

Packaging code —

Section 8: Wooden boxes, cases and crates

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Packaging and Freight Containers Standards Policy Committee (PKM/-) to Technical Committee PKM/553, upon which the following bodies were represented:

- British Fibreboard Packaging Association
- EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)
- PIRA
- Timber Packaging and Pallet Confederation
- Timber Research and Development Association
- United Kingdom Tea Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Brewers' Society
- British Wood Preserving and Damp-proofing Association
- Forestry Commission
- Ministry of Defence
- Power Fastenings Association
- Road Haulage Association Ltd.
- South African Bureau of Standards

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Publication(s) referred to	Inside back cover

Foreword

This Section of BS 1133 has been prepared under the direction of the Packaging and Freight Containers Standards Policy Committee. It is a revision of BS 1133-8:1981 which is withdrawn. BS 1133 was originally issued in December 1943, primarily to give guidance on the packaging of Service and other Government supplies. In practice, however, the code was used not only by Government departments and contractors but also by civilian packers and, accordingly, it was amended to suit commercial requirements and new Sections were added as necessary.

Various Sections of the code have been revised and the most recent revision of Section 8 was in 1981. This revision of Section 8 updates and expands the information on sawn wood species, sheet materials and fasteners. More information is given on case styles and components and a section on wirebound cases and crates is reinstated.

The packaging code now consists of the following Sections all of which are published separately with the exception of Sections 1 to 3 which are published in one volume.

- *Sections 1 to 3: Introduction to packaging;*
- *Section 4: Mechanical aids in package handling;*
- *Section 5: Protection against spoilage of packages and their contents by micro-organisms, insects, mites and rodents;*
- *Section 6: Temporary protection of metal surfaces against corrosion (during transport and storage);*
- *Section 7: Paper and board wrappers, bags and containers;*
- *Subsection 7.1: Wrapping papers;*
- *Subsection 7.2: Bags and envelopes;*
- *Subsection 7.3: Cartons and boxes;*
- *Subsection 7.4: Fibreboard drums;*
- *Subsection 7.5: Fibreboard cases and fitments;*
- *Subsection 7.6: Moulded pulp packaging;*
- *Subsection 7.7: Composite containers;*
- *Section 8: Wooden boxes, cases and crates;*
- *Section 10: Metal containers;*
- *Subsection 10.1: Tins and cans;*
- *Subsection 10.2: Metal drums;*
- *Subsection 10.3: Metal collapsible tubes;*
- *Section 12: Methods of protection against shock (excluding cushioning devices);*
- *Section 13: Twines and cords for packaging;*
- *Section 14: Adhesive closing and sealing tapes;*
- *Section 15: Tensional strapping;*
- *Section 16: Adhesives for packaging;*
- *Section 18: Glass containers and closures;*
- *Subsection 1: Terminology;*
- *Section 19: Use of desiccants in packaging;*
- *Section 21: Regenerated cellulose film, plastics films, aluminium foil and flexible laminates;*
- *Section 22: Packaging in plastics containers.*

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to viii, pages 1 to 98, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Subsection 1. General

1 Scope

This Section of BS 1133 provides guidance for manufacturers, users and specifiers of wooden boxes, cases and crates for industrial applications.

Subsections 1 to 3 of the standard contain guidance on wood species, sheet materials and fastenings likely to be encountered by UK manufacturers or export packers.

Subsections 4 to 6 of the standard give guidance on the design of:

- a) industrial cases and crates;
- b) ranges of smaller sawn wood boxes for general use;
- c) ranges of plywood and wood based sheet boxes and cases;
- d) plywood cases of metal edge construction;
- e) wirebound boxes and cases.

It should be noted that a knowledge of engineering principles is necessary to produce a design specification from the information given in certain tables, particularly in relation to large cases and crates.

NOTE 1 Much of the information in this standard may also be of value in other areas where wood is used in packaging and distribution, e.g. agricultural boxes and pallets.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

Subsection 2. Wood for packaging

2 Sawn wood

2.1 Species suitable for packaging uses

2.1.1 General

Wood is a natural material and it is not possible to control its quality by methods appropriate for manufactured packaging materials such as plastics or metal. The species and grade should be selected to suit the particular end use and information to assist in selection is given in this subsection.

Wood is classified as softwood (the conventional term for both the timber and the trees belonging to the botanical group *Gymnosperms*) or hardwood (from deciduous trees), irrespective of whether it is actually physically hard or soft. As far as commercial timbers are concerned softwoods are all conifers. Most wood used for packaging applications is softwood, but hardwood may also be used.

The heaviest (denser) species of timber are usually stronger, although they are often more difficult to work and fasten. Where the properties of a timber species are not known, it is advisable before use to check the strength and the ease with which nails can be driven into the wood (commonly referred to as nailability). The latter property may be particularly relevant when improved nails, such as annularly threaded nails, are used because these are more difficult to drive and may cripple on entry into very dense species.

NOTE Cripple is the failure by bending, whilst only partly driven, of a nail or staple during insertion into timber.

Some timbers such as sweet chestnut are also particularly liable to cause acidic corrosion of metallic objects with which they are in contact and this hazard should also be considered.

Sapwood (the outer layer of the tree trunk which, in the growing tree, contains living cells and reserve materials, e.g. starch) is often lighter in colour than the inner heartwood, but may not be distinguishable. Sapwood contains starches and is more susceptible to insect and fungal attack than heartwood, but it is not practicable to specify heartwood for wooden box, case or crate construction nor is it necessary for the short life of the average wooden container.

2.1.2 British grown species

2.1.2.1 Softwoods

2.1.2.1.1 Pines

Pines are among the stronger of the softwoods used for packaging and, on a volume basis, pines from all sources are probably used more extensively than any other species. The heartwood of the timber is often a reddish brown in colour and is usually resinous. Knots tend to be large and scattered, with a tendency to loosen on drying. Pines have a greater susceptibility to sapstain (blue stain) (see note) than other species and it is essential that care is taken to avoid close piling after sawmill conversion whilst still at a high moisture content.

NOTE Sapstain is a stain in softwood sapwood resulting from the growth of certain fungi which derive their nourishment from wood cell contents, but do not cause decomposition of the wood cells themselves. The stain is greyish blue in colour and hence is also referred to as blue stain.

The following pines are used for packaging purposes.

- a) Corsican pine. Widely planted in Southern and Eastern England, availability elsewhere is somewhat limited. It is one of the stronger softwoods, as may be seen from Table 9, and an excellent all round board material. It is essential that care is taken in storage as this species is susceptible to blue stain.
- b) Lodgepole pine. Planted to some extent in Wales and Scotland, it is similar in strength to European redwood (see 2.1.3.2).
- c) Maritime pine. Planted to a limited extent in Southern England. When dried to 20 % moisture content, it falls halfway between the UK spruces and imported maritime pine in bending strength.
- d) Scots pine. Widely planted in the Eastern half of Britain. It should be noted that the same species, when imported from Scandinavia and the USSR, is known as European redwood. The different geographical origins cause a variation in the texture, density, number and size of knots resulting, amongst other features, in the British grown timber, when dried, having greater resistance to indentation and cleavage. Other mechanical properties are similar to those of the imported timber.

2.1.2.1.2 *Spruces*

Spruces are the lightest of the main packaging timbers listed and second only to the pines in the volume used for packaging. Spruces tend to be lighter in colour and less resinous than the pines and knots tend to be small, tight and concentrated in nodes.

a) Norway spruce. Widely planted throughout the UK, it has the advantage of a good stiffness to weight ratio. The British grown wood is generally lower in strength properties than that of the same species imported from Scandinavia, which is known as whitewood (see 2.1.3.2).

b) Sitka spruce. The most widely planted species in the UK, it is often used where light weight is essential, having a good strength to weight ratio. Knots tend to be small. The timber grown in Eire tends to be slightly higher in density and average strength but is not available in the same volume as the British grown timber.

2.1.2.1.3 *Other conifers*

This group includes the strongest softwoods which tend to be used for specialist purposes rather than for general use.

a) Douglas fir. Widely planted in the British Isles and the strongest and stiffest of the UK softwoods listed. Some splitting may be experienced when nailed but increasing the distances of the nail from the edge, or the use of a smaller diameter nail, may reduce this to acceptable levels.

b) Larch. Three varieties are available throughout Britain (see Table 1), although European larch is less likely to be encountered. The larches are stronger in bending and harder and tougher than most softwoods. Splitting may be troublesome where nails are driven near the edge of boards, but this may be reduced by the same means indicated for Douglas fir.

Table 1 lists the density values of the British grown softwoods described in 2.1.2.1.

2.1.2.2 *Hardwoods*

These vary in colour, strength, weight and other properties and include the strongest UK timbers. There is only a low volume used in packaging except for specialized functions, largely due to limited availability, higher cost, and the fact that some species are difficult to nail. In general, UK hardwoods are used in distance blocking and heavy duty skidwork where high compression or scuffing strength is required. Hardwoods are frequently supplied in the green (undried) and therefore weaker state and users should make allowances for this.

a) Aspen. [See item h).]

b) Ash and Beech. Possessing excellent strength properties, these species are well suited for top quality box and case members. One problem that may arise is the crippling of longer nails where hand-driving is undertaken. Another is that the difference between radial and tangential shrinkage is greater than in most other species and this can lead to greater distortion after drying.

c) Birch. A species with high strength properties very similar to oak, although availability is limited and dependent on locality. Some difficulties may arise due to splitting but pre-boring or the use of pointless or reduced diameter nails may be advantageous.

d) Elm. A difficult timber to work, but with exceptional nail holding properties. When available, the timber is ideal for distance blocking or for short lengths. The elms are typically some 30 % weaker than oak in bending, but considerably better than softwoods with regard to nail holding.

e) Horse-chestnut. A soft, easily worked timber with strength characteristics similar to those of softwoods. This species should not be confused with sweet chestnut which is an acidic timber, liable to corrode steel fastenings, and not recommended for packaging.

f) Oak. This species occurs throughout Britain, mainly in the South and the Midlands. It is difficult to nail, and pre-boring or the use of pointless nails may be necessary. The timber is acidic and will promote corrosion of steel fastenings in damp conditions. It is often thought of as being much stronger than softwoods, but the difference in bending strength is quite small.

g) Plane. Of limited availability, the better quality timber being used for decorative work. It has high resistance to cleavage and indentation; other strength properties are similar to those of pines.

h) Poplar. A number of species/cultivars have been planted chiefly in the Severn Valley, Kent and Eastern England. The five types (including aspen) most suitable for packaging (see Table 2) have not all, so far, been subjected to strength tests. There are a very large number of poplar cultivars which have been developed in Europe (see 2.1.3) and the USA, and many, particularly those grown in Southern Europe, have rather weak timber. Poplars have a clean white colour, good strength to weight ratios and are resistant to abrasion. Care should be taken to minimize the effects of shrinkage and distortion on drying.

i) Willow. Strength properties in general are similar to poplar, but the species may be suitable for blocks where bending strength is unimportant. Crack willow can suffer from splitting during conversion and nailing, the white willow being superior to this respect.

Table 2 lists the density values of the British grown hardwoods described in 2.1.2.2.

Table 1 — Density values of British grown softwoods suitable for packaging

Standard name	Other names	Botanical name	Density ^a
			kg/m ³
fir, Douglas	Columbian pine ^b Oregon pine ^b	<i>Pseudotsuga menziesii</i>	530
larch, Dunkeld	hybrid larch	<i>Larix × eurolepis</i>	530
larch, European	—	<i>Larix decidua</i>	590
larch, Japanese	—	<i>Larix kaempferi</i>	560
pine, Corsican	—	<i>Pinus nigra maritima</i>	520
pine, lodgepole	contorta pine	<i>Pinus contorta</i>	470
pine, maritime	Portuguese pine ^b	<i>Pinus pinaster</i>	530
pine, Scots	red deal European redwood ^b Baltic redwood ^b	<i>Pinus sylvestris</i>	520
spruce, Norway	white deal European whitewood ^b	<i>Picea abies</i>	420
spruce, Sitka	silver spruce	<i>Picea sitchensis</i>	400

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

^b This species is also imported under this name.

2.1.3 European grown species

2.1.3.1 General

This category also includes those species grown in the USSR which are widely imported into Europe. The most important species are described in 2.1.3.2 and 2.1.3.3.

2.1.3.2 Softwoods

The following softwoods are used for packaging purposes.

- Whitewood. Widely imported from Scandinavia and the USSR for the construction, joinery and packaging industries. It has good working properties and a high stiffness to weight ratio. One of the lightest of the species used in packaging, the timber will vary in strength according to its geographic origin, the more northerly grown timber tending to be stronger due to its slower growth. Commonly known as European whitewood/European or Norway spruce.
- Maritime pine. An important UK packaging species extensively imported from Portugal where the plantation grown timber tends to be heavier and generally stronger than that grown in Britain although strength will vary widely with plantation location. The good all round properties and availability in volume explain its large share of the UK market. It has a tendency towards large knots and knot clusters which can reduce strength. The species has outstanding nail holding properties.
- Redwood. Widely distributed in Europe and Northern Asia and an important packaging species in the UK. It is commonly known as European redwood. The sapwood band is creamy white to yellow in colour, narrow in northern growing areas, but becoming wider in southerly areas. The heartwood is pale yellowish brown to red brown, resinous and usually distinct from the sapwood. The timber is easily worked and takes nails well, although resin can be a problem. When grown in the UK it is customary to refer to this species as Scots pine [see 2.1.2.1.1 d)].

d) Douglas fir. [See 2.1.2.1.3 a).]

e) Larch. [See 2.1.2.1.3 b).]

f) Norway spruce. [See 2.1.2.1.2 a) and 2.1.3.2 a).]

Table 3 lists the density values of the European grown softwoods described in 2.1.3.2.

Table 2 — Density values of British grown hardwoods suitable for limited uses

Standard name	Other names	Botanical name	Density ^a
			kg/m ³
ash, European	English ash	<i>Fraxinus excelsior</i>	710
aspen, European	English aspen	<i>Populus tremula</i>	450
beech, European	English beech	<i>Fagus sylvatica</i>	690
	Slavonian beech		
birch, European	English birch silver birch	<i>Betula spp.</i>	670
chestnut, European horse-	—	<i>Aesculus hippocastanum</i>	520
elm, Dutch	—	<i>Ulmus × hollandica</i>	580
elm, English	—	<i>Ulmus procera</i>	560
oak, European	English oak	<i>Quercus spp.</i>	720
plane, European	English plane lacewood	<i>Platanus spp.</i>	640
poplar, black	robusta	<i>Populus × euramericana</i> “robusta”	450
	European black poplar black	<i>Populus nigra</i>	
	Italian poplar ^b	<i>Populus × euramericana</i> “serotina”	
poplar grey	—	<i>Populus canescens</i>	480
poplar, white	abele	<i>Populus alba</i>	450
willow, white	—	<i>Salix alba</i>	450
	crack willow	<i>Salix fragilis</i>	

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

^b This species is also imported under this name.

Table 3 — Density values of European grown softwoods suitable for packaging

Standard name	Origin	Other names	Botanical name	Density ^a
				kg/m ³
fir, Douglas	widely distributed in UK and Europe	Columbian pine, Oregon pine	<i>Pseudotsuga menziesii</i>	530
fir, silver	Central and Southern Europe	European silver pine	<i>Abies alba</i>	480
larch, Dunkeld	widely distributed	hybrid larch	<i>Larix × eurolepis</i>	530
larch, European	widely distributed	—	<i>Larix decidua</i>	590
larch, Japanese	widely distributed	—	<i>Larix kaempferi</i>	560
pine, Corsican	UK and Southern Europe	—	<i>Pinus nigra maritima</i>	520
pine, lodgepole	Europe	contorta pine	<i>Pinus contorta</i>	470
pine, maritime	France, Portugal, Greece	Portuguese pine	<i>Pinus pinaster</i>	530
redwood	USSR, Finland, Sweden, Poland, UK	European redwood, red deal, Baltic redwood	<i>Pinus sylvestris</i>	520
whitewood	USSR, Finland, Sweden, Poland, UK	European spruce, white deal, Norway spruce	<i>Picea abies</i>	450

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

2.1.3.3 Hardwoods

The following hardwoods are used for packaging purposes.

a) Poplar. Six main types including aspen are found in Europe, but the most common commercial species are the black Italian poplar and, when plantation grown, the hybrid *Populus × euramericana*.

For their low weight, poplar timbers are relatively strong and tough, but whilst the species traditionally seen in the UK, the black Italian poplar, falls between maritime pine and spruce in strength, the faster grown Southern European hybrids are weaker than spruce. Density or specific gravity is always a good measure of strength and it has to be noted that poplar from Turkey, as generally imported for packaging, has the lowest density of all the species likely to be used in British case making. Poplars of the *Populus × euramericana* hybrids imported from Turkey may be up to 35 % weaker than Portuguese maritime pine, or up to 20 % weaker than Sitka spruce. These values are based upon breaking strength in the well-dried condition. Turkish poplar is likely to take nails well and its rather woolly nature means that it would be less likely to splinter than the spruces.

The poplar hybrids dry rapidly, but tend to retain moisture in pockets. There is also a tendency for some knots to split.

b) Elm and horse-chestnut. [See 2.1.2.2 d) and e).]

c) Beech. Southern and Mid-European beech is a very strong timber with properties similar to UK grown beech. There may be a slight reduction in density, reducing strength by a small amount.

Table 4 lists the density values of European hardwoods.

2.1.4 North American grown species

2.1.4.1 General

Timber from Canada and the USA is widely used for packaging in the UK. The timber in Canada and Alaska is predominantly coniferous, with approximately 90 % softwood and 10 % temperate hardwood; while that in the USA is approximately 70 % softwood and 30 % temperate hardwood.

North America does not use the European appearance grades for quality and, to assist selection, Table 11 includes broadly equivalent packaging grades. The main softwood species imported into the UK for packaging are described in 2.1.4.2. (Table 5 also includes other species for reference purposes, although they are not as widely used.)

Table 4 — Density values of European grown hardwoods suitable for limited uses

Standard name	Origin	Other names	Botanical name	Density ^a
aspen, European	Europe	poplar, balsam poplar	<i>Populus tremula</i>	kg/m ³ 450
beech, European	Northern and Central Europe	Slavonian beech	<i>Fagus sylvatica</i>	690
chestnut, European	Europe to Western Asia	horse-chestnut	<i>Aesculus hippocastanum</i>	520
elm, Dutch	UK, Europe	—	<i>Ulmus × hollandica</i>	580
poplar, black	France, Belgium, Turkey	robusta	<i>Populus × euramericana</i> “robusta” <i>Populus nigra</i>	450
	UK, Europe	black Italian poplar	<i>Populus × euramericana</i> “serotina”	450
poplar, grey	Europe	—	<i>Populus canescens</i>	480
poplar, hybrid (Turkish) ^b	Southern Europe, Turkey	euramericana	<i>Populus euramericana</i>	370

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

^b Not given as a standard name in BS 7359.

Table 5 — Density values of North American grown softwoods suitable for packaging

Standard name	Origin	Other names	Botanical name	Density ^a
				kg/m ³
fir, alpine	Western Canada, Western USA	mountain fir	<i>Abies lasiocarpa</i>	370
fir, amabilis	Western Canada, Western USA	Pacific silver fir	<i>Abies amabilis</i>	420
fir, balsam	widely distributed	balsam	<i>Abies balsamea</i>	400
fir, grand	Western Canada, Western USA	lowland fir	<i>Abies grandis</i>	450
fir, noble	Western Canada, Western USA	—	<i>Abies procera</i>	420
hemlock, eastern	Eastern Canada, Eastern USA	white hemlock	<i>Tsuga canadensis</i>	470
hemlock, western	Alaska to North-western USA	Pacific hemlock, British Columbia hemlock	<i>Tsuga heterophylla</i>	500
larch, tamarack	Canada and Northern USA	eastern larch	<i>Larix laricina</i>	580
pine, jack	Canada	princess pine	<i>Pinus banksiana</i>	500
pine, lodgepole	Western Canada, Western USA	contorta pine	<i>Pinus contorta</i>	470
pine, ponderosa	Western Canada, Western USA	Californian white pine, western yellow pine, British Columbian soft pine	<i>Pinus ponderosa</i>	480
pine, southern	Southern USA	loblolly pine	<i>Pinus taeda</i>	670
		shortleaf pine	<i>Pinus echinata</i>	
		longleaf pine	<i>Pinus palustris</i>	
		slash pine, yellow pine	<i>Pinus elliottii</i>	
pine, sugar	US Pacific coast	Californian sugar pine	<i>Pinus lambertiana</i>	430
pine, western white	North-western USA	Idaho white pine	<i>Pinus monticola</i>	450
pine, yellow	Eastern Canada, Eastern USA	eastern white pine, northern pine	<i>Pinus strobus</i>	420
spruce, black	Canada	water spruce, eastern Canadian spruce	<i>Picea mariana</i>	480
spruce, Engelmann	mountain regions	mountain spruce	<i>Picea engelmannii</i>	450
spruce, red	Canada	yellow spruce	<i>Picea rubens</i>	450
spruce, Sitka	Western coastal areas	silver spruce, tideland spruce, menzies spruce	<i>Picea sitchensis</i>	450
spruce, white	widely distributed	eastern Canadian spruce	<i>Picea glauca</i>	420

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

2.1.4.2 Softwoods

The following softwoods are used for packaging purposes.

a) Balsam fir. The timber is very similar to spruce in colour and general appearance, but is coarser and less lustrous. There is practically no difference in colour between sapwood and heartwood, but the ends of logs usually show a wide sapwood band and a darker core, although this is not really noticeable once the log is converted. The wood is fairly light in weight, softer than spruce and the timber is easily worked and takes nails well.

b) Jack pine. A timber of the hard-pine class, with a sapwood about 40 mm wide, yellowish in colour and a heartwood varying in colour from pale to reddish brown. It is not unlike European redwood (*Pinus sylvestris*) in appearance, but is more resinous and coarser in texture. It has similar strength to European redwood and Portuguese maritime pine (see Table 9).

c) Black spruce. A slow-growing tree, also known as swamp or water spruce, comparatively small, sometimes no more than 12 m high. It is similar to white spruce in appearance, but heavier, harder and stronger.

d) Douglas fir. A strong timber with similar properties to the same species grown in the UK.

e) Hemlock. Western hemlock is similar to European redwood in strength, but can suffer from splitting when nailed. Eastern hemlock has a tendency to warp and twist during drying and is considerably less strong than western hemlock.

f) White spruce. The wood is almost white to pale yellowish brown in colour, closely resembling a European whitewood. It is straight-grained, lustrous and slightly resinous. The wood weighs approximately 420 kg/m³ when dried, but, since a proportion of other species may be included in shipments, this weight is conservative and the average weight could be a little higher. It takes nails well. The timber is generally marketed as Canadian spruce and, while the bulk of shipments contain mostly timber of *Picea glauca*, they may contain some red spruce, black spruce and balsam fir.

g) Red spruce. Similar to white spruce in appearance, but the prominent late wood bands give a more sharply defined annual growth ring and greater density.

NOTE Strength values in accordance with BS 373 are not available for inclusion in Table 9.

h) Southern pine. A commercial mixture of four species from the southern states of the USA as listed in Table 5, also called southern yellow pine. Each species varies individually from a medium to a high strength.

Table 5 lists the density values of North American softwoods.

2.1.4.3 Hardwoods

These are occasionally imported and are suitable for shorter lengths and blockwork. Only the main species are described.

a) Ash. Black ash is the primary packaging species amongst the ashes. It has good all round strength properties.

b) Birch. Its characteristics are not dissimilar to ash, but paper birch (as packaging grades commonly are) is somewhat weaker. It takes nails well.

c) Maple. For packaging, the variety exported is usually soft or silver maple. Its strength is similar to that of many average softwoods. It is easily worked, but slow drying.

NOTE Soft (or silver) maple is not the maple variety referred to under the EEC plant health controls in Table 25.

d) Poplar. It has low strength properties, but is easily nailed. It is of low density and may distort during drying.

Table 6 lists the density values of North American hardwoods.

2.1.5 Other sources and newly introduced species

In timber terms, the commercial introduction of a species within the last ten years still qualifies for the term “new species”. There are frequently little practical or test data available on such timbers. The reference to other sources encompasses long established sources such as South-east Asia. It should also be noted that several of the North American species in 2.1.4 could also qualify as new species entries.

a) Kapur/keruing. Imported from South-east Asia, these are among the strongest of the species included in this standard. Their availability may be limited because of competition from other end uses. Some resin exudation may occur with keruing, whilst kapur may promote corrosion of fastenings due to its slightly acidic nature. The different species of keruing vary in strength and the lowest value for this species was used in preparing the figures given in Table 10.

b) Mengkulang. Imported from South-east Asia, this species has a strength slightly better than that of beech, but is easier to nail. It is one of the strongest species available for specialized packaging and is useful where high strength is required.

Table 6 — Density values of North American grown hardwoods suitable for limited uses

Standard name	Other names	Botanical name	Density ^a
ash, American	Black ash, brown ash, red ash, Canadian ash	<i>Fraxinus nigra</i> <i>Fraxinus pennsylvanica</i> <i>Fraxinus americana</i>	kg/m ³ 560 to 670
birch	American birch, white birch, yellow birch, paper birch	<i>Betula</i> spp.	610 to 710
maple	Soft maple, silver maple, red maple, Oregon maple, Pacific maple (boxelder)	<i>Acer</i> spp. <i>Acer saccharinum</i> <i>Acer rubrum</i> <i>Acer macrophyllum</i>	550 to 630
poplar	balm poplar, balsam poplar, black poplar, tacamahac poplar, Canadian poplar	(<i>Acer negundo</i>) <i>Populus balsamifera</i> <i>Populus grandidentata</i>	(less than 550) 460

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

c) Radiata pine. This species is the backbone of the southern hemisphere softwood industry, although it is not native to those parts. It is indigenous to only a small area around Monterey in the state of California, USA, where it is also known as insignis or Monterey pine and where it is a relatively unimportant species.

Although the species is insignificant in North America, in that many other species are healthier and yield much greater volumes of commercial softwood, its habit of growth in the southern hemisphere is quite outstanding. Its relatively recent introduction to the UK as a packaging species is due to large volumes now being available from the southern hemisphere. In New Zealand it is in its second or third commercial rotation on the North Island. The tree out-performs every other species with regard to growth on almost every southern hemisphere site and consequently has been heavily planted in Chile, South Africa, Australia and New Zealand.

d) Elliottis pine. *Pinus elliottii* is one of the heavier and stronger of the four species comprising southern yellow pine as commercially grouped and exported by the USA. It is commonly known as slash pine or longleaf pine in the USA. It is included in this section to cover Brazilian elliottis pine. When grown in Brazil the species is normally plantation grown and, since it grows faster in Brazil than in the USA, it would be expected to be weaker and the existing USA strength data would probably not be relevant.

Table 7 lists density values of newly introduced species and timbers from other sources.

2.1.6 Special considerations

2.1.6.1 Chemical treatments

Timber is frequently chemically treated to avoid decay or insect attack (see clause 6).

2.1.6.2 Acidic timbers encouraging corrosion

Contact between metal fastenings (particularly steel) and certain species is likely to encourage early corrosion even in the absence of excessive moisture (see 5.4.2).

2.1.6.3 Nasal or skin irritants

Although dust problems are particularly associated with certain species, airborne wood dust can cause irritation due purely to its physical characteristics. This is a basic problem which should be dealt with in the same way as a problem from dust arising from any material.

Where irritation occurs due to a particular species, it has been shown that, in many instances, it is related to specific chemical constituents in the wood. The response of an individual to a particular irritant species depends entirely on that individual. One person may be temporarily totally incapacitated and others may be completely unaffected.

Table 7 — Density values for timber from other sources and for newly introduced species

Standard name	Origin	Other names	Botanical name	Density ^a
				kg/m ³
fir, silver	Central and Southern Europe	European silver pine	<i>Abies alba</i>	480
kapur	South-east Asia, Sabah	—	<i>Dryobalanops</i> spp.	770
keruing	South-east Asia, Malaysia	—	<i>Dipterocarpus</i> spp.	760
mengkulang	South-east Asia, Malaysia	—	<i>Heritiera</i> spp.	730
pine, Austrian	Central Europe	Bosnian pitch pine	<i>Pinus nigra</i> var <i>nigra</i>	800
pine, elliotii	Brazil	pitch pine, longleaf pitch pine, yellow pine, slash pine	<i>Pinus elliotii</i>	—
pine, maritime	France	—	<i>Pinus pinaster</i>	—
pine, radiata	Chile, New Zealand South Africa, Kenya	insignis pine, Monterey pine	<i>Pinus radiata</i>	480

^a Density values are averages for the species air dried to 15 % to 20 % moisture content.

It is usually within a tree's heartwood that the wood extracts giving rise to colour and scent are found and it is with certain particular combinations of these compounds that the irritant chemicals are found. Even within a species, these irritants will vary in their intensity from tree to tree.

Table 8 lists species known to cause problems to those machining them. It deliberately includes certain species not included in the packaging species described earlier since, quite frequently, non-packaging timbers are used for cleats, rubbing strips or other hard wearing items in the construction of packaging, while plywoods imported into the UK may contain veneers of these species. The table is not intended to be definitive.

Table 8 — Some irritant timber species

Standard name	Severity of irritation
African mahogany guarea makoré mansonia western red cedar	Well established as a skin or nasal irritant
abura afrormosia ayan dahoma keruing peroba rosa rosewood teak	Occasionally irritant
African celtis agba avodiré Central American cedar haldu idigbo missanda obeche	Possibly irritant

2.2 Strength of sawn wood and factors affecting strength

2.2.1 General

Manufacturers and specifiers of wood packaging need to use a quality system for their sawn timber purchases. This is because both the aesthetics and the strength of wood play a part in producing acceptable packaging. There are three factors involved: basic strength of a species, visual appearance grading and strength grading. Strength grading may be by visual or mechanical means.

2.2.2 Basic strength

2.2.2.1 General

Unlike timber for building purposes, typical sizes of packaging timber cannot be purchased in guaranteed minimum strengths. This is not to say that a great deal of data does not exist with regard to the strength of packaging timber and relevant data is listed in Table 9 and Table 10. However, the tables should be used with some care since the values of bending strength are not working stresses but the mean of the average breaking strengths, which means that, at best, 50 % of a given species will be weaker than the listed values, at worst (and in fact in almost every practical usage of the timber), the average strength will be substantially less than that given.

Table 9 — Strength properties of clear^a softwoods (see note)

Standard name	Origin	Botanical name	Moisture content		
			green	20 %	12 %
			Mean bending strength		
			N/mm ²	N/mm ²	N/mm ²
fir, balsam	Canada	<i>Abies balsamea</i>	43	53.1	74.5
fir, Douglas	Canada	<i>Pseudotsuga menziesii</i>	54	66.6	93
fir, Douglas	UK	<i>Pseudotsuga menziesii</i>	53.1	65.3	91
fir, silver	Central and Southern Europe	<i>Abies alba</i>	41	52.2	77
fir, silver	UK	<i>Abies alba</i>	43	54.3	79
hemlock, western	Alaska to North-western USA	<i>Tsuga heterophylla</i>	52	66.1	97
larch, Dunkeld	UK	<i>Larix × eurolepis</i>	43	55.3	82.6
larch, European	UK	<i>Larix decidua</i>	53	66.7	96.3
larch, Japanese	UK	<i>Larix kaempferi</i>	48	60	85.6
pine, Corsican	UK	<i>Pinus nigra maritima</i>	41	53.3	81
pine, jack	Eastern Canada	<i>Pinus banksiana</i>	45	57.4	84.7
pine, lodgepole	UK	<i>Pinus contorta</i>	41	54.3	85
pine, maritime	Portugal	<i>Pinus pinaster</i>	47.4	59.8	86.8
pine, maritime	UK	<i>Pinus pinaster</i>	36	48.2	77
pine, radiata	Chile	<i>Pinus radiata</i>	38.1	49	73.2
pine, radiata	Kenya	<i>Pinus radiata</i>	41	54.3	85
pine, radiata	New Zealand	<i>Pinus radiata</i>	38	53.3	91.6
pine, Scots	UK	<i>Pinus sylvestris</i>	46.2	59.4	88.9
pine, yellow	Canada	<i>Pinus strobus</i>	42	53.8	80
redwood	USSR, Finland, Sweden, Poland	<i>Pinus sylvestris</i>	44	57.1	86.5
spruce, black	Eastern Canada	<i>Picea mariana</i>	38	48.1	70
spruce, Norway	UK, Eire	<i>Picea abies</i>	36	46.7	71
spruce, Sitka	Canada	<i>Picea sitchensis</i>	39	49.9	74
spruce, Sitka	UK, Eire	<i>Picea sitchensis</i>	35	44.9	67
spruce, white	Eastern Canada	<i>Picea glauca</i>	36	40.8	49.7
whitewood	USSR, Finland, Sweden, Poland	<i>Picea abies</i>	39	51.3	79.5

NOTE This table is primarily intended for comparison between species and not for design purposes.

^a "Clear" signifies that data is obtained from small specimens of knot free, straight grained timber tested in accordance with BS 373. Commercial timber is not likely to be clear and therefore will be weaker than the values given.

Table 10 — Strength properties of clear^a hardwoods (see note)

Standard name	Origin	Botanical name	Mean bending strength		Compression strength
			Moisture contents		
			green	20 %	green
			N/mm ²	N/mm ²	N/mm ²
ash, European	UK	<i>Fraxinus excelsior</i>	66	82	27
beech, European	UK, Northern and Central Europe	<i>Fagus sylvatica</i>	65	81.8	28
elm, Dutch	UK, Europe	<i>Ulmus</i> × <i>hollandica</i>	44	53.7	19
elm, English	UK	<i>Ulmus procera</i>	40	49.1	19
kapur	Sabah	<i>Dryobalanops</i> spp.	81	92.4	41
keruing	Malaysia, Sabah	<i>Dipterocarpus</i> spp.	70	83.3	35
mengkulang	Malaysia, Sabah	<i>Heritiera</i> spp.	81	91.8	40
oak, European	UK	<i>Quercus petraea</i>	59	71.4	28
plane, European	UK	<i>Platanus</i> × <i>hybrida</i>	54	—	24
poplar, Italian black ^b	UK, Europe	<i>Populus</i> × <i>euramericana</i>	41	50.9	19
poplar, grey	Europe	<i>Populus canescens</i>	44	54.3	20
poplar, Turkish ^b	Southern Europe	<i>Populus euramericana</i>	32	39	—
willow, white	UK	<i>Salix alba</i>	36	44.6	15

NOTE This table is primarily intended for comparison between species and not for design purposes.

^a “Clear” signifies that data is obtained from small specimens of knot free, fine, straight grained timber tested in accordance with BS 373. Commercial timber is not likely to be clear and therefore will be weaker than the values given.

^b Not given as a standard name in BS 7359.

The values listed¹⁾ have been arrived at through carefully conducted tests to the most appropriate standard, BS 373, and represent the best available data.

Table 9 and Table 10 should not be used for basic case and crate design unless safety factors are introduced. Such factors would typically allow for the weakening incidence of knots, wane, excessive spring wood and slope of grain.

The main use of Table 9 and Table 10 is to make valid comparisons between species so that a case manufacturer or specifier can evaluate a species and determine whether special allowances or extra thicknesses are needed due to it possibly being weaker than a tried and tested species.

2.2.2.2 Softwoods

Two sets of bending strength values are given in Table 9: the green (see note) or fresh cut strength, which applies to most British and Portuguese grown softwood upon assembly; and the 20 % strength, a strength which applies to some imported species, such as European redwood or Canadian white spruce because of their drier state upon import to the UK.

NOTE Green moisture content is normally taken as a level of above 28 % (fibre saturation point), the point at which a further increase of moisture does not affect wood strength.

After a period in use, most packing case softwood will dry to 20 % moisture level and comparisons are more realistically made at this level. Where values for timber tested to BS 373 are not available, species have not been included in Table 9.

¹⁾ The values listed are mainly taken from “The Strength Properties of Timber”, produced by the Princes Risborough Laboratory of the Building Research Establishment and available from the Department of the Environment, Building Research Establishment, Garston, Watford, Herts WD6 2EL.

2.2.2.3 *Hardwoods*

Hardwoods tend not to be used in UK packaging where bending strength is of paramount importance, but are often used in situations where compression strength, abrasion resistance and nail holding strength are of greater importance (blocks, short bearers etc.) and, accordingly, compression strength is additionally listed in Table 10. The bending strength of packaging grades of hardwoods is, in reality, far less than given in column 4 since the wood qualities sold into the packaging market normally have a large proportion of grain slope, knots and wane. Details of the effects these naturally occurring features have upon sawn wood strength are given in BS 4978.

Hardwoods dry more slowly than softwoods and are normally used in thicker sections. Consequently they remain nearer to the green strength values for much of the lifetime of a typical case and only the green strength values are relevant (see Table 10).

NOTE This may not apply to Far Eastern hardwoods which are imported in a drier state.

2.2.3 *Appearance grading*

Unlike the more modern stress (strength) grading, the system of appearance grading has its roots in the last century yet still flourishes in the sale of commercial timber today. The system of appearance grading is not concerned with strength, but, as its name implies, with outward appearance. For selection of packaging grades of timber, with the exception of very large cases and crates, there is no alternative, since the stress grading system does not extend down to small sizes (the minimum is 35 mm thick). It should be noted that appearance grades are not necessarily inferior to stress grades, e.g. redwood sold as "Scandinavian 5th appearance grade" may well be both stronger and more attractive in appearance than redwood sold as "SC1 stress grade" (see 2.2.4 and Table 12).

Many species are not covered by the system but where an accepted visual appearance grading system exists, Table 11 gives the approximately equivalent grade numbers. There is no internationally recognized scheme for appearance grading but several countries have their own grading schemes which align approximately as shown in columns 3 and 4 of Table 11.

2.2.4 *Strength grading*

Strength grading, or stress grading as it is more commonly known, is an official strength grading system backed by extensive laboratory research and by BS 4978. In many building applications its use is mandatory. The system guarantees a minimum strength in each individual piece of timber that carries a quality stamp. The stamp carries information as to the strength class and a prime advantage of the new strength class system is that purchasers can specify by strength regardless of species. There are two methods of stress grading: visual (by qualified technicians) and machine (by computer controlled non-destructive test machines).

The grades used in the visual and the machine systems are given in Table 12; they relate to safe working stresses and are identical for both visual and machine grades. Since stress grading offers low strength grades as well as extremely high ones, the manufacturer/designer of large cases should be aware which species and grades are appropriate. Table 12 gives those grades suitable for heavy packaging when coupled with appropriate sections and lengths. As indicated in Table 13, SC1 is the weakest grade available, but is, nevertheless, perfectly adequate for most packaging applications, including heavy cases, provided adequate sections are used.

Unlike visual appearance grading, there has been a degree of international harmonization between countries operating visual and machine stress grading systems, hence Table 12 is able to show European Commission for Europe (ECE) grades and North American grades at appropriate points. By showing these in addition to British Standard grades, all commercially available species are covered.

Table 11 — Equivalent appearance grades of wood for packaging

Name	Country of origin	Acceptable packaging grade	Higher packaging grade
Douglas fir-larch	Canada	No. 3 common	No. 2
hem-fir	Canada	No. 3 common	No. 2
redwood	USSR, Sweden, Finland, Poland	Russian 5th Scandinavian 6th	Russian 4th Scandinavian 5th
spruce-pine-fir ^a	Canada	No. 3 common	No. 2
whitewood	USSR, Sweden, Finland, Poland	Russian 5th Scandinavian 6th	Russian 4th Scandinavian 5th

^a Spruce-pine-fir imported from Canada comprises the four major species mixed at random (balsam, fir, jack pine, black and white spruce).

Table 12 — Softwoods for packaging purposes available stress graded (showing equivalent grades)

Species	Origin	Equivalent gradings to strength classes (SC) in BS 5268-2			
		SC1	SC2	SC3	SC4
Corsican pine	UK		GS	M50	SS
Douglas fir-larch	USA/Canada	No. 3		GS, S6, No. 1, No. 2	SS, S8, Sel.
hem-fir	USA	No. 3		GS, S6, No. 1, No. 2	SS, S8, Sel.
larch	UK			GS, S6	SS, S8
redwood	Europe			GS, M50, S6	SS, S8
Scots pine	UK			GS, M50, S6	SS, S8
southern pine	USA			GS, SS, No. 1, No. 2, No. 3	SS, S8
spruce, Norway	UK	GS, S6	SS, M50, S8	M75	
spruce-pine-fir	Canada	No. 3		GS, M50, S6, No. 1, No. 2	
spruce, Sitka	UK	GS, S6	SS, M50, S8	M75	
whitewood	Europe			GS, M50, S6	SS, S8
whitewood, western	USA	GS, No. 3	No. 1, No. 2	SS, S8, Sel.	

NOTE 1 Strength classes (SC) are derived from BS 5268-2. For packaging purposes SC1, SC2 or SC3 are usually adequate.

NOTE 2 Visual grades GS and SS (identical to machine grades MGS and MSS) together with machine grades M50 and M75 are those designated in BS 4978.

NOTE 3 Grades S6 and S8 of the ECE "Recommended standard for stress grading of coniferous sawn timber" (1982) are equivalent to grades GS and SS respectively.

NOTE 4 Grades No. 1, No. 2, No. 3 and Select Structural (Sel.) are designated in the rules of the National Lumber Grading Association (NLGA) of Canada and in the National Grading Rules for Softwood Dimension Lumber (NGRDL).

The strength classes have particular maximum stress values assigned to them which are given in Table 13. However, the short life and short term loads applicable to packaging can reasonably permit considerably greater stresses in the timber in use and, for this reason, a packing case stress column has been entered to give designers a guide to typical factors of safety in the industry. Naturally a designer will have to look at the consequences of failure in a case before deciding to reduce the basic stress limits of Table 13. For an appreciation of factors of safety applying to packing case working stresses, the mean bending strength of individual species should be compared with Table 9.

2.3 Basic sizes of sawn softwoods and hardwoods

2.3.1 General

As outlined in 2.1, the UK imports timber from many parts of the world in addition to producing its own. This results in a wide choice of species available to the user but, since there is as yet no effective international standardization of sizing, it also results in a relatively wide range of basic sizes. For example, European softwoods are cut to metric sizes whereas North American softwoods are cut and marketed in imperial units. The UK timber trade adopted metric units in the 1970s and in practice North American sizes are rounded off to the nearest millimetre. Canadian timber is imported both as sawn sections and also as surfaced (planed) pieces.

BS 4471 covers the sizes of softwoods available from supplying countries with details of acceptable tolerances and further machining which may be carried out for particular end uses.

Although some logs are still available “in the round” most hardwoods are now imported as sawn sections, cut to specific thicknesses. BS 5450 defines parcels of hardwood as consisting of three product groups:

- a) specified widths, square edged;
- b) random widths, square edged;
- c) random widths, waney edged.

Both British Standards quote the moisture content on which the sizes are based and describe how actual sizes at other moisture contents can be estimated since timber is a hygroscopic material and its width and thickness will vary with changes in moisture content.

Table 13 — Working stress limits for large size stress graded packaging timber

Strength class to BS 5268-2	Green stress	Stress at 20 % moisture content	Packing case working stress
	N/mm ²	N/mm ²	N/mm ²
SC1	2.3	2.8	5.6
SC2	3.3	4.1	8.2
SC3 (S6) ^a	4.3	5.3	10.6
SC4 (S8) ^a	6.0	7.5	15.0

^a ECE grades.

Table 14 — Basic cross-sectional sizes of sawn softwood

Thickness mm	Width (mm)								
	75	100	125	150	175	200	225	250	300
16	×	×	×	×					
19	×	×	×	×					
22	×	×	×	×	×	×	×		
25	×	×	×	×	×	×	×	×	×
32	×	×	×	×	×	×	×	×	×
36	×	×	×	×					
38	×	×	×	×	×	×	×	×	×
44	×	×	×	×	×	×	×	×	×
47	×	×	×	×	×	×	×	×	×
50	×	×	×	×	×	×	×	×	×
63		×	×	×	×	×	×		
75		×	×	×	×	×	×	×	×
100		×		×		×	×	×	×
150				×		×			×
200						×			
250								×	
300									×

NOTE 1 Certain sizes may not be obtainable in the range of species and grades which are generally available.

NOTE 2 × = available.

2.3.2 Softwood

Details of the basic dimensions of sawn softwood are given in Table 14 and Table 15.

In addition, surfaced (planed) softwoods are imported from Canada and the USA known as CLS (Canadian Lumber Standards) or ALS (American Lumber Standards) respectively.

BS 5268-2 gives geometrical properties and sizes of surfaced softwoods of North American origin. Details of those sizes that are generally available are given in Table 16.

Table 15 — Basic lengths of sawn softwood (in m)

1.80	2.10	3.00	4.20	5.10	6.00	7.20
	2.40	3.30	4.50	5.40	6.30	
	2.70	3.60	4.80	5.70	6.60	
		3.90			6.90	

NOTE Lengths of 6.00 m and over may not be generally available.

Table 16 — Sizes of surfaced North American (CLS or ALS) softwoods

Thickness	Width
mm	mm
38	63
38	89
38	114
38	140
38	184
38	235
38	285

NOTE CLS or ALS surfaced softwood has rounded arises not exceeding 3 mm radius.

Table 17 — Basic cross-sectional sizes for sawn hardwoods (from BS 5450:1977) based on a moisture content of 15 %

Thickness	Width (mm)										
	50	63	75	100	125	150	175	200	225	250	300
mm											
19			×	×	×	×	×				
25	×	×	×	×	×	×	×	×	×	×	×
32			×	×	×	×	×	×	×	×	×
38			×	×	×	×	×	×	×	×	×
50				×	×	×	×	×	×	×	×
63						×	×	×	×	×	×
75						×	×	×	×	×	×
100						×	×	×	×	×	×

NOTE × = available.

CLS or ALS softwood of sizes given in Table 16 is surfaced on four sides (S4S). It should comply with either of the following standards:

- CSA 0141-1970 (Canadian Standards Association), approved by the Canadian Lumber Standards Accreditation Board; or
- NBS PS 20-70 (National Bureau of Standards), approved by the American Lumber Standards Board of Review.

2.3.3 Hardwood

Methods of measurement of hardwoods are given in BS 5450 and can be more complex than measurement of softwood. Most hardwoods are imported in specific thicknesses but random widths which are within an agreed and accepted range. They may also be imported as cut-to-size dimension stock or as logs sawn through and through and cut to size on order. Through and through sawing results in planks of uniform thickness which may be tapered along their length with waney edges.

Table 17 gives information on basic cross-sectional sizes for sawn hardwoods and Table 18 lists permissible deviations on basic widths.

**Table 18 — Permissible deviations on
hardwood basic widths (from BS 5450:1977)**

Basic size	Minus deviation	Plus deviation
mm	mm	mm
Under 25	1	3
25 to 75	2	6
76 to 125	3	9
126 to 300	4	12

3 Plywood suitable for packaging use

3.1 General

Plywood is an ideal packaging material limited only by its higher cost than sawn wood of the same thickness. It usually has superior performance under arduous conditions whilst retaining comparatively high strength/low weight properties.

Plywood is usually manufactured to the national standard of the country of origin. In certain countries where standards do not exist, standards such as the British, US or German plywood standard may be adopted by exporting countries as an aid to their production and marketing. Plywood for packaging has, typically, 3, 4, 5 or 7 plies; the larger the number of plies, the higher the quality and the lower the chance of distortion due to moisture, or high load (see 3.3) which can occur in packaging applications.

During manufacture, synthetic resin adhesive is applied by roller spreaders, sprayers or coaters and the veneers are assembled with the grain of each at 90° to the adjacent veneer. In certain circumstances this practice of bonding at right angles is varied to produce a plywood with special characteristics.

The resultant assembly is known as a lay-up which is then subjected to pressure and heat. After cooling, the panels are trimmed, usually to 2 400 mm × 1 200 mm, although other sizes such as 2 440 mm × 1 220 mm and 1 525 mm × 1 525 mm are available from certain countries.

The international harmonization of plywood specifications has made extremely slow progress over the years and even now a comprehensive International Standard does not exist. This is largely due to plywood's complex mixture of variables including:

- a) adhesive type;
- b) veneer type;
- c) thickness and grade of veneer;
- d) veneer lay-up;
- e) surface finish;
- f) overall panel thickness.

For packaging applications this lack of standardization has had less effect than in industries such as the building industry which is particularly demanding. The critical three variables in packaging are:

- 1) adhesive type (moisture resistance);
- 2) veneer species (avoidance of surface decay);
- 3) overall panel thickness (strength).

3.2 Plywood adhesives

3.2.1 General

The type of adhesive used in plywood manufacture is critical if satisfactory end use is to result. Problems which occasionally arise with delamination and loss of integrity are almost entirely due to either:

- a) lack of knowledge on the part of the purchaser, through the unknowing selection of an interior grade when cases are to be stored externally; or
- b) the purchase of plywood from an unreliable source which may not be subject to adequate quality control (the result may be an inadequate quantity of adhesive or the use of an interior grade of adhesive with no warning of lack of moisture resistance).

Whatever the origin of plywood, buyers in the Northern European countries often assess the performance of imported plywoods against their own national standards and this is likely to continue until there is a universally applied International Standard for plywood manufacture.

3.2.2 Adhesive classification

3.2.2.1 General

The two main types of plywood available are urea formaldehyde bonded and phenol formaldehyde bonded, although the latter predominates for packaging purposes where enhanced moisture resistance is required.

3.2.2.2 Urea formaldehyde (UF) bonded

This type of bond is used in moisture resistant (MR) or interior type (INT) plywood. Moisture resistant plywoods will survive full exposure to weather for limited periods only. They will withstand cold water for a long period and hot water for a limited time, but fail when exposed to boiling water. Interior plywood is required to be strong and durable in dry conditions and to be resistant to cold water.

3.2.2.3 Phenol formaldehyde (PF) bonded

This type of bond is used in weather and boil proof (WBP in UK terminology) and Exterior or Exposure 1 (North American terminology) type plywoods. Such bonds are required to be highly resistant to weather, micro-organisms, cold and boiling water (an accelerated laboratory weather test) and both wet and dry heat.

3.2.2.4 Melamine urea formaldehyde (MUF) bonded

A third type of adhesive, urea formaldehyde fortified with melamine and known as MUF, is used in some types of plywood manufactured in the Far East. Bonds are more resistant to moisture and weather than UF, but not as resistant as PF. It is sometimes conveniently designated CBR or cyclic boil resistant, which is a grade slightly below WBP.

Different countries have different designations for the adhesive classes; these may be marked on the face of the plywood and a guide is given to plywood grade equivalence in Table 19.

Plywood can either be described by reference to the national standard (as in Table 19) or more quickly and conveniently by the commercially used description. Table 20 lists plywoods commonly used for packaging.

3.3 Plywood grade and thickness

The typically short life and lack of need for aesthetics in packing case design means that short term strength and water resistance are the main criteria for design.

For most plywoods the visual quality of plywood veneers are characterized by letter designations, e.g. CD Exterior has one side veneer of a higher quality (C) than the other side (D). For wood packaging applications, veneer appearance of C or D is adequate for most purchasers.

NOTE Grade A indicates no knots, grading through B, BB, C, CC to D which means large open knots. BB/CC indicates a BB grade veneer on one side and a CC grade on the other.

Of particular relevance to export packers is the type of adhesive used (see 3.2.2) and whether the veneer characteristics restrict external exposure to weather. The fact that plywood has an Exterior (USA), WBP (UK), X (France), EXT 1 (Netherlands) or AW 100 (Germany) bond does not mean that it is suitable for unprotected exterior exposure in its asreceived state. The timber veneers of plywood needs to be durable in addition to being adequately bonded and, with thinner grades of plywood, the imbalance caused when the outer veneer becomes saturated (thereby expanding) and the inner veneer remains dry can cause an outward bowing of sheathing if not tied at sufficient centres to maintain rigidity.

3.4 Veneer species

Although the life of a packaging case is rarely sufficient to consider the length of time after which a perishable softwood starts to degrade, there are certain types of degradation which look unattractive, namely surface moulds and stains. Certain hardwood plywoods may be particularly badly affected and moulds may occur within a few weeks in adverse conditions of high humidity.

Table 19 — Comparison of adhesive designations for assessing imported plywood

Country	Standard	Outside climate		Inside climate		
UK	BS 6566	WBP	CBR	MR	INT	—
Belgium		72-100	04-100	03-67	24-15	—
Netherlands	NEN 3278	EXT 1	EXT 2	INT 1	INT 2	INT 3
Germany		AW 100	A 100	IW 67	IF 20	—
France ^a		CTB X	CTB Y	CTB 0	Interior	—
Canada	CSA 0121-M CSA 0151-M	Exterior	—	—	—	—
USA	PS 1-83	Exterior	Exposure 1	Interior	—	—
USA ^b	PS 51-71	Type I	—	Type II	Type III	—
South Korea		WBP	Type I	Type II	Type III	—
Japan		—	Type I	Type II	Type III	—

^a The designations are taken from a publication produced by the Centre Technique du Bois et d'Ameublement.
^b Also applicable to South Korean plywood imported into the UK.

Table 20 — Commercial plywoods for packaging

Type	Face marking and/or veneer grade	Origin	Adhesive classification (see 3.2.2)	Popular commercial classification ^a	Average density	Intended exposure
Beech faced	BB	Romania	MR	Romanian beech	kg/m ² 670	short term
Birch faced	WG	Finland	WBP	Finnish birch-faced	670	long term
Birch	C	USSR	MR	Russian birch	670	short term
Softwood	Regular sheathing	Canada	Exterior	CSP sheathing	430/530	long term
Far Eastern mixed	BB/CC	South-east Asia	WBP	—	400/770	long term
Far Eastern mixed	BB/CC	South-east Asia	Type I	—	400/770	medium
Far Eastern mixed	BB/CC	South-east Asia	MR	—	400/770	short term
Gaboon	B/BB	France, Israel	WBP	—	430	medium
Spruce	CPC, CPD, CC	Sweden	WBP	—	420	long term
Spruce	III, IV	Finland	WBP	—	420	long term
Softwood	CX/CY	USSR	WBP	Russian softwood CX	420	long term
Southern pine	CC Exterior	USA	Exterior	USA CCX	550	long term
Southern pine	CD Exp. 1	USA	Exposure 1	USA CDX	550	medium
Douglas fir	CC Exterior	USA	Exterior	USA CCX	550	long term

^a Not always strictly correct terminology, but widely used in the industry.

4 Other wood based products used in packaging

4.1 General

A growing interest in using timber waste as economically as possible led to the development of sheet materials of a lower cost than plywood. Fibreboard (fibre building board) was introduced towards the beginning of the century and wood chipboard became a possibility when synthetic resins were developed after the Second World War. These products resulted in less and less waste from each log taken from the forests. Waferboards are a more recent introduction; they use larger wood chips and less resin, and are lighter than other sheet materials of comparable volume. Although these products use wood as the raw material, unlike sawn wood their quality can be controlled.

4.2 Wood chipboard

Wood chipboard is particleboard made exclusively from small particles of wood together with a binder, the particles being larger than in fibreboard and the binder normally being synthetic resin. Boards are available from 3 mm to 50 mm thick and may be of uniform construction through their thickness, of graded density, or of distinct 3- or 5-layer construction to give enhanced bending strength properties without excessive weight.

Wood chipboard has progressively superseded blockboard and laminboard and uses wood wastes, including forest thinnings, planer shavings and other joinery shop residue. The product is not as demanding in terms of raw materials and skilled labour as plywood, and wood chipboard mills are now located in most countries of the world.

Production involves taking wood apart mechanically and reconstituting it using adhesives. The production process is highly automated and most woody parts of a tree are usable. The final stage is a pressure/heat cycle to cure the adhesive in the board.

There are alternative processes to the above where boards are formed by extrusion of the particle/resin mix through a heated die. The particles lie with their longer dimension at right angles to the direction of board extrusion. A further development has been the Mende process used to produce a continuous ribbon of very thin chipboard, typically 3 mm or 4 mm thick.

Wood chipboard in sheet form has a low strength to weight ratio and is difficult to nail due to a combination of high density (500 kg/m³ to 700 kg/m³) and thickness (12 mm to 20 mm) in excess of most fibreboard or plywood. The thinner boards are easier to work, but have low impact resistance.

Recent developments have encouraged the use of processed wood for moulded blocks. Their performance equals that of most sawn softwoods in terms of fastener retention but exceeds it in terms of dimensional stability under changing humidity.

Typically the wood chips and cutter shavings are mixed with a glue-wax suspension during manufacture and this mixture is placed in a mould which is then pressed under high pressure and heated to cure. Moulded chipboard distance blocks provide pallet-based case manufacturers with an alternative method of production with more uniform quality. The extremely small dimensional variations facilitate automatic feeding of blocks where this operation is important.

4.3 Flakeboard

4.3.1 General

There are basically two types of flakeboard: waferboard and orientated strandboard.

4.3.2 Waferboard

Waferboard is a flakeboard made of specially prepared flakes, predominantly from small particles of wood, and a binder. It is normally made from wood wafers or flakes at least 32 mm in length, randomly orientated.

4.3.3 Orientated strandboard (OSB)

OSB is a 3-layer flakeboard in which the grain of the flakes in each of the layers is aligned, the orientation in the centre layer being across the board, while the grain of the flakes in the surface layers lies parallel to the long axis of the board. The description orientated structural board is also used for this material.

The method of producing waferboard and orientated strandboard is essentially that used to produce wood chipboard but with significant differences, for example only small roundwood logs are used, and the use of wood waste is not possible.

The logs have their bark removed, are cut to length and then put into a waferizer which reduces them to wafers (waferboard) or strands (OSB) and the wafers or strands are dried in a tumble drier. After drying to a moisture content of between 3 % and 8 %, the majority of fine particles are removed from the finish. The dry wafers or strands are stored to await further processing and blended with phenol formaldehyde (PF) adhesive with a proportion of either paraffin slack wax or wax emulsion. A waferboard mat is then formed by random distribution of wafers. The mat-forming section of an OSB production line orients the strands of the first layer mainly in one direction. The second layer is then oriented at right angles to the first, and so on. It is the orientation process which gives the panel properties more akin to plywood.

Flakeboards should be seen as comparable with, or replacements for, plywood, since their properties and handling qualities are more akin to those of plywood rather than fibreboard or wood chipboard.

Waferboards are of greater interest to the packing case maker because they tend to be light and easier to nail.

4.4 Fibreboard (fibre building board)

Fibreboard, more correctly termed fibre building board (see BS 1142), is defined as sheet material, usually over 1.5 mm thick, made from fibres of ligno-cellulosic material. It is sold as hardboard, medium board and softboard (insulating board). Table 21 provides information on the characteristics of the different grades.

During the 1920s and early 1930s, further techniques were developed to break solid wood down into fibres and reconstitute these under heat and pressure as a strong and durable panel: hardboard. The wet process is the most common technique for manufacturing hardboard, medium board and softboard.

Certain packaging applications make use of fibreboard where moisture resistance is not critical. Particular applications are fruit and vegetable trays strengthened by wood battens. Hardboard and medium board, which are produced between 3 mm and 12 mm thick, are the most suitable for packaging applications.

NOTE In packaging, the term “fibreboard” is also used to refer to cases made of solid or corrugated fibreboard. Solid fibreboard is made from recycled paper and typically is less than 2.5 mm in thickness, while corrugated fibreboard consists of one or more sheets of fluted paper (fluting) glued to two or more liners.

Table 21 — Fibre building board grades

Product	Grade	Thickness	Density
Hardboard Hardboard	standard moisture resistant (tempered) TE, TN	mm 3 to 6	kg/m ³ 800
		3 to 12	960
Medium board	high density	8 to 12	560 to 900

Both solid and corrugated fibreboard may be used in conjunction with wood in some packaging applications and care should be taken to clarify the actual material required. BS 1133-7.5 gives guidance on solid and corrugated fibreboard cases and fitments.

5 Moisture in wood and the avoidance of problems in storage and use

5.1 Sawn wood

Before wood is stored or used to construct boxes or cases, it is usually necessary to remove a portion of the water it contains. The reason for drying timber prior to storage is that wood of many species will decay if kept at a high moisture content for long periods. At high moisture contents certain species, particularly some pines, cannot safely be stored even for a few days in the close piling that is normal in packaging timber yards. Susceptible species may develop unsightly moulds (light surface growths which can be brushed off) or sapstain/bluestain, which penetrates throughout the sapwood causing permanent staining, if one of the following is not carried out:

- stacking with thin spacers between each board or batten to allow free passage of air and dispersal of humidity until the timber is at, or below, 20 % moisture content when close piling under cover creates no risk;
- kiln drying to 20 % moisture content and storing under cover;
- immersing in fungicidal solutions which provide short term protection from sapstain and mould in order that the timber can safely be close piled at high moisture contents for a limited period for maximum space utilization.

Below about 20 % moisture content, known as the decay safety line, timber is generally safe from such discoloration or damage.

It is essential that timber be dried to a level appropriate to its end use and that all sheet materials are stored in such a way that moisture ingress is minimal. Wood, provided that it is at 20 % moisture content or below, may be close piled only if adequate protection from rain is available and then the wood will not suffer significant changes in moisture content. However, softwoods and permeable hardwoods of very low moisture content will take up moisture more quickly than the less permeable hardwoods so that storage and temporary exposure to weather should be adjusted accordingly.

Water is a chemical constituent of timber, not just a contaminant or a carry-over from the water-conducting function in the tree. A proportion of the water in wet wood (up to 30 %) is chemically bound in varying degrees to the wood fibres. Living trees and freshly felled sawn timber can contain much more water than this (up to some 200 % of free water). The moisture content figure can be over 100 % because the mass of water is expressed as a percentage of the dry mass of the wood.

Percentage moisture content = $\frac{\text{mass of wet wood} - \text{mass of dried wood}}{\text{mass of dry wood}} \times 100$

Thus a piece of wet wood, the mass of which is made up of half dry wood and half moisture, would have a moisture content of 100 %.

The abbreviation “emc”, which stands for equilibrium moisture content, occurs frequently in relation to timber being dried and timber in service. Wood is hygroscopic, that is, its moisture will change to levels which are related to the temperature and humidity of the surrounding air. An emc value is the moisture content which a piece of timber will achieve when exposed for a long period to air at a particular relative humidity and temperature (although temperature has the lesser effect).

The approximate relationship between relative humidity (r.h.) and equilibrium moisture content (emc) of sawn wood is as given in Table 22.

Table 22 — Relationship between relative humidity (r.h.) and equilibrium moisture content (emc) in sawn wood

Relative humidity	Equilibrium moisture content
%	%
80	18
70	15
60	13
50	11
40	9
30	7.5

Much packaging timber is machined and assembled at a high moisture content, often at 30 % to 40 %, but, although it is easier to nail and often easier to machine at these high moisture contents, shrinkage will be more marked than if assembly had taken place at a more normal 20 %.

Water over and above the fibre saturation point level fills, or partially fills, the cavities of the wood fibres. Its removal during the drying of the wet wood reduces only the mass of the wood, not its dimensions. When the cell cavities are empty of water, but their walls are still holding water to their maximum capacity, the wood is said to be at fibre saturation point, fsp. For most common timbers, this point falls between 25 % and 30 % moisture content. Further drying below fsp will result in shrinkage as the fibre walls contract. This process happens in reverse if dried wood is put into a wet environment and absorbs water.

5.2 Plywood

Plywood uses identical species to sawn wood, yet, when subjected to moisture changes, plywood’s cross-laminated construction provides superior dimensional stability in the plane of the panel. The swelling or shrinkage of wood along the grain with changes in moisture content is small, being only about 1 % of that across the grain. In plywood, therefore, the tendency of individual veneers to swell or shrink crosswise is greatly restricted by the relative longitudinal stability of the adjacent plies (veneers). The vastly superior strength of wood along its grain can easily counteract the small forces set up by the wood across its grain due to moisture movement.

Moisture expansion of a plywood panel that is free to move consists of a uniform restrained swelling across the full width or length, and a less restrained swelling at the edges. Edge swelling is independent of panel size, varies with the thickness of veneers having grain perpendicular to the direction of expansion and, for the same veneer thickness, is about twice as great for face plies as for inner plies.

The appropriate relationship between relative humidity and equilibrium moisture content of sawn plywood is given in Table 23.

In package assembly, under UK conditions, relative humidity may vary between 30 % and 70 %, with corresponding moisture contents ranging from 6 % to 13 %. Total dimensional changes of a 1 200 mm × 2 400 mm standard plywood panel exposed to this change in conditions may be expected to average about 1 mm across the width and 2 mm along the length, showing substantial improvement upon the performance of sawn woods.

Table 23 — Relationship between relative humidity (r.h.) and equilibrium moisture content (emc) in sawn plywood

Relative humidity	Equilibrium moisture content
%	%
80	16
70	13
60	11
50	9
40	7
30	6

5.3 Measurement of moisture content

There are two methods of measuring moisture content in general use. The most common method, using a moisture meter, is an essentially non-destructive test which is based upon the fact that the electrical properties of timber vary with its moisture content. It is particularly appropriate for packaging work where high accuracy is not needed. A skilled user of such a meter can obtain results within 2 % of the true moisture content.

The most common and accurate moisture meters are of the electrical resistance type. These work on the principle that, as the moisture content of a piece of timber increases, its electrical resistance decreases; conversely, timber with a low moisture content has a high resistance. Conductivity is usually measured between two pin-like electrodes which are pushed or hammered into the timber to be tested. Corrections have to be applied with varying species to improve the accuracy of the results. The main advantage of a moisture meter is that it gives an instant reading which, although as an individual reading may not be highly accurate, can be repeated many times with little effort to give an overall picture of moisture content and its distribution. The portability of the instrument is also a major advantage and moisture meters have gained wide acceptance in determining moisture content during the processing, storage, transportation, installation and in-service checking of timber and timber products. The range over which the better meters are accurate is 9 % to 28 %, but this assumes that the meter is accurately calibrated initially.

NOTE The readings given by moisture meters are sometimes influenced by the presence of salts, such as those from waterborne preservatives, e.g. the very common copper chrome arsenate (CCA), and from contamination by sea water. Such salts increase the conductivity of the wood, particularly at higher moisture contents, and give falsely high readings of moisture content. The magnitude of this effect is variable and it is not usually possible to correct the readings. When the presence of such salts is suspected, higher than expected moisture readings should be examined further. The alternative oven method is often the only accurate substitute.

When measuring plywood with an electric meter, it should be regarded as a separate material and not treated merely as the timber species from which it is made. The moisture content readings obtained with a resistance-type meter on plywood are often misleading and they should not be regarded with confidence since the presence of soluble chemicals in the gluelines of certain types of plywood affect the reading obtained. The effect encountered with some varieties of exterior plywood can be particularly large. Resistance-type meters may, in extreme cases, indicate moisture values of approximately double those obtained by the more accurate oven drying methods.

The alternative method of measuring moisture content, the oven drying method, is destructive in that it involves taking the piece of timber (or a sample of it), weighing it to determine the mass of wood plus the water it contains, drying it again to obtain the dry mass and using the formula given in 5.1 to calculate the moisture content. This is the more precise method, but it is only necessary for packaging research work.