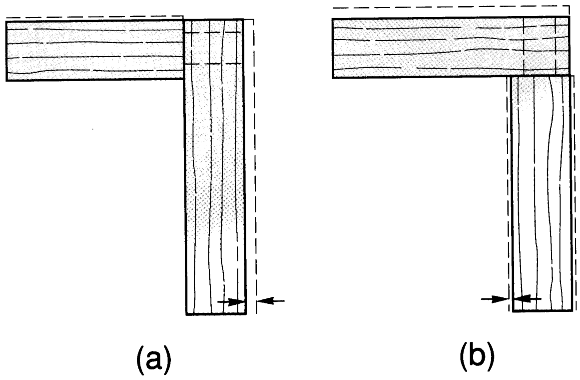

Figure 15 Limitation of vertical or horizontal movements
(a) Framing detail to minimise vertical movement
(b) Framing detail to minimise horizontal movement

Exposure to sunlight. The coefficient of thermal expansion of wood is small compared to most other building materials, and is therefore normally ignored in design situations. However, direct exposure of a timber to tropical sun will result in rapid drying of the exposed surface. This will produce cupping and/or splitting as the exposed surface shrinks relative to the unexposed surface. Timber cladding, doors and external joinery are particularly susceptible to this effect and therefore, wherever possible, should be protected from direct sunlight by generous roof overhangs or deep reveals (Figure 16).

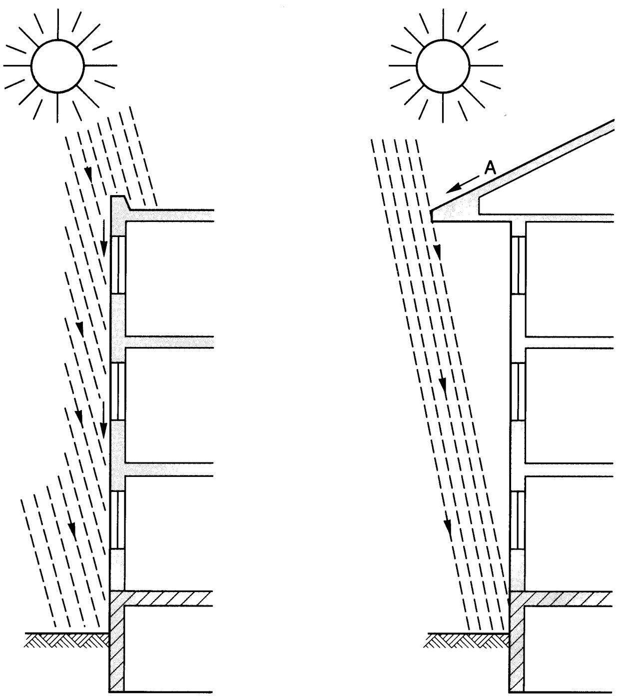

Figure 16 Use of roof overhang to protect external joinery and cladding from rain and direct sunlight

All timber, but particularly finely jointed components, should always be protected from direct sunlight on site before use, to avoid distortion and splitting.

In air-conditioned buildings, temperature gradients set up across external walls and doors will also result in associated moisture gradients which can have similar distorting effects on timber.

Shrinkage and swelling of timber-based panel products. Timber veneers and particles or fibres in panel products, such as plywood and chipboard, are also subject to dimensional change in response to moisture changes.

In the case of plywoods, the use of alternate layers of veneers oriented at right angles to each other compensates to a large extent. The resulting changes in width or length of panels are less, compared with solid wood, though swelling and shrinkage in thickness will be similar. Plywood is therefore an excellent material for use under tropical climates provided that the type of adhesive and durability of the timber species are adequate. Plywood as cladding will still need protection by an impermeable coating if excessive splitting of the exposed surface veneer is to be avoided.

In contrast, fibre-boards, wood-wool cement slabs and chipboards (particle-boards) bonded with [illegible] resins, tend to exhibit a degree of swelling and associated strength loss on prolonged exposure to very high humidity. This is most marked with particle-board types bonded with urea formaldehyde (UF) resins. Board types bonded with phenolic (PF) resins or melamine-modified urea formaldehyde (MF/UF) resins are less susceptible. For this reason, use of UF-bonded boards should be restricted to internal parts of structures and to climates where the humidity and temperature changes do not present a high risk of internal condensation. However, where it is proposed to use PF or MF/UF particle-boards in conditions of persistently high humidity, specific evidence of suitability should be sought from the board manufacturer.

A recent innovation is the use of cement-bonded particle-boards. These are particularly stable in relation to moisture and are highly durable.

BRE Digest 323[1] and British Standard BS 6566: Part 7: 1985[2] give further guidance on the selection of panel products for particular uses.

3 DETERIORATION BY FUNGI AND INSECTS

Deterioration of timber results from attack both by various species of fungi, which ultimately decompose the wood substance into a crumbly or fibrous consistency, and by certain insect species which tunnel into the wood. This process occurs naturally in fallen timber as part of the recycling of nutrients in the forest environment. Fungal deterioration, however, cannot take place in dry wood, and many of the insect species are also limited by dry conditions. Therefore a crucial requirement in protecting timber building components against fungal decay and insect attack is to ensure that they be protected from moisture as far as is practical.

Natural durability. The tree from which timbers are cut consists of an inner core of usually darker coloured heartwood and a surrounding zone of lighter coloured sapwood (Figure 17). The proportions of sapwood and heartwood vary depending on the species, and on the age and geographical origin of the tree. The sapwood of all timbers must be regarded as 'perishable' (likely to be destroyed by fungal decay within 5 years or less under persistently damp conditions). Heartwood durability varies from perishable to very durable (not less than 25 years of decay-free service under damp conditions), depending on the timber species.

The terms heartwood and sapwood must not be confused with hardwood and softwood. Hardwood timber is that derived from deciduous trees whereas softwood timber is that derived from coniferous trees such as pines and firs. Although most softwoods are

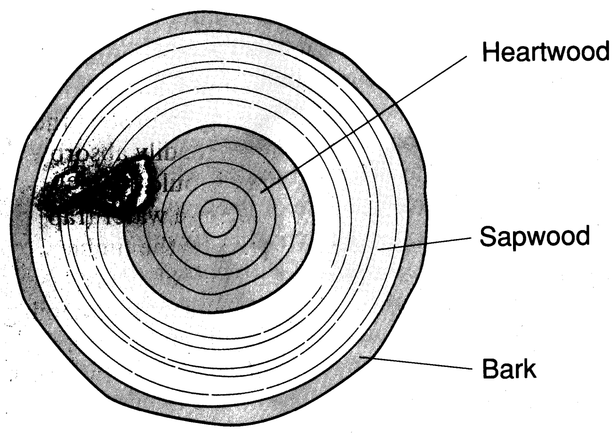

Figure 17 Section through a typical tree to show heartwood and sapwood zones

rated as only moderately durable or worse, hardwoods vary in durability from perishable to very durable. Not all hardwoods are hard or particularly strong; some are relatively soft and weak.

In general, sapwood is also more susceptible than heartwood to insect attack, although no recognised classification for susceptibility exists. More detailed guidance on the durability ratings of specific timbers is available in the *Handbook of hardwoods*[3] and *A handbook of softwoods*[4].

Palms and bamboos are neither hardwoods nor softwoods. They are related to grasses and come within a completely separate botanical class. They behave differently from hardwood and softwood timbers in all respects, and information on their performance as building materials is best obtained locally.

The resistance of timber-based panel products to insect and fungal attack is determined largely by the resistance of the timber from which it has been manufactured. However, a wide range of products is available using a variety of combinations of timbers, adhesives and, in some cases, preservative treatment. Manufacturers should be consulted for specific evidence of suitability for particular hazard situations.

Plywoods complying with class H of British Standard BS 6566: Part 7[2] and cement-bonded particle-boards can be considered suitable for continuously high humidity conditions.

Staining fungi. Freshly-felled timber will tend to become infected by various staining fungi if not dried rapidly. Some staining will be only superficial and can be removed later by machining, but fungi of the sap-staining type can cause a blue or black stain throughout the timber. While not significantly affecting the strength of the timbers, this type of unsightly stain does increase their permeability. Affected timber absorbs water more rapidly when exposed to wetting conditions, for example as window joinery. This makes it more prone to decay. Increased permeability can also result in abnormally high uptakes of wood preservative.

Preventing fungal decay. Many traditional building designs have relied on the use of locally available timbers of high natural durability. Supplies of many such timbers are becoming increasingly expensive and difficult to obtain. Where only less durable timbers such as softwoods are available, careful consideration must be given to extending their service life by ensuring that the design of the building incorporates features which protect the timber components against damp conditions which cause decay.

Prevention of timber decay in buildings depends on three basic design requirements:

- protection from wetting by rain,
- ventilation to allow initial drying and avoid condensation, and
- isolation from ground moisture.

Protection from wetting by rain. In a tropical climate, rainfall may often be high, particularly at certain times of year. Special attention must be given to preventing rain-water from entering buildings and wetting timbers. Rain-water goods, gutters, downpipes and soakaways must all be appropriately sized. Roofs with large overhangs are traditionally employed to reduce the flow of rain-water over wall surfaces and external joinery such as windows (Figure 16). Alternatively, canopies or deep reveals may be used to provide some degree of protection for windows (Figure 18). If external joinery or timber cladding is not protected in this way, the service life of the components can be expected to be significantly reduced.

Where generous overhangs to roofs are not possible, then flashings and cappings may provide useful

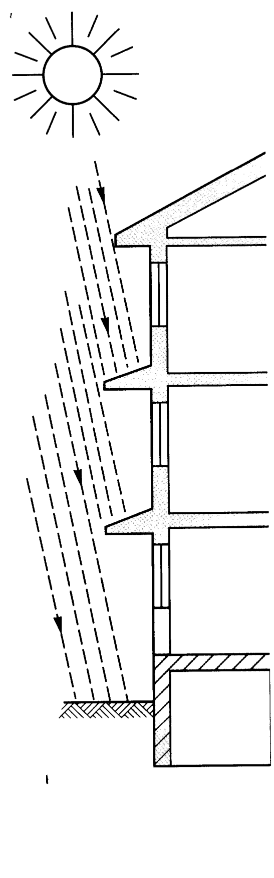

Figure 18 Use of canopies to protect external joinery

protection of timber. Direct nailing of metal flashings to wood should be avoided, as unequal thermal expansion can cause buckling. Timber absorbs moisture more readily through end-grain surfaces, and so all such surfaces exposed to rain, such as post-ends or beam-ends, should be protected by caps, sealants or flashings (Figure 19).

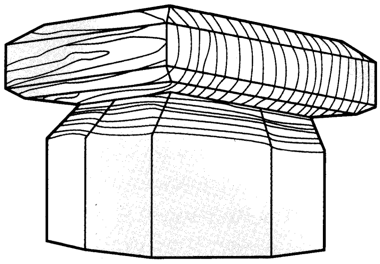

Figure 19 Capping of end-grain of posts to protect against wetting

Ventilation to allow initial drying and to avoid condensation. Tropical climates do not generally present any particular problems in ventilation and drying. However, when green timber is used it should not be built tightly into masonry, as this will restrict drying and enhance the risk of decay, particularly in less durable timbers.

Care is required in the design of air-conditioning systems, where external air humidities are high and substantial localised cooling is achieved. They can occasionally cause problems of condensation in unventilated voids, and timbers exposed to persistent wetting in this way will be at risk of decay.

Isolation from ground moisture. If timber structures are allowed to bear directly on, or are embedded in, the ground then moisture from the soil will tend to dampen the timbers around the contact area, resulting in a high risk of fungal decay. Isolation from the ground by means of a concrete base and/or steel fixing such as a shoe (Figure 20) will help to reduce this problem. Wherever possible, a conventional damp-proof membrane should be incorporated in any concrete or masonry base where timbers bear directly on the base. Where steel shoes are used, an additional damp-proof membrane is unnecessary to protect the timbers. Because end-grain surfaces readily absorb moisture, the design of metal shoes should [illegible] creating a narrow gap which can act as a water trap between the metal and the end-grain of the timbers. End-grain surfaces of timber posts should, ideally, be coated with a waterproof sealer capable of maintaining its flexibility throughout its service life. Examples are bitumen solutions, chlorinated rubber paints, two-pack epoxy and polyurethane coatings.

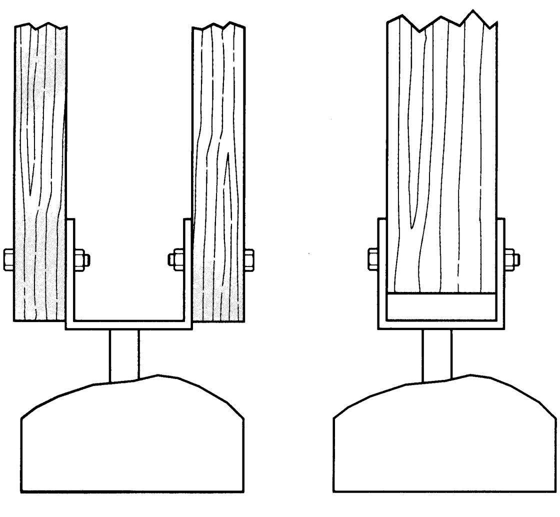

Figure 20 Two designs of steel shoe to provide ground connections for timbers. (Note that the designs avoid trapping of water at the timber end-grain)

Preventing insect attack. In many parts of the tropics insect attack can be the most serious and rapid cause of deterioration, much more serious than fungal attack. Damage results from attack by two types of insect, wood-boring beetles and termites.

- *Wood-boring beetles*

Although a large number of beetle species attack trees and felled logs, most of these die out as the timber is dried. Damage by pinhole borers, otherwise known as ambrosia beetles, is the most common type of beetle attack in undried timber, but in dried timber it is invariably extinct. The characteristic clean-cut circular tunnels, devoid of bore dust, 1 mm to 3 mm in diameter, often with dark staining in and around them, are readily identified. Provided that the timber has not already been seriously weakened, once dried, it is usually acceptable for use.

Other wood-boring beetles of the types known as ‘longhorn beetle’ or ‘jewel beetle’ may attack standing trees or felled logs, and the attack may continue for some time in dry timber in service. However, few of these cause significant problems, provided that the timber is carefully inspected before use and that any material that has tunnels filled with bore-dust is rejected.

A small number of beetle species is able to attack dry timber and may cause significant damage in service. It is therefore important that insect damage to timber delivered to site be correctly identified.

Throughout the tropics the most serious hazard from beetle attack to dried timber is presented by the group known as powder-post beetles. This group comprises a large number of species of *Lyctidae* and *Bostrychidae.* In most tropical hardwoods only the sapwood is attacked, but damage is often rapid and severe, causing complete powdering of the sapwood over as little as one year. Timber species with high starch content and large pores are especially prone to infestation. Local guidance on susceptibility of particular timbers may be available and the *Handbook of hardwoods*[3] also provides information. Softwood timbers are immune from attack.

Infestation often begins during the drying and storage of timber, but often it is not noticed during the handling of timber on the building site. Exit holes, 1 mm to 5 mm in diameter, and ejected fine-bore dust then usually appear some time after the timber has been installed. A high level of incidence often occurs as a result of poor stock hygiene in sawmills and timber yards. [illegible]sted material discovered in storage must be [illegible]d or burnt promptly. Remedial tre[illegible] insecticide is rarely completely effective.

If sapwood cannot be excluded from supplies of susceptible tropical hardwood, the only method of ensuring that the timber will not become infested in service is to treat it with a wood preservative containing an insecticide.

- *Termites*

Termites of the 'subterranean' type are common throughout most tropical areas and, although concentrated in underground nests, will enter buildings and attack timbers. Subterranean termites enter buildings only through the surrounding soil and through narrow tubes of soil particles which the termites construct over surfaces above-ground. By these means the termites are able to attack timbers several floors above ground level. Termites are not particularly discriminating in their choice of timber on which to feed. The majority of timbers are susceptible, as are most wood-based panel products. A notable exception is cement-bonded particle-board which is effectively immune from attack.

Protection of building timbers against this type of termite attack can be provided by a number of methods (Figure 21):

- *Termite shields (sheet metal forming a complete and continuous projection around the perimeter of external walls and around the bases of posts)*
  The purpose of these shields is to prevent the termites from constructing soil tubes from the ground into the building and to enable all such tubes to be readily observed and brushed away during routine maintenance. Shields must extend horizontally outwards 50 mm and then downwards for 50 mm at an angle of 45° and must be placed at least 200 mm above ground level. They must also project into sub-floor cavities where suspended ground floors are used. In humid climates, copper or stainless steel sheet may be necessary to resist corrosion, but galvanised steel or zinc is adequate for drier climates. Joints must be completely sealed by soldering or brazing.

- *Soil poisoning (the introduction of an insecticide-treated band of soil around the base of the walls of buildings and under ground-floor slabs)*
  The purpose of this treatment is to present a toxic barrier between the termites in the soil and the building. Treatment of the soil is normally carried out by spraying an insecticide emulsion onto soil as it is backfilled into the foundation trench, or onto the oversite and hardcore before the pouring of a concrete floor slab. A variety of insecticidal formulations are available for this purpose. Most are based on the insecticides permethrin and chlorpyriphos. Use of this type of treatment carries the risk that it may contaminate ground-water. Manufacturers' instructions must therefore be followed closely and users should be aware of any national or local restrictions on treatments or specific insecticides.

- *Wood preservation (impregnation of timbers with a wood preservative containing an insecticidal component)*
  To be effective under tropical conditions, treatments must achieve deep penetration. Surface spraying or short dips are unlikely to be effective. Suitable types of preservative are those based on creosote, copper chromium arsenate salts or, for internal timbers only, boron salts or persistent insecticides such as permethrin.

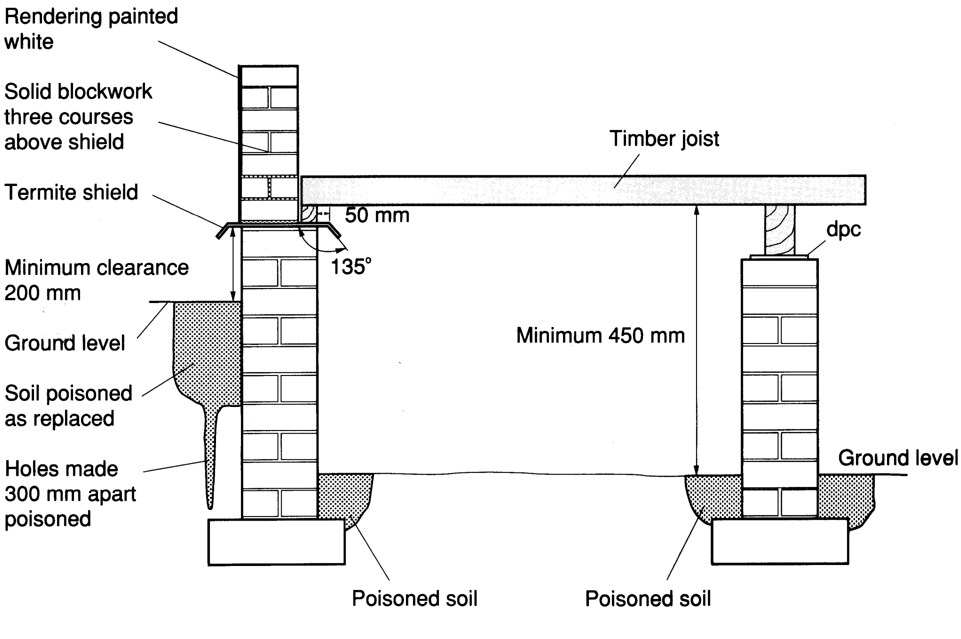

Figure 21 Design of buildings to avoid access by subterranean termites

As an alternative to preservative treatment a naturally durable timber species may be used, although only the heartwood of these species is resistant. Most naturally-durable timbers tend to be expensive: for example teak, iroko, opepe and greenheart. Published data on their levels of termite resistance may relate to timber from mature forest trees rather than from faster-grown plantation trees which can be less durable. It follows that reliance on natural durability should be supported by local evidence of satisfactory performance.

Although in theory any one of these methods alone should be sufficient to prevent attack by subterranean termites, in practice it is advisable to install a combination of measures where the termite hazard is known to be severe.

Details of termite control measures are available in BRE's Overseas Building Note 170[5].

In the moister areas of many tropical countries 'drywood termites' may also present a problem for timber in buildings. Coastal zones, moist savannah and woodland areas can be affected. Drywood termites do not live in underground nests, but individuals will enter buildings and can establish colonies in any susceptible timbers. Detection is therefore difficult, as no soil runways are present. Soil poisoning and termite shields are ineffective as preventive methods, and only the use of naturally durable timbers or preservative treatment will provide a guarantee of protection.

At present drywood termites present a severe hazard only in parts of Africa, the Caribbean, Malaysia, the Philippines and parts of Central and South America. However, with increasing movement of timber world-wide, the distribution of these pests may change. Local information on the status of drywood termites should always be sought before specifying timbers.

4 WOOD PRESERVATION

In constructions or components which cannot be protected from dampness, timbers of low natural durability will not resist fungal decay sufficiently to give an acceptable service life. Extended service life can be achieved in these circumstances only by use of timbers of higher natural durability or by applying preservative treatment to timbers of low durability.

In the past, locally grown hardwood timbers of high natural durability were often readily available in tropical countries and were therefore frequently used in high decay-hazard situations. Supplies of such timbers are now often restricted and they are usually too expensive for most routine structural purposes. The use of certain specific 'prestige' timbers from non-sustainable natural forest resources may also be regarded as environmentally unacceptable and in some countries is subject to strict government regulation. The use of preservative treatment is therefore the most frequently adopted solution to extend the life of timber components exposed to damp conditions.

The type of preservative treatment appropriate to the circumstances will depend upon the severity of exposure to moisture of the timber component. The following broad categories can be identified:

Ground contact

Timbers in direct contact with the ground or concrete are at high risk of decay. Any water-soluble preservative treatment will also be at risk of being leached out of the timber. Under these conditions creosote or preservatives based on leach-resistant inorganic salt combinations such as copper/chromium/arsenic (CCA) should be used. Both of these preservative types are best applied by industrial processes involving pressure and vacuum periods, usually while the timber is dry and held in a sealed treatment cylinder. Where such processes are not available, creosote may be introduced to timber by the hot-and-cold open-tank process. Seasoned timber is immersed in a tank of creosote which is then heated, expelling air from within the wood. On cooling, the creosote penetrates the submerged timber due to the vacuum created by the contraction of the residual air. Both creosote and CCA provide protection against fungal decay, and against attack by beetles and termites. Both also discolour the treated wood, making it brown in the case of creosote and green in the case of CCA. Such coloration is useful on site in determining whether timber has been treated. British Standards BS 144[6] and BS 4072[7] give detailed specifications for treatments with creosote and CCA respectively. In selecting the appropriate treatment schedule, the specifier will need to take into account the permeability of the timber species to be treated. Permeability ratings for timbers are given in the *Handbook of hardwoods*[3] and *A handbook of softwoods*[4] and in BRE *Digest* 296[8].

External joinery and cladding

Where these components are exposed to direct wetting by rain, and no protective surface coatings such as paints are to be applied, creosote or CCA should again be used. However, problems with dimensional changes during treatment may mitigate against the use of the CCA water-borne formulations on precisely jointed components. Where the timber is to be painted, other formulations are also suitable, based principally on light organic solvents. A variety of active ingredients is used, imparting fungicidal or insecticidal properties, or both, to the formulation. These include tributyltin oxide and other esters, pentachlorophenol, zinc and copper carboxylates, lindane and synthetic pyrethroids. Preservatives should be selected as appropriate to meet the perceived biological threat (fungal decay and/or insect attack). Treatment of the timber should be by industrial processes similar to those used for creosote and CCA, although less severe pressure and vacuum levels are used. British Standard BS 5707[9] gives further details of suitable treatments, using light organic solvent-based preservatives. Diffusion treatments with water-soluble boron-containing compounds can also be used for painted external components, as the paint film protects against leaching of the boron in service. For diffusion treatment, green timber is immersed in a tank of hot concentrated boron solution. Subsequent close stacking of the timber under a close-fitting water-imp[illegible]cover, such as polyethylene sheeting, al[illegible]n compound to diffuse deeply into the [illegible]atment the timber is air- or kiln-dried before use. Boron diffusion provides protection against fungi and insects.

Internal timbers exposed to condensation

Most timbers inside buildings are protected from direct wetting and will not be at risk of fungal decay. They will not require preservative treatment unless termites or particular beetle species are known to present a hazard. However, where the particular climate or use of the building will result in frequent or persistent condensation on internal timbers, then some degree of protection against fungal decay will be necessary. All the preservative treatments used for ground-contact or external timbers out-of-ground will provide suitable protection. However, for use on some internal timbers certain characteristics of these treatments may prove unacceptable. In particular the following disadvantages should be considered:

● *Creosote*

Cannot be overpainted, can stain adjacent materials and has a persistent odour which is usually considered offensive in domestic dwelling but may be acceptable in stabling, barns and other out-buildings.

● *CCA*

Treatment induces some swelling distortion which may be unacceptable for components cut to precise dimensions, and may also cause splitting on drying. Treated timber can corrode some metals unless they are suitably protected, for example by galvanising.

On-site application of preservatives

For timbers exposed to fungal or insect hazards in tropical climates, the use of deeply-penetrating treatment methods described here provides the most effective form of preservation. However, in some circumstances neither industrially pre-treated wood nor pressure/vacuum treating facilities will be available. Simple dip treatment, brush or spraying may be the only methods for which facilities exist. Only creosote and organic solvent-based preservatives may be applied successfully in these ways. Dip, brush or spray will not provide adequate protection in a tropical climate against severe fungal hazard (for example in ground contact) or against termites. These treatments will provide a degree of protection against beetle attack, although this will depend to some extent on the permeability of the timber species. BRE Digest 378[10] gives further guidance on all methods for applying wood preservatives.

Safe use of wood preservatives

All wood preservatives contain active ingredients which, if the products are misused, could potentially cause harm to people or the environment. It is therefore important that preservative products are used only when necessary and then strictly in accordance with manufacturers' instructions. Many countries have national legislation controlling the use of pesticidal products, and in some countries particular ingredients are banned altogether. Such legislation may change from time to time and it is therefore important to be aware of and to comply with relevant regulations before using preservatives or importing treated wood. Safe application of preservatives requires appropriate training and facilities. If these are not available, the use of industrially pre-treated timber should be the preferred method of achieving enhanced timber durability. Where such timber is not available and on-site preservation using brush, spray or dip treatments is the only option, supervision and training of the personnel involved must be rigorous. Overseas Building Note 183[11] gives more detailed guidance on all aspects of preservation of timber for use in tropical climates.

5 WOOD FINISHES

The particular combinations of temperature, humidity, solar radiation and rainfall in tropical climates create a generally aggressive environment for coatings. As a consequence, coatings are likely to deteriorate three or four times faster than they would in temperate climates. Coatings may fail by 'chalking', fading, cracking and flaking. Ideally, maintenance should be carried out before cracking or flaking has exposed the underlying timber to the weathering effects of rain and strong sunlight. This is because coatings applied to weathered surfaces tend not to last as long as those on fresh surfaces. Similarly, painting of new external cladding should be performed as soon after installation as possible, provided that the timber is dry. Paints should be selected as appropriate for exterior use, and should have good durability and film flexibility to accommodate swelling and shrinkage of timber substrates. Types of paint suitable for on-site application include solvent-borne and alkyd products and water-borne acrylics. Light-colour paints minimise the adverse effects of solar radiation.

Many hardwood timber species are impermeable and dimensionally stable and these can provide a particularly good paint substrate. However, some species may contain oily extractives which can inhibit drying of some paints or present problems of achieving even coverage during application. In the humid tropics, rapid fouling of painted surfaces by algae or moulds can be a particular problem. Where this is known to occur, paints containing fungicidal or algicidal additives should be specified to prevent the need for regular cleaning and repainting.

6 TIMBER ADHESIVES AND FASTENINGS

In persistently humid climates, adhesives for use in timber structures need to be especially resistant to moisture. Those complying with European Standard EN 301 Type 111[12] are suitable. Adhesives of the non-waterproof, 'interior' type are suitable only for internal fittings in dry climates. Many tropical timbers contain particularly aggressive extractives, such as tannins, which may corrode metal fastenings at a more rapid rate under high humidities than would be expected under temperate climate conditions. Unsightly black staining around ferrous metal fastenings may also be induced. It is important therefore that the metallic fittings selected be suitably resistant to corrosion or provided with appropriate protective treatments. Where costs are justified, stainless steel may be used.

7 CONCLUDING COMMENTS

This Note explains the difficulties which may be experienced when using timber in buildings in tropical climates, and describes methods by which these problems may be overcome. Many of the problems described in this Note cannot readily be remedied in the completed building and are inherent in the design and specification of the component or structure. To obtain satisfactory performance from timber under tropical conditions it is therefore essential to consider carefully both the overall building design and the design detail of timber joints. The risk of attack by beetles or termites may be peculiarly local and particularly severe in certain areas, or associated with use of particular timber species. Local advice on the severity of such hazards is therefore important in establishing the need for suitably durable timbers or preservative treatments. Even then, an apparent absence of problems with traditional designs and materials should not be regarded as a guarantee of the performance of new materials or designs. A comparatively small additional cost in upgrading the natural or conferred durability of timber in a construction can provide dramatic increases in service life so as to represent a considerable economy over the extended life of the building. Careful attention to design detail can prevent or reduce exposure of timbers to risks of attack at little or no extra cost.

8 ACKNOWLEDGEMENTS

Publication of this Note has been funded by the United Kingdom Overseas Development Administration as part of the UK aid programme to developing countries.

9 REFERENCES

1 **Building Research Establishment.** Selecting wood-based panel products. BRE Digest 323. BRE, Garston, 1987 (new edition 1992).

2 **British Standards Institution.** Plywoo
Specification for classification of resi
fungal decay and wood borer attack. BS 6566: Part 7:1985 (1991).

3 **Farmer R H.** Handbook of hardwoods. Second edition. BRE, Garston, 1972.

4 A handbook of softwoods. Second edition. BRE, Garston, 1977.

5 **Building Research Establishment.** Termites and tropical building. BRE Overseas Building Note 170. BRE, Garston, 1976.

6 **British Standards Institution.** Wood preservation using coal tar creosotes. Part 1. Specification for preservative. Part 2. Methods for timber treatment. BS 144:Part 1:1990. Part 2:1990.

7 **British Standards Institution.** Wood preservation by means of copper/chromium/ arsenic compositions.
Part 1. Specifications for preservatives.
Part 2. Methods for timber treatment.
BS 4072:Part 1:1987. Part 2:1987.

8 **Building Research Establishment.** Timbers: their natural durability and resistance to preservative treatment. BRE Digest 296. BRE, Garston, 1985.

9 **British Standards Institution.** Solutions of wood preservatives in organic solvents. BS 5707:
Part 1: 1979. Specifications for solutions for general purpose applications, including timber that is to be painted.
Part 2: 1979 (1986). Specification for pentachlorophenol wood preservative solution for use on timber that is not required to be painted.
Part 3: 1980 (1990). Methods of treatment.

10 **Building Research Establishment.** Wood preservatives: application methods. BRE Digest 378. BRE, Garston, 1993.

11 **Tack C H.** Preservation of timber for tropical building. Building Research Establishment Overseas Building Note 183. BRE, Garston, 1979.

12 **European Committee for Standardization** (CEN). Adhesives, phenolic and aminoplastic, for load bearing timber structures; classification and performance requirements. EN 301:1992.

OVERSEAS BUILDING NOTES — Titles available

154	February 1974	Calcium silicate bricks (G E Bessey)
160	February 1974	Low cost housing in urban and peri-urban areas
[illegible]	April 1975	Production and use of lime in the developing countries (G E Bessey)
[illegible]	June 1975	Board linings to walls
[illegible]	November 1978 (rev)	Building research centres and similar organisations throughout the world
[illegible]	October 1975	The thermal performance of concrete roofs and reed shading panels under arid summer conditions (Adil Mustafa Ahmad)
165	December 1975	Buildings and the environment (Miles Danby)
166	February 1976	No-fines concrete
169	August 1976	Development in paints and surface coatings
170	October 1976	Termites and tropical building
171	December 1976	Protection of steelwork in building
173	April 1977	Bricks and mortar
174	June 1977	Sewage treatment in hot countries (Duncan Mara)
176	October 1977	Building materials in the Arabian Gulf (T R Allison)
177	December 1977	Avoiding faults and failures in building (G E Bessey)
178	February 1978	Village water supplies (A M Cairncross)
180	June 1978	Bitumen coverings for flat roofs (W Kinniburgh)
181	August 1978	The management of resources on construction sites (Roger A Burgess)
182	October 1978	Roofs in hot dry climates (Y A Mukhtar)
183	November 1979	Preservation of timber for tropical building (C H Tack)
184	February 1980	Stabilised soil blocks for building (M G Lunt)
186	June 1980	Fire protection and building regulations (R E H Read and H L Malhotra)
187	August 1980	The design of septic tanks and aqua-privies (John Pickford)
188	April 1981	Buildings and tropical windstorms (Keith J Eaton)
189	May 1982	Sanitation for developing communities (R F Carroll)
190	July 1982	Earthquake risk to buildings in the Middle East
191	February 1984	Guidelines for foundation design of low-rise buildings on expansive clay in northern Jordan
192	February 1985	Solar energy applications (D Lush and J Campbell)
193	April 1989	Mechanised emptying of pit latrines (R F Carroll)
194	August 1990	Disease reduction by improved house construction (R F Carroll)
195	March 1991	Disposal of domestic effluents to the ground (R F Carroll)
196	April 1991	Health aspects of latrine construction (R F Carroll)
197	March 1992	Bricks and blocks for low cost housing (R F Carroll)
198	March 1993	Alternatives to OPC (R G Smith)
199	May 1993	Timber in tropical building (R W Berry)

Printed in the UK for HMSO Dd.8380779, 5/93, C15, 38938