STRUCTURAL USE OF HARDWOODS

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Structural use of hardwoods

When compared with structural softwoods, hardwoods in the medium to high density ranges have

- greater strength and stiffness
- availability in longer lengths and larger sections
- higher density, giving superior fire resistance
- greater natural durability
- more varied aesthetic appeal as exposed members.

Choosing hardwoods may allow a designer to use timber throughout a structure without the need to switch to other materials, such as steel or concrete, for long spans or heavy loadings. They can be used, for example, for bridge beams and joists, lintels or for parts of built-up components such as trusses.

The hardwoods preferred for structural use generally have greater natural durability than the commonly used softwoods. They do not therefore normally require preservative treatment, provided that the vulnerable sapwood is excluded.

Structural hardwoods may be strength graded in accordance with BS 5756: 1997 *Specification for visual strength grading of hardwood*. They are allocated into strength classes defined in BS EN 338: 1995 *Structural timber. Strength classes*. Properties for individual species are also given in BS 5268-2.

The density of many of the species used for structural purposes provides greater fire resistance than that of the lower density softwoods. This is acknowledged by the slower charring rates given in BS 5268-4 Section 4.1 *Recommendations for calculating fire resistance of timber members*.

Strength Grading and Strength Classes

Strength grading

For hardwoods, strength grading may be undertaken to the rules laid down for visual grading in BS 5756. Strength grades are defined for different types and applications (see Table 1).

BS 5268 - 2 defines three moisture content Service classes:

Service Class 1

Characterised by a moisture content in the materials corresponding to a temperature of 20° C and the relative humidity of the surrounding air only exceeding 65% for a few weeks each year. In such conditions most timber will attain an average moisture content not exceeding 12%.

Service Class 2

Characterised by a moisture content in the materials corresponding to a temperature of 20° C and the relative humidity of the surrounding air only exceeding 85% for a few weeks each year. In such conditions most timber will attain an average moisture content not exceeding 20%.

Service Class 3

Due to climatic conditions, is characterised by higher moisture contents than Service Class 2.

Dry graded timber should be used in Service Classes 1 and 2 (see Table 1). Timber with a target thickness of 100 mm or more is difficult and slow to dry and may therefore be graded and marked WET.

Marking

Hardwoods strength graded in accordance with BS 5756 should be marked with:

- the species and grade
- the company responsible for the grading
- the Certification body and the BS number; BS 5756
- DRY, KD (kiln dried) or WET as appropriate.

Strength classes

Timbers of similar strength properties are grouped together into strength classes. These are defined in BS EN 338, which includes six strength classes for hardwoods, D30 - D70, see Table 2 wood Information Sheet 4-7 *Timber strength grading and strength classes* gives more details.

BS EN 338 gives characteristic values for strength and stiffness properties for each strength class. These are used in the limit states design system laid down in Eurocode 5 and are derived from test values, taking no direct account of factors of safety or other significant factors which are applied as part of the design process. Great care should therefore be taken not to mix the codes with differing safety systems, Table 3 shows the characteristic values for the hardwood strength classes.

BS 5268-2 is a permissible stress design code which gives grade stresses for the strength classes defined in BS EN 338 and also for the individual hardwood species included. Table 4 shows the BS 5268-2 grade stresses for the hardwood strength classes.

Type 1 Guide to hardwood types and appropriate structural grading systems

Type of hardwood	Purpose	Grade designations	Application notes
Temperate	Applications involving large* cross sections	THA, THB	Installed at high moisture content in Service class 3 conditions - situations expected to remain wet - BS 5268-2 calls for grade stresses to be modified, see Clause 2.6.2. Clause 2.6.1 advises on difficulty of drying thick timber (ie over 100mm). Scope 1.1 advises that the code 'does not cover well tried and traditional methods…which have been employed successfully over a long period of time'. "Green oak", which is carpentry jointed, is installed in the knowledge that drying-out will occur slowly in service. This is 'traditional', as indicated in Code Scope 1.1. Construction professionals, craftspersons and clients should understand capabilities and limitations - both of the techniques and their own knowledge.
Temperate	Applications involving smaller** cross sections	TH1, TH2	Installed in Service class 1 or 2 conditions - grade stresses need not be modified for moisture content. Pre-drying is feasible. Section sizes are expected to be at or below those in Clause 2.6.1
Tropical	All sizes	HS	A simple single-grade system for tropical hardwoods. These rarely contain significant knots, but specialist understanding of their characteristics may call for additional advice from suppliers.
Large* cross sections - no dimension less than 100 mm and cross sectional area greater than 20000 mm²			
Smaller** cross sections - dimensions less than 100 mm and cross sectional area equal to or smaller than 20000 mm²			

Table 2 Guide to hardwood types and appropriate structural grading systems

Species	Strength class				
	D30	D40	D50	D60	D70
Balau					HS
Ekki				HS	
Greenheart					HS
Bangkirai		HS			
Karri		HS			
Oak*	TH1 THB	THA			
Note: the TH2 grade of oak does not meet the requirements for the D30 strength class. Designs for this species/grade are better based on the grade stresses given in BS 5268-2 for the individual species and grades, see Table 5					

Table 3 Strength graded hardwoods assigned to BS EN 338 strength classes

Strength properties N/mm²	**D30**	**D40**	**D50**	**D60**	**D70**
Bending	30	40	50	60	70
Tension parallel to grain	18	24	30	36	42
Tension perpendicular to grain	0.6	0.6	0.6	0.7	0.9
Compression parallel to grain	23	26	29	32	34
Compression perpendicular to grain	8.0	8.8	9.7	10.5	13.5
Shear	3.0	3.8	4.6	5.3	6.0
Stiffness properties kN/mm²					
Mean MoE parallel to grain	10	11	14	17	20
5th percentile MoE parallel to grain	8.0	9.4	11.8	14.3	16.8
Mean MoE perpendicular to grain	0.64	0.75	0.93	1.13	1.33
Mean shear modulus	0.60	0.70	0.88	1.06	1.25
Characteristic density kg/m³	530	590	650	700	900

Table 4 Grade stresses and moduli of elasticity for hardwood strength classes for Service classes 1 and 2 (BS 5268-2)

N/mm²	*D30*	*D40*	*D50*	*D60*	*D70*
Bending parallel to grain	*9.0*	*12.5*	*16.0*	*18.0*	*23.0*
Tension parallel to grain	*5.4*	*7.5*	*9.6*	*10.8*	*13.8*
Compression parallel to grain	*8.1*	*12.6*	*15.2*	*18.0*	*23.0*
*Compression perpendicular to grain**	*2.8/2.2*	*3.9/3.0*	*4.5/3.5*	*5.2/4.0*	*6.0/4.6*
Shear parallel to grain	*1.4*	*2.0*	*2.2*	*2.4*	*2.6*
Modulus of elasticity:					
Mean	*9500*	*10800*	*15000*	*18500*	*21000*
Minimum	*6000*	*7500*	*12600*	*15600*	*18000*
Average density kg/m3 at 20°C / 65% RH	*640*	*700*	*780*	*840*	*1080*

** When specification excludes wane at bearing areas, the higher value of compression perpendicular to grain stress may be used; otherwise the lower values apply.*

Design to BS 5268-2

Structural design using hardwoods to BS 5268-2 is little different in principle from using softwoods. Some points to note however are, that the strength properties of individual hardwood species may be higher than those for the strength class to which the species belongs. For example designers using oak may wish to take advantage of this by basing their designs on an individual species and grade (see Table 1).

Table 1 discusses timber of 100 mm or greater thickness which is graded and supplied wet, but which is used in Service Class 1 or 2 situations. This may be considered to dry out in service. In this case, the design detailing should take account of the shrinkage and fissuring which will inevitably occur in the timbers as they dry down to their equilibrium level.

BS 5268 - 2 includes a table giving likely in-service moisture contents and moisture contents which should not be exceeded at the time of erection. However, TRADA research has shown that these moisture contents are higher than those often found in practice, see Table 5.

In situations where shrinkage and the possibility of splits are not acceptable, such as in non-traditional, non-carpentry style architecture, timber should be installed at the moisture content which it will attain in use. For heated buildings this means that the timber should be kiln dried to 10-12% see Table 5 Service Class 1. The specifier must therefore assess the feasibility of obtaining kiln dried material and must balance the cost implications against the consequences of timber shrinkage after installation.

Sizes

EN 1313-2 1998 *Round and sawn timber -Permitted deviations and preferred sizes -Hardwood sawn timber* gives permitted deviations and preferred sizes for hardwood sawn timber. The UK National Annex to this BS EN has added certain extra thicknesses. The same standard states ‘If the timber is for structural use, the reduction limits specified in BS 5756 apply’. Life used to be simpler for specifiers when BS 5268-2: 1991 gave tables of section sizes for hardwoods. These were removed for no technical reason. On the basis of common practice, and an amalgam of these former and current standards, TRADA Technology advises that the sizes shown in Table 6 are likely to be commonly available.

Because hardwoods are often provided by specialist suppliers, and in the case of those from temperate sources, sawn to order, a much wider range than that indicated may be possible, by arrangement. In traditional carpentry, larger sizes are common, and the specialists involved have contact with appropriate suppliers. Likewise, traditional marine and freshwater construction specialists have access to large sizes of timbers such as ekki and greenheart. For further information see TRADA Technology’s *Hardwoods in Construction.*

Table 5 Moisture content (mc)

Service Class	Examples of use in building	Average mc likely in service: BS 5268-2 %	Average mc found in TRADA research %	Max mc of individual pieces at time of erection: BS 5268-2 %
1	Internal in continuously heated building	12	10 - 12 or lower (individual readings down to 6)	20
2	Covered and generally heated	15	11-12	20
	Covered and generally unheated	18	15-17	24
3	External, exposed	20 or more		

Table 6 Sizes of surfaced hardwoods for structural purposes

Thickness or breadth of section mm	Width or depth of section* mm								
	72	97	120	145	170	195	220	245	295
35	✓	✓	✓	✓	✓	✓	✓	✓	✓
47	✓	✓	✓	✓	✓	✓	✓	✓	✓
60	✓	✓	✓	✓	✓	✓	✓	✓	✓
72	✓	✓	✓	✓	✓	✓	✓	✓	✓
97	✓	✓	✓	✓	✓	✓	✓	✓	✓

Depth of section is termed 'Height of Section', in some EN standards and codes*

For sawn sizes under 100mm, a reasonable guide is to add 3mm to the dimensions given in Table 6 and add 5mm to dimensions greater than that value. Trade practices vary from region to region with regard to sawing allowances for shrinkage on drying. Suppliers should be contacted at the design stage if in doubt.

Design to Eurocode 5

DD ENV 1995-1-1: 1994 *Eurocode 5: Design of timber structures. General rules and rules for buildings* can be used as an alternative to BS 5268-2. Although Eurocode 5 is currently a Draft for Development, it is confirmed in the Building Regulations for England and Wales as acceptable for use as the basis of design. The definitive BS EN version is due to be published early in 2004 and will then gradually replace BS 5268-2. Eurocode 5 is a limit states design code and as such represents a radically different design method from the permissible stress approach traditionally used in the UK.

Guidance on design to Eurocode 5 is given in a series of documents available from TRADA. These range from introductory Wood Information Sheets to specialist guidance for engineers - see Further information.

Specialist hardwood design

For many structural applications of hardwoods, particularly British and other European species, modern design methods and standards may not be appropriate. Also, designers may wish to use timbers which are not included in BS 5268-2. Reclaimed timber may be considered but specialist guidance should be sought on grading, moisture content and freedom from metallic objects. Assurance should also be provided that salvaging is not being undertaken to the detriment of existing structures, particularly Listed Buildings.

Demonstrating compliance with British Standards and recognised design codes, such as BS 5268-2 and Eurocode 5, is a rapid and convenient method of gaining Building Regulations approval. However, it is not the only route, and conformity with other reliable, independent and well established recommendations is often equally acceptable to Approving Authorities.

Conservation and repairs to historic buildings and other structures may demand very careful selection of oak or other hardwood. Special forms of drying, available from specialist suppliers, can be called upon where complex laminated or carved sections are needed. An example of where this was necessary is in the restoration of the fire damaged roof of Windsor Castle. In such cases there is close liaison between the specifier, the timber supplier and the fabricator. The supplier can thus 'fine tune' his proposed solutions and select material to meet the special needs of the designer and manufacturer. Structural timber repairs often employ a range of techniques. The TRADA Technology publications *Resin repairs to timber structures* and *Assessment and repair of structural timber* give guidance to professionals involved in the design and execution of such repairs.

In other projects using traditional timbers, such as oak, a 'carpentry' style of architecture and design using large, 'square type' cross-sections with mortised, tenoned and dovetailed joints may be adopted. Member sizes then are often dictated by stiffness rather than strength and may be governed by the thicknesses required to form the joints. In such cases, specifying high strength grades is expensive and wasteful. Qualities available from ‘carpentry quality’ oak may be perfectly adequate and may make more efficient use of the woodland resource than unnecessary over-specification.

BS 5268-2 contains grade stresses for only a limited number of hardwoods, mostly tropical species. Information on oak was reinstated in the 1996 edition, having been included in its forerunner, CP 112. The former code’s (CP 112) grading system of ‘numbered visual grades’ required the grader to know the end use of the piece, ie whether it was to be a beam or column. The numbered grades, 75, 65, 50 and 40 were ‘strength ratios’ – they expressed percentage strengths of a notionally perfect piece of timber – the basic stress grade, or 100 grade.

A Design Guide, *Hardwoods in Construction*, published by TRADA in 1991 contains further information on basic and grade stresses for European-grown hardwoods, graded in accordance with principles laid down in the document and based on the old ‘numbered grades’. The ‘numbered’ grading system can also be employed in the *in-situ* assessment of existing structures. Its use may avoid unnecessary intervention in historic structures and may allow the structural engineer to justify the load carrying capacity of an existing structure and its components.

Hardwoods in Construction also contains a section on ‘Designing with hardwoods not in BS5268 Part 2’ and explains how such timbers can be assigned to strength classes. The Design Guide was written before the introduction of BS EN 338 *Strength classes*, but much of the information is still relevant to specialist designers wishing to broaden the range and application of hardwoods used in structural design.

Hardwood composites

Hardwoods in glulam can be straight sections or curved beams, arches and portals. Curved hardwood glulam beams are often favoured in the design of footbridges. BS 5268-2 gives methods for determining the relevant design stresses. Hardwood laminations are strength graded and the BS EN 338 strength class of the laminates is used to assign the glulam strength class. Grade stresses for glulam can be calculated from the strength class of the laminates. Further information is given in the Wood Information Sheet 1 - 6 *Glued laminated timber*.

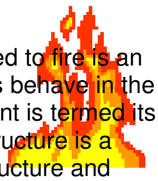
The ability of conventional adhesives for glulam to produce satisfactory glue lines must be considered more carefully than for most softwoods. Some hardwoods have acquired a good reputation for gluing, such as jarrah, keruing and kapur. Iroko has also become popular for use in bridge beams and similar exterior uses. Others, such as teak are more difficult to glue satisfactorily.

Some structural hardwoods, such as greenheart and ekki, are so dense that their shear resistance is higher than the shear strength of conventional glue lines. In addition, extractives and oils in some timbers make gluing a highly specialised operation. Advice should be sought from timber technologists and adhesive suppliers before specifying glulam from hardwood species.

Mechanical laminating using steel dowels is used for long span bridges, built using ekki and similar dense hardwoods. The dowels, often stainless steel, are driven through pre-drilled holes, designed for an interference fit. Design rules for this method are included in BS 5268- 2 and in Eurocode 5.

In 1994 comprehensive repair work using replacement timbers on a like-for-like basis, was carried out on the mechanically laminated Dutton Lower Horse Bridge (*picture below*) on the River Weaver in Cheshire. Built between 1915 and 1919 of hardwood, it has been in continuous use since that date.

Timber in fire



The behaviour of timber structures exposed to fire is an issue of major importance. How structures behave in the first and second phases of fire development is termed its reaction to fire. The reaction to fire of a structure is a measure of how easy it is to ignite that structure and also how easy that structure contributes to the fire development and spread. This may be important for the intended use of the structure or the influence of the fire on the structure’s surroundings.

Once we reach the fully developed fire phase it is assumed that all combustible materials present are burning. We are therefore interested in the fire resistance of the structure, a measurement of the ability of a system to withstand fire.

Fire resistance is defined in BS4422:2005 as “the ability of an item to fulfil, for a stated period of time, the required fire stability and/or integrity and/or thermal insulation and/or expected duty specified in a standard fire resistant test". Fire resistance is therefore a property of the elements of an item and not its materials.

Structural elements are required to maintain their load bearing capability for the appropriate period and separating elements must resist the passage of fire or excessive heat. The principle is one of maintenance of structural stability and containment of the fire until fire fighting is successful.

Set against the complex interactions of an assembly and a mixture of materials is the predictable speed at which timber burns known as the 'charring rate'.

Different timbers char at varying rates, largely as a function of their density, with the higher density timbers charring more slowly. For structural timbers listed in BS 5268: Part 2 this rate of depletion is taken at 20 mm in 30 minutes, from exposed face. Certain of the denser hardwoods, such as Oak and Sapele (densities in excess of 640 kg/m³), which are used for structural purposes, have char rates of only 15 mm in 30 minutes, whereas lower density timbers such as Western Red Cedar (density 390 kg/m³) have rates of 25 mm in 30 minutes.

Charring rate

Type of Timber	Charring per minute
Softwood	0.80 mm
Softwood Glue Laminated	0.70 mm
Hardwood	0.55 mm

Bridges and structures supplied by Sarum Hardwood Structures are typically manufactured in Ekki, which has a density of 1070 kg/m³, giving it superior fire reaction, fire resistance and inhibiting the development of fire.

All timbers supplied by SHS are obtained from responsibly managed sources. If required, timber can be sourced from independently certified forests managed in accordance with the principles and criteria established by the Forest Stewardship Council (FSC).

FSC

Responsible Forest Management
SA-COC-001654 AV

Hardwoods

The pleasing and natural appearance of hardwood makes it an ideal material for bridges and boardwalks in the countryside and parklands, where it blends harmoniously with its surroundings.

Hardwoods :
- ✓ Require minimal maintenance
- ✓ Provide an extended life without the need for preservative treatment
- ✓ Have excellent vandal and fire resistant characteristics

EKKI

Lophira Alata		Family	Ochnaceae

Other names

Kaku	(Ghana)	Akoura	(Gabon)
Azobe	(Ivory Coast)	Eba	(Nigeria)
Bongossi	(Cameroons)	Hendui	(Sierra Leone).

Distribution

Ekki grows in West Africa from Sierra Leone to Nigeria and the Cameroons and is a tree of the heavy rain forests and swamps.

The tree

Ekki is a large tree, attaining a height of 45 to 50m and a diameter of 1.5m.

The timber

The sapwood is pale pink and sharply defined from the heartwood, which is red-brown to dark brown with a somewhat speckled appearance due to white deposits in the pores. The grain is usually interlocked and the texture is coarse. The wood is extremely hard and heavy, weighing 960 to 1120 kg/m3 when dried.

Kiln drying

Very difficult to dry and generally shakes badly; serious degrade is likely, especially surface checking and end splitting. Ekki needs to be piled with special care.

Durability

Very resistant to decay and one of the most durable woods yet known in West Africa.

Working qualities

Very difficult to work using hand tools but can be worked with less trouble, by machines. Nailing requires pre-drilling.

Uses

Too hard for some purposes, but is suitable for heavy construction especially wharves, bridge building and decking, sleepers, flooring - especially heavy duty flooring. It is ideal for all forms of marine work for piling, sea defences, groynes and jetties and any use where high strength and durability is a prime requirement.

EUROPEAN OAK

Quercus petraea Liebl (Quercus sessiliflora Salisb) Quercus robar Liebl (Quercus pedunculata Ehrh)

Other names

Known also as English, French, Polish, Slavonian, etc. Oak, according to origin

Distribution

Europe, Asia Minor and North Africa.

The tree

Both species reach a height of 18 - 30m or more, depending upon growth conditions and diameters are about 1.2 - 2m.

The timber

The sapwood is 25 mm to 50 mm wide and lighter in colour than the heartwood which is yellowish-brown. Quarter-sawn surfaces show a distinct silver-grain figure due to the broad rays. The annual rings are clearly marked by alternating zones of early-wood consisting of large pores, and dense late-wood. Conditions of growth accordingly govern the character of the wood to a great extent; for example, in slowly grown wood the proportion of dense late-wood is reduced in each annual growth-ring, thus tending to make the wood soft and light in weight.

The weight of oak varies according to type; that from the Baltic area, western Europe, and Great Britain being about 720 kg/m3 and that from Central Europe about 672 kg/m3 on average after drying.

Kiln drying

Oak dries very slowly with a marked tendency to split and check, particularly in the early stages of drying, and there is considerable risk of honeycombing if the drying is forced.

Strength

Both types have well known and high strength properties.

Durability

Durable

Working qualities

The working and machining properties of Oak vary with the mild to tough material which either machines easily or with moderate difficulty. These basic properties are concerned with growth conditions, but they may be exaggerated by indifferent drying methods which allow plain-sawn boards to cup, or severe case-hardening to develop, causing excessive wastage in planing and moulding, cupped stock in re-sawing, and a greater degree of blunting of cutting edges.

In general, Oak finishes well from the planer or moulding machine. The wood can be stained, polished, waxed and glued satisfactorily, takes nails and screws well, except near edges, when the wood should be pre-bored, and takes liming and fuming treatments well.

Uses

Oak, when well-grown and well-graded is the finest of timbers. There is none better for boat building, docks, harbours and sea defence work, for railway wagon construction, ladder rungs, post and rails, sills and for all purposes of exposure and in contact with the ground.

MASANRANDUBA

Manikara Bidentata A. DC Family Sapotaceae

Syn. Mimusops Bidentata A.D.C. Chev.

Other names

Balata (Guyana); Bolletrie (Surinam); Nispero (Panama); Maparajuba (Brazil)

Distribution

The trees are native to the West Indies, Central America and northern South America.

The tree

Commonly a large, well-formed tree, reaching a height of 30.0m to 45.0m with diameters of 0.6m to 1.2m and occasionally up to 1.8m or more. Usually without buttresses, but often basally swollen.

The timber

The heartwood is light red to rose red when freshly cut, turning dark reddish brown on exposure; sapwood whitish or pale brown, distinct, but not sharply demarcated from the heartwood. The grain is usually straight but sometimes interlocked, and the texture in fine and uniform. The wood is hard and extremely heavy, and weighs about 1050kg/m^3 when dried.

Drying

Generally reported to be difficult to dry, tending to develop severe checking, warp and casehardening and requiring care in piling to assure a slow rate of drying. However, reports from Puerto Rico state that 25mm lumber air dried to 19 per cent moisture content in four months with only a small amount of degrade in the form of very slight cup, crook and bow, and without apparent surface checking.

Strength

Similar or superior to greenheart in bending strength, shock resistance, hardness, shear, and in across-the-grain properties of compression and tension, but slightly weaker than greenheart in compression parallel to the grain (crushing strength) and in elastic resilience in bending, and quite inferior in stiffness.

Durability

Durable to very durable.

Working qualities

Moderately easy to work despite its high density. It machines and finishes to a very smooth surface. The wood takes a find polish and has the appearance of walnut. Gluing requires special care because of the wood’s resistance to absorption of moisture.

Uses

Steam bending, boat frames, shuttles and loom harnesses, billiard cues; heavy construction, bridges, flooring in industrial plants, stair treads.

BALAU

Shorea spp. Family Dipterocarpaceae

Distribution

The hard, heavy timber species of Shorea occurring in South East Asia are grouped under common trade names peculiar to the area. Thus Selangan Batu (hard Selangan) is the name used in Sabah, Brunei and Sarawak, while Balau is used to describe the heavy Malaysian species.

Balau

Balau is generally separated into two types in Malaysia, i.e. Balau and Red Balau.

Balau is produced mainly from Shorea Atrinervosa, Shorea Elliptica, Shorea Foxworthyi, Shorea Glauca, Shorea Laevis, Shorea Maxwelliana and Shorea Submontana.

Red Balau is produced mainly from Shorea Guiso, Shorea Kunstleri, Shorea Collina and Shorea Ochrophloia

The timber

Selangan Batu is a yellowish-brown timber with interlocked grain, and coarse, but even texture. According to species, durable to very durable.

Balau is a yellow-brown, brown or reddish-brown timber with interlocked grain and a moderately fine and even texture. It is classified in Malaysia as being very durable.

Red Balau is a purplish-red or dark red-brown timber with an interlocked grin and a coarse but even texture. It is classified in Malaysia as being less durable that Balau, i.e. moderately durable.

Red Selangan Batu (Sabah), and Alan, or Meraka Alan (Sarawak and Brunei) are approximately equal in colour and characteristics to Red Balau.

Average weights (air dry)

Balau and Selangan Batu No.1	881 to 980 kg/m3
Red Balau	800 to 880 kg/m3
Selangan Batu No. 2	850 kg/m3
Alan	850 to 880 kg/m3
Red Selangan Batu	850 kg/m3

Average strength properties

All species mentioned have hard, heavy and strong timber with strength properties similar to those of Greenheart.

Uses

All species are suitable for heavy structural work, bridge and wharf construction, sleepers, flooring and boat framing, but the higher durability of Balau and Selangan Batu renders them more suitable for adverse conditions of use.