Introducing wood

One advantage which timber has over almost all other materials is that trees are a living, and therefore renewable, resource.

Timber and other forest products can be grown and harvested in just the same way as any other form of agriculture, though on a longer time scale. The need to treat timber as a crop, with the attendant requirements of good husbandry and management has been recognised for some time, although the problems associated with clear felling areas of forest for agriculture and fuel have not yet been overcome in all areas of the world.

As a natural material the efficient utilisation of timber requires some form of selection and grading. An understanding of the characteristics and properties of timber as a raw material will enable the designer or user to ensure that timber is used to best effect.

This Wood Information Sheet (WIS) explains the terms used when describing timbers and their properties. Products manufactured from timber such as wood-based panels are covered in separate sheets.

This WIS is an overview of the subject with signposts to more detailed sources that are listed at the end.

TRADA Technology recommends *Eurocode 5* [1] for structural design of timber. However, this WIS includes a summary of variations when using *BS 5268-2 Structural use of timber. Code of practice for permissible stress design, materials and workmanship* [2].

Contents

Figure 1: Scots pine

Key points

- Every tree has two botanical names – the genus to which it belongs and a specific name applicable to it alone – followed by the name of the botanist who was responsible for naming the plant.
- Hardwoods and softwoods are grouped by whether the tree is cone-bearing, not by the hardness of the timber.
- The heartwood provides the strength in a tree while the sapwood conducts water from the roots to the leaves. Sapwood is generally unsuitable where durability is critical.
- A log may be cut several ways to convert it to timber – quarter sawn, through and through and plain.
- The moisture content of wood has a significant effect on its durability and dimensional stability. It is therefore critical for specifiers to understand the relationship between moisture content at the time of installation and in service, in order to achieve the best results with timber.
- Durability refers to wood's resistance to biodegradation. Specifiers can select species according to their durability rating.
- Preservatives can increase the durability of wood. The most durable species are generally hardwoods, which are generally unsuitable for preservation because the wood does not permit the chemical to penetrate far.
- Wood generally performs well in corrosive situations and, for this reason, is preferred for some industrial structures.
- Wood is graded visually and in grading machines to assign a characteristic strength for structural purposes.
- Eurocode 5 lists the characteristic strengths needed for structural design. Wood's strength to weight ratio (when measuring strength along the grain) is ranked with common metals. However, it has a lower tensile strength across the grain and lower shear strength parallel to the grain.

Nomenclature

Botanical

Botanical classification allocates plants into divisions that have certain gross features in common. These are successively sub-divided on the basis of similarity into smaller orders, then families, genera and eventually species.

An international agreement exists for the scientific naming of plants, based on the system adopted by the Swedish botanist Carl Linnaeus and published in his Species Planetarum in 1753. In this system every plant receives two names – a generic name according to the genus to which it belongs and a specific name applicable to it alone. The specific name is followed by the name of the botanist who was responsible for naming the plant, often abbreviated.

Thus *Pinus pinaster* Ait is the botanical name of maritime pine, where

- *Pinus* indicates that it belongs to the genus of true pines
- *pinaster* is the particular species of pine
- Ait is the botanist Aitchison, abbreviated to Ait, who published the original description of the tree that was universally accepted scientifically.

The botanical names of timber species are those of the trees from which the timber is produced. It is important that specifiers use the proper species name if a particular timber is required.

Different species of the same genus can produce timbers with quite different features. For example, sapele (with its pronounced stripe figure) and utile (which is quite plain) are different species of the genus *Entandrophragma*. On the other hand, because the features used by botanists for distinguishing individual species may appear in the flowers or leaves, the timber from closely related tree species may be very similar, or even in some cases indistinguishable. For example, English oak is made up of two species of the genus Quercus, and afzelia from a number of species of the genus *Afzelia*.

Trade or common names can be misleading since the same name can be used for different species in different countries or they may differ according to tradition in regions of a country.

BS EN 13556 Round and sawn timber. Nomenclature of timbers used in Europe [3] indicates the botanical species and English standard name. It also indicates where a commercial name is botanically inappropriate by the use of inverted commas, such as 'Douglas fir' which has also been known as 'British Columbian pine' and 'Oregon pine'. The timber belongs neither to the genus of true firs (*Abies*) nor the true pines (*Pinus*) but is in the separate genus of *Pseudotsuga* and given the full botanical name of *Pseudotsuga menziesii* (Mirb) Franco.

Commercial

The commercial division of timbers into 'hardwoods' and 'softwoods' has evolved from long traditions when the timber trade was dealing with a limited range of species. Today, however, this division bears little relation to the softness or hardness of the timber. Softwoods are produced from coniferous or cone bearing trees which have needle-like leaves and are mostly evergreen, such as pines and yew. Hardwoods are produced from broad-leaved trees which produce seeds contained in an enclosed case or ovary, for example an acorn or walnut.

Structure of wood

All living organisms are composed of cells. In the growing tree different cell tissues perform different functions; some store and convey food manufactured in the leaves, some convey liquids, while others provide strength and elasticity to the tree to withstand storms and gales, and to support a heavy crown of branches. Most of the conducting and supporting cell tissue is vertically arranged in the tree and can be seen in the grain direction of timber. Food storage and conduction across the tree is largely a function of narrow ribbons of weak cells, known as rays, which run across the grain.

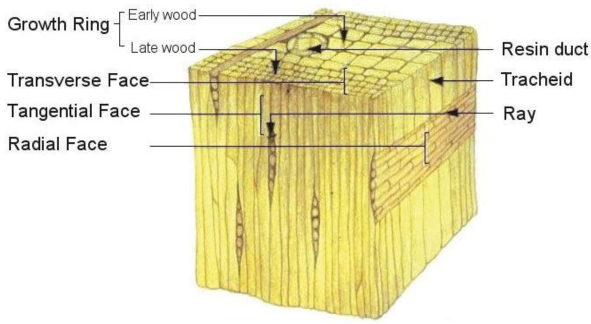

Figure 2: Structure of softwood

In softwoods (*Figure 2*) the vertical elements are known as trachieds, which are arranged in an almost geometrical fashion. Liquid sap can pass through the cavities of these cells and from one trachied to another through microscopic openings in the cell walls, known as pits. The configuration and types of pits affect the permeability of the timber, which in turn affects the ease with which it can be treated with preservatives. They also provide a diagnostic feature used in species identification.

The vertical elements in hardwoods (*Figure 3*) vary considerably in size and arrangement according to species, but the majority of these cells are fibres with very thick walls which give support to the tree. Other cell tissues are soft and thin walled (parenchyma); they may store food, or in some timbers may secrete oil, or crystals of calcium oxalate, or similar chemicals. Most of the remaining wood structure is composed of vertical cells or vessels generally known as pores. These tend to form a distinctive pattern and aid identification since the presence of pores separates a hardwood from a softwood and the pattern may be characteristic of a particular species.

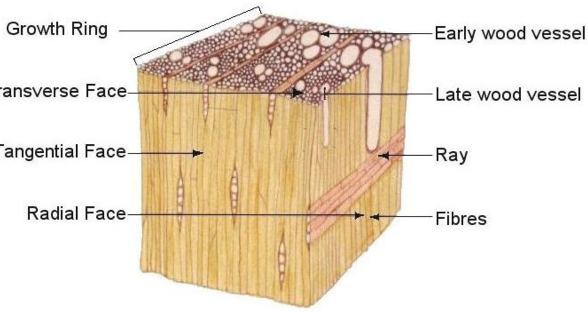

Figure 3: Structure of hardwood

The horizontal elements (or rays) are much more varied in hardwoods than in softwoods. In softwoods they are generally narrow and short in length; in hardwoods they may also be wide and high. It is the rays which produce the characteristic flecks in beech and the typical 'silver grain' figure in quarter sawn oak.

Wood substance is composed almost entirely of organic matter. The structural components consist of cellulose, hemicellulose and lignin. In effect, the lignin acts as a bonding and stiffening agent within the woody structure, while the cellulose and hemicellulose provide elasticity and tensile strength.

Other chemicals are often present, as part of the cell wall structure or in the cell cavities. Sugar is manufactured by the tree as food, some of which may be converted into starch and stored in thin walled cells as grains. Cellulose itself is made up from sugar units. Pigments determine the colour of wood; tannins are secreted in the wood and bark; latex, resins and gums are produced by some species; calcium salts commonly occur in hardwoods, appearing as chalky deposits in the pores or in special ducts. These are responsible for the white deposits often seen in iroko. Silica may occur as particles in the cell walls or, more frequently, in the ray cell cavities of many hardwoods. Large quantities of silica may cause blunting of the cutting edges of tools. On the other hand, a high silica content tends to render wood more resistant to attack by marine borers.

Growth rings

A 'growth ring' is the layer of wood produced in one growing season and an annual ring corresponds to an annual period of growth. The rate of growth is usually expressed as the number of growth rings per 25mm, measured radially on the end grain of a log or piece of converted timber. Early wood (also less correctly known as spring wood) is the less dense wood formed during the earlier stages of growth of each growth ring. Late wood (also less correctly known as summer or autumn wood) is denser wood formed during the later stages of growth of each growth ring.

In softwoods, the early wood consists of thin walled, relatively weak trachieds, while the late wood consists of darker coloured, thick walled tracheids (*Figure 4*).

Figure 4: Growth rings in softwood

In hardwoods, some species such as oak and ash have clearly defined growth rings where the early wood is marked by one or more continuous rows of large pores, while the remainder of the ring consists of smaller pores set in a dark, denser background of fibres. These are known as ring porous species (*Figure 5*).

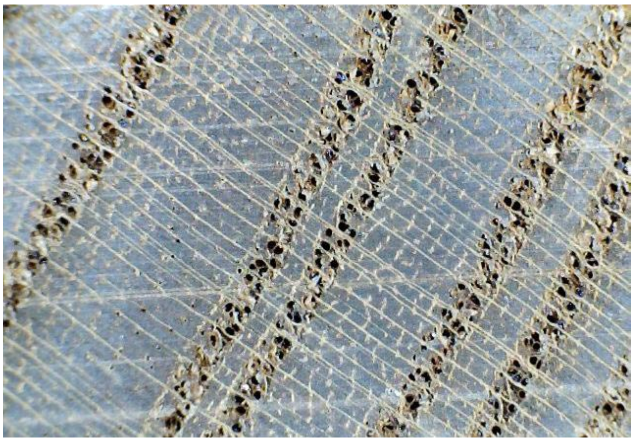

Figure 5: Ring porous hardwood

In some hardwoods, such as hickory and often walnut and teak, the early wood is marked by incomplete rows of large pores while the late wood is basically the same as the ring porous types. Wood of this type is known as semi ring porous (*Figure 6*).

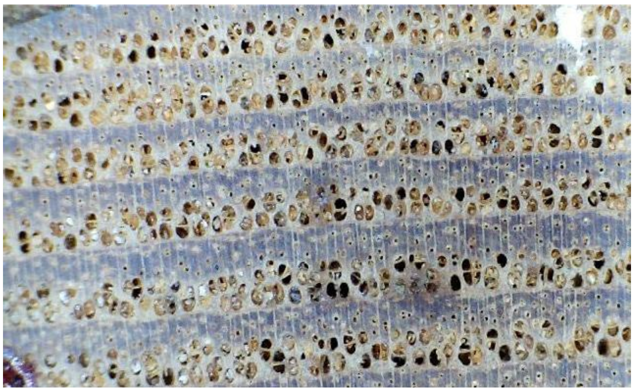

Figure 6: Semi ring porous hardwood

A further group, known as diffuse porous (*Figure 7*), may or may not have the annual growth clearly defined. Where demarcation is noticeable this is generally formed by a narrow band of darker or lighter coloured tissue formed either at the commencement or termination of growth. In this group pores are distributed more or less uniformly throughout the wood.

Figure 7: Diffuse porous hardwood

Grain, texture and figure

'Grain' refers to the general direction of the fibres relative to the axis of the tree. Thus, grain may be straight, spiral, diagonal, interlocked or wavy (*Figure 8*).

'Texture' refers to the structural character of the wood as revealed by touch or reaction to cutting tools. This is largely determined by the distribution and size of the various types of cells. If the cells, particularly the pores and rays, are small in size, the texture is said to be fine; and coarse if the cells are large. Timber with little variation in the size of cells and with little contrast between early wood and late wood is said to have even texture. Timber with considerable variation in the size of cells or a distinct contrast between early and late wood has an uneven texture.

Figure 8: The drying checks in this telegraph pole have followed the spiral nature of the grain

'Figure' in wood refers to ornamental markings seen on the cut surface of timber, formed by the structural features of the wood (*Figure 9*).

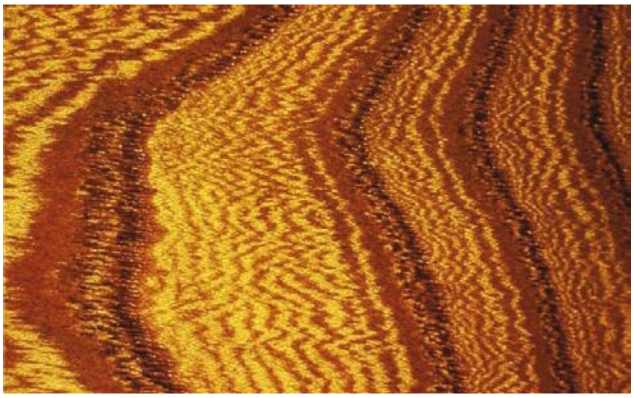

Figure 9: Partridge breast' figure in elm

Knots

All normal branches originate from the centre of the tree, known as the pith. The portion which becomes embedded in the main trunk appears as a 'knot' in the converted timber. Where a branch has been sawn off close to the bole of the tree, the scar is rapidly covered and normal wood is produced thereafter. This type of knot is generally referred to as sound, live or tight. Where branch stubs are left after breaking off, they may remain for some time before new growth absorbs them. Generally this produces a dead (or loose) knot in converted timber.

Sapwood and heartwood

The trunks of many trees show a darker coloured area in the centre; this is the 'heartwood'. Its function is almost entirely to provide the mechanical support of the tree. Around the outside of the heartwood is a ring of often lighter coloured 'sapwood' which conducts water from the roots to the leaves. Not all trees show a difference in colour between the sapwood and heartwood, but both exist in all mature trees. The cells undergo chemical and physical changes in their conversion from sapwood into heartwood. Food or waste materials may be converted into complex organic substances resulting in colour changes. Outgrowths (or tyloses) from the cell walls may occur, blocking the conducting cells so that wood which was permeable as sapwood may become impermeable as heartwood. This is a regular feature in white oak and is one reason why coopers favour this timber for making barrels.

Sapwood should be regarded as having low resistance to fungal or insect attack regardless of species; the resistance of heartwood varies considerably depending on the species. Trees with richly coloured heartwood can provide highly decorative timber. Many of the softwoods used for structural purposes, such as European redwood, will nearly always contain a significant amount of sapwood as the trees are small in diameter.

Conversion of logs into timber

The pattern in which timber is converted from a log influences its appearance and behaviour.

'Quarter sawn' timber (*Figures 10 and 11*) is converted so that the growth rings meet the face of the board at an angle of not less than 45°. Quarter sawing has the advantage of producing boards which are most stable during drying and of producing attractive ray or stripe figures. Such conversion produces narrower boards and costs are increased because of repeated turning of the log during cutting. It is therefore mostly used for the conversion of decorative hardwoods.

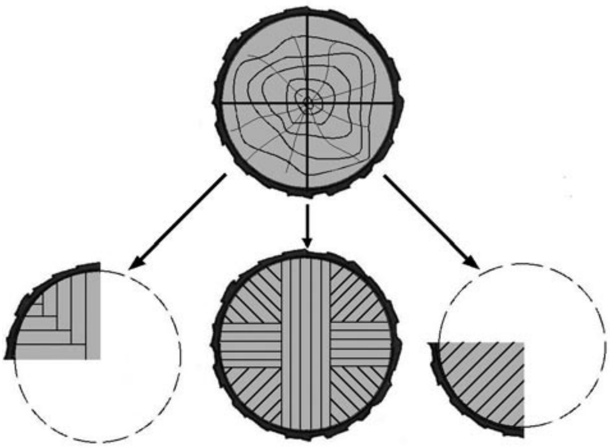

Figure 10: Quarter sawn

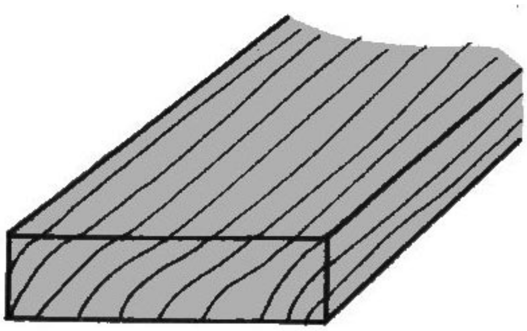

Figure 11: Quarter sawn plank

'Through and through' sawing (*Figure 12*) is a method of cutting logs by parallel cuts in the general direction of the grain.

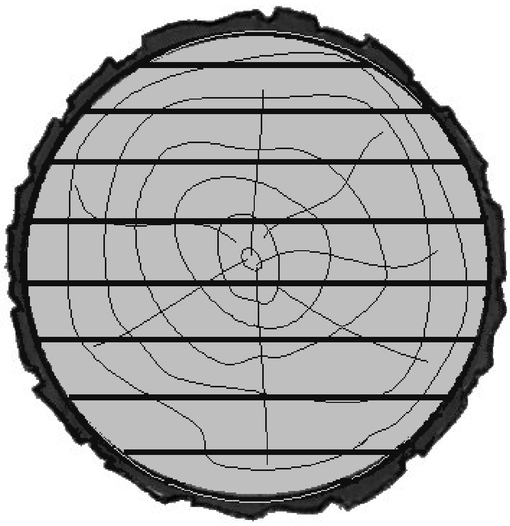

Figure 12: Through and through sawn

The growth rings in 'plain sawn' timber (*Figure 13*), also known as flat sawn or slash sawn, meet the face at an angle of less than 45°.

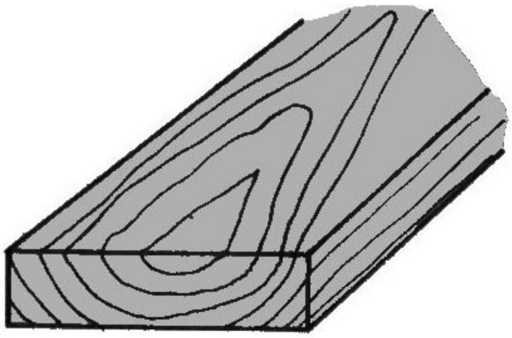

Figure 13: Plain sawn plank

The end grain of timber is particularly strong and resistant to abrasion; this is highlighted in the use of end grain blocks for flooring. However, end grain surfaces are relatively porous since they expose mostly open cell cavities. This section of wood is therefore vulnerable to moisture pick-up, which in adverse environments could lead to decay. End grain surfaces should therefore be protected by detail design or by finishes, particularly in exterior situations.

Importers with their own conversion facilities may receive hardwood logs, although the trend is for hardwood to be imported already sawn in an assortment of lengths and widths. Some species, particularly those used for flooring, will be imported as short blocks or strips. European hardwoods are likely to be imported cut through and through, retaining the waney edge (where the corner is missing on one or both edges of the board resulting from being cut from the circumference of the log) or in the form of square edged sawn timber (where the edges have been sawn and are at 90 degree angles).

Softwood logs are usually converted in their country of origin direct to the section sizes appropriate for construction and joinery.

Moisture content

Wood will always contain water; when felled 'green' wood is saturated (the cell cavities are full of water). Moisture content is expressed as a percentage of the oven dry weight of wood; thus green timber may have a moisture content greater than 100%. As the wood dries out, water leaves the cell voids until the moisture content of the wood reaches about 28%, a state known as 'fibre saturation point'. This does not produce significant shrinkage. Below this value, water which is bound in the cell walls starts to be removed and the wood will shrink as it dries. Similarly expansion occurs as the moisture content increases up to the fibre saturation point.

Wood loses moisture until the amount of water in the wood balances the amount of water in the air around it, which means the wood reaches 'equilibrium' with its service environment. The equilibrium moisture content will vary as the humidity of the surrounding air changes. Wood that is thoroughly air dried under cover in the UK will attain a moisture content of around 18%. Kiln drying will be necessary to achieve moisture contents lower than this. Correct specification is particularly important if the timber is to be used in heated buildings. Timber below about 20% moisture content is also sufficiently dry to prevent fungal decay occurring. Most constructional timber is strength graded at 20% and should be installed at this moisture content or lower, depending on the environmental conditions, whereas most consumer goods for use internally should normally incorporate wood prepared and assembled at about 12% moisture content.

'Movement' is the term commonly used to describe the expansion and contraction of wood with changes in its moisture content. Movement along the grain is negligible, as is the movement of wood with varying temperature, whilst movement tangentially and radially are more pronounced. The avoidance of unwanted movement is the essential reason why users and specifiers must relate the moisture content of wood at the time of fabrication to that which will be in equilibrium with the intended environment. It is equally important to maintain this moisture content during storage and installation.

The degree of movement exhibited by timbers varies with species. Where dimensional stability is of special importance a timber with small movement characteristics should be specified. If the finished thickness of a piece is critical, the designer must be careful to specify the required dimension at the desired final moisture content.

WIS 4-14: Moisture in timber [4] explains the significance of moisture content in more detail.

Durability

The term 'durability' usually refers only to wood's resistance to biodegradation. The main biological agents which attack timber are fungi, insects and marine borers.

BS EN 350-2 Guide to natural durability and treatability of selected wood species of importance in Europe [5] gives densities and data on the natural durability of many commercially available timber species.

Degradation of timber may take the form of moulds or stains which are harmless except to appearance, or fungal decay (rot) where the timber decays, shrinks and critically loses strength. Fungal attack can be prevented by maintaining the wood at a moisture content below 20%.

'Woodworm' is a commonly used term to describe the degradation of wood by insect larvae. The most significant insect pest attacking timber in buildings in the UK is the common furniture beetle which can infest dry wood, although it is usually confined to sapwood unless fungal decay is present. *WIS 2/3-32: Timber fungi and insect pests* [6] outlines the more important fungi and insects that can affect timber.

The permeability of sapwood in many species makes it readily amenable to preservative treatment, an advantage since the sapwood of all timbers is considered susceptible to decay.

Some species however, are considered refractory to treatment penetration, and alternatives should be considered when treatment is deemed necessary. Information on the treatability of timber can be found in *BS EN 350-2*. Sapwood is also more susceptible to insect attack than most heartwood and some insects will infest only the sapwood of certain timbers.

The durability of heartwood varies with species; its resistance to fungal attack is tested in accordance *BS EN 350-1 Durability of wood and wood-based products. Natural durability of solid wood. Guide to the principles of testing and classification of natural durability of wood* [7] by placing 50 x 50mm stakes in the ground and timbers are allocated to one of five categories depending on their longevity in this situation:

Class 1: very durable
Class 2: durable
Class 3: moderately durable
Class 4: slightly durable
Class 5: not durable.

The durability of timber can be increased by the use of preservative treatments. These range from superficial surface application by brushing, dipping or spraying to methods using pressure and vacuum cycles to force the preservative into the timber.

Timber preservatives are available in many formulations: solvent-based, micro-emulsions, water-based and oil-based products. The use of chemicals in these formulations is rigorously controlled with the likes of chromated copper arsenate (CCA) and creosote no longer available for general use.

The use of a particular treatment material is largely dependent on the 'use class' (sometimes referred to as service or hazard classes) into which it will be installed. Use classes run from 1 (interior, covered and therefore well protected from decay) through to 5 (in salt water, a highly aggressive environment). *BS 8417 Preservation of wood. Code of practice* [8] details use classes, natural durability recommendations and specifying treatments for wood. Superficial applications should be confined to in-situ treatment for remedial work or for protecting newly cut surfaces of previously treated timber where this is unavoidable. Machining operations should as far as possible be undertaken before treatment.

Preservation should not be regarded as a substitute for finishing treatments. For external use a naturally durable species or preservative treatment should be selected. Finishing treatments will enhance and maintain the appearance of the timber; unprotected it will eventually 'weather' to a grey colour and the surface will become roughened. Exterior wood stains, which are available in a wide variety of colours, are recommended for exterior use.

The main effects of internal exposure are colour change and the accumulation of dirt. The latter can be reduced by the choice of a suitable finish but some colour change is largely unavoidable with any form of transparent or translucent finish available at present. Typically, light coloured woods are likely to darken while the darker coloured woods are likely to become somewhat lighter. Colour changes in service may be a result of colour changes in the finish, the timber, or both.

WIS 4-28: Durability by design [9] explains how designers can extend the service life of timber components by attention to details.

Chemical resistance

The chemical resistance of wood and its compatibility with other materials in corrosive atmospheres may be important to specifiers. Because timber generally performs well in corrosive situations, it is widely used for swimming pool structures and for dock and harbour work. Timber's resistance to weak acids and solutions of acidic salts is better than the common ferrous metals. Alkalis tend to soften wood, although there is useful resistance to weak solutions at normal temperatures.

Performance in fire

Although timber is a combustible material, the keyword for its performance in fire is 'predictability'. Although it burns, this results in a loss of section at a predictable speed known as the 'charring rate' which varies with the density of the species. This predictability allows timber structures to be designed with a known period of fire resistance. The thermal insulation properties of timber are such that the temperature of the timber only a few millimetres under the burning zone will be close to normal. The unburnt timber retains its strength and, unlike more conductive materials such as metals or concrete, is not subject to expansion or sudden loss of strength. Indeed, timber is often used to protect these more vulnerable materials in structures.

Impregnation treatments and surface coatings are available to retard the spread of flame over the surface of timber and wood-based sheet materials. The positive properties of timber in fire are recognised in British Standards and the Building Regulations which allow the correct use of timber in a wide range of situations.

Many uses of timber result in it being subjected to high temperatures for varying periods. The difficulty of generalising about the effect of heat on wood in service is that it is time-dependent – a long time at lower temperatures can have a greater effect on strength and appearance than shorter heating at higher temperatures. As a general rule, timber should not be exposed continually at temperatures above 70°C.

WIS 4-11: Wood-based panel products and timber in fire [10] explains fire performance in more detail.

Grading

Appearance grading assesses the appearance of timber simply by considering the size and position of characteristics, such as knots, splits and checks in relation to decorative requirements. This is appropriate for joinery and furniture. On the other hand, grading for strength (known as strength grading) must assess the effect of these characteristics on the strength of a piece of timber.

Strength grading may be carried out visually or by machine.

Visual grading assesses the effect of visible features which reduce the strength of the timber.

Strength grading machines measure the stiffness of the timber, which is directly related to its strength and has the advantage of taking density into account, a factor not practicable for the visual grader. On the other hand, machine strength grading is generally supplemented by visual inspection to assess features such as wane (the missing edges or corners of boards), fissures (splits in the surface of the timber), wormholes (flight or exit holes left by timber boring insects or their larvae) and abnormal defects.

To supplement home-grown material, the UK imports timber from a wide range of countries, each producing materials to their own national standards. Thus there is a very wide range of options of species and grades available. *BS EN 338 Structural timber. Strength classes* [11] classifies softwoods in 12 strength classes (from C14 to C50) and hardwoods into 8 strength classes (from D18 to D70). It tabulates strength, stiffness and density for designers to apply in *Eurocode 5*.

Variation when using BS 5268

BS 5268-2 tabulates 'working stress' design parameters according to strength classes (defined in *BS EN 338)* as well as extensive tables for calculating design parameters for common species.

Over-design and over-specification are wasteful and expensive, in terms of the direct cost and the overall use of the resource. There is no advantage in using timber that is stronger than required or using highly decorative timbers if they are to be enclosed within a structure or concealed by paint or other finishing treatment. Designers, specifiers and users of timber should therefore select suitable species and grades of timber, coupled with appropriate protective and finishing treatments for the intended purpose. The available range of timber species as well as the various types of structural timber composites and wood-based sheet materials means that timber and its derivatives can, with careful selection and specification, fulfil almost any function required.

WIS 4-7: Timber strength grading and strength classes [12] explains the system for grading timber and assigning strength classes.

Strength characteristics

For its weight, timber is extremely strong in tension along its grain, and the stronger species of wood rank with aluminium alloy and substantially exceed steel in their specific strength to weight ratio. However, timber has lower tensile strength across the grain and lower strength in shear parallel to the grain.

Wood, being a natural material, is substantially more variable than manufactured materials. This variability is taken into account by strength and quality grading and, where appropriate, by the choice of acceptable working stresses. Comprehensive design data for softwoods, hardwoods, glued laminated timber and wood-based panel products are included in *Eurocode 5*.

References

1. BS EN 1995-1-1:2004+A1:2008 Eurocode 5. Design of timber structures. General. Common rules and rules for buildings, BSI
2. BS 5268-2:2002+A1:2007 Structural use of timber. Code of practice for permissible stress design, materials and workmanship, BSI
3. BS EN 13556:2003 Round and sawn timber. Nomenclature of timbers used in Europe, BSI
4. WIS 4-14: Moisture in timber, TRADA Technology, 2011
5. BS EN 350-2:1994 Durability of wood and wood-based products. Natural durability of solid wood. Guide to natural durability and treatability of selected wood species of importance in Europe, BSI
6. WIS 2/3-32: Fungi and insect pests in timber, TRADA Technology, 2011
7. BS EN 350-1:1994 Durability of wood and wood-based products. Natural durability of solid wood. Guide to the principles of testing and classification of natural durability of wood, BSI
8. BS 8417:2011 Preservation of wood. Code of practice, BSI
9. WIS 4-28: Durability by design, TRADA Technology, 2012
10. WIS 4-11: Wood-based panel products and timber in fire, TRADA Technology, 2009
11. BS EN 338:2009 Structural timber. Strength classes, BSI
12. WIS 4-7 Timber strength grading and strength classes, TRADA Technology, 2011

Further Reading

TRADA publications

British grown hardwoods: the designers' handbook, TRADA Technology, 1996

Hardwoods in construction. TBL 62. 1991. 112 pages

Structural timber composites, TRADA Technology, 1996

Timbers of the World: Set of 9 books, TRADA, 1978

About TRADA

The Timber Research and Development Association (TRADA) is an internationally recognised centre of excellence on the specification and use of timber and wood products.

TRADA is a company limited by guarantee and not-for-profit membership-based organisation. TRADA's origins go back over 75 years and its name is synonymous with independence and authority. Its position in the industry is unique with a diverse membership encompassing companies and individuals from around the world and across the entire wood supply chain, from producers, merchants and manufacturers, to architects, engineers and end users.

Our aim

To provide members with the highest quality information on timber and wood products to enable them to maximise the benefits that timber can provide.

What we do

We seek to achieve this aim through active and on-going programmes of information and research. Information is provided through our website, an extensive collection of printed materials and our training courses.

Research is largely driven by the desire to update and improve our information so that it continues to meet our members' needs in the future.

TRADA Technology is contracted by the Timber Research and Development Association to prepare and publish all Wood Information Sheets.

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