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TIMBER IN BOATBUILDING

Wood has always been a favourite building material for small craft and, despite the advent of new materials and the increasing difficulty of obtaining suitable long length, large end section durable timbers, it is still popular. The development of new timber products, improved adhesives, and new techniques has made boatbuilding by the amateur much more popular. In order to provide guidelines for timber selection, Standards Australia publish a Standard AS 1738-1975 *Timber for marine craft*.

Timber for planking, stringers, chines, and ribs should be selected for straightness of grain, low shrinkage, and freedom from defects. If the boat is to be seaworthy, very few defects can be tolerated in these particular parts so knots, shakes, decay, compression failures, and brittle heart must be carefully excluded. Tight gum veins, borer holes and surface checks will not cause trouble unless they are concentrated in a relatively small area. They can usually be satisfactorily caulked.

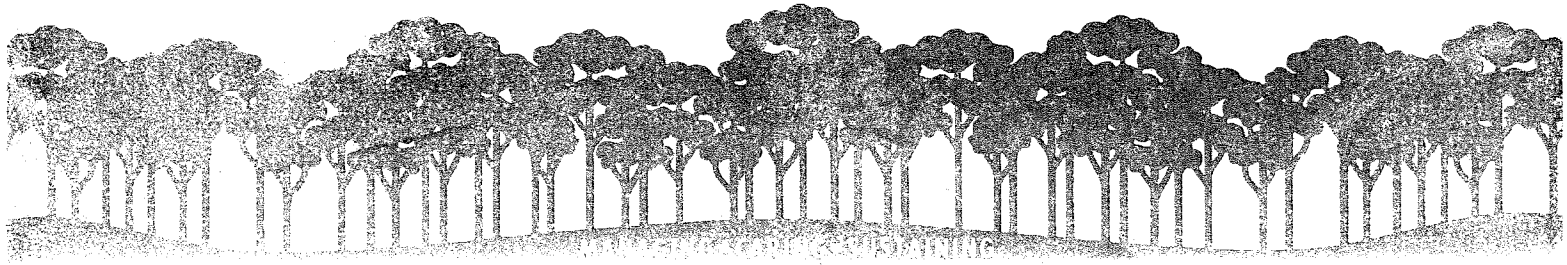
Unless the boat is to be of glued construction, or will be out of water for considerable periods, there is no need to use timber dried to 12% moisture content, except for interior fittings. However, because it shrinks while drying, timber for the upper parts and interior framing should have a moisture content of less than 20%, while those parts customarily submerged should not be less than 20%. Of course requirements such as these are usually much easier to specify than to observe because of the time normally required to build a boat. To minimise shrinkage during construction or when the boat is out of the water, all boards should be quarter sawn.

It is not always possible to build small craft entirely of durable timbers and, since the decay hazard in a boat kept on moorings is high, it is necessary to take precautions. Some preservative-treated plywood and timbers are available. Where such material is not obtainable, either from stock or on order, non-durable timbers should be liberally treated with a recognised preservative. Australian Standard 1604-1980 *Preservative treatment for sawn timber, veneers and plywood*, should be consulted for types of preservative and appropriate loadings.

The chief advantages of timber and plywood are:

- positive buoyancy;
- high strength in relation to weight;
- resilience and ability to withstand suddenly applied shock loads;
- ease of shaping, bending and finishing without the need for special equipment;
- good appearance;
- high durability when properly selected, installed and ventilated;
- ability, in many cases, to accept treatment with preservatives to give long-term durability under severe conditions and where ventilation is inadequate;
- ease of working without requiring closely controlled factory conditions in respect of temperature and humidity;
- resistance to abrasion;
- ability to be altered at relatively low cost.

Developments in plywood and adhesives have opened up a new field for constructing water craft. The main advantage of plywood is that it is flexibile and that it is obtainable in large sheets. Providing a marine grade plywood is used and correct methods of application are adopted, the plywood chine system is very successful. New methods, new materials and new forms of construction have been tried and adopted and there is still scope for progress in these fields of construction.



TIMBER FOR BOATBUILDING

Seasoning of timber

Generally, timber used in boatbuilding should not exceed 20% moisture content except when the craft is usually moored; then the planking below water line should be above 20%. Laminated masts and spars, as well as joinery, should be in the range of 10% to 15% moisture content.

The most accurate method of checking the moisture content of timber is by determining the loss of moisture when a weighed sample is completely dried in an oven using the technique described in Australian Standard 1080 Part 1, 1972 *Methods of test for timber - moisture content* and State Forests of New South Wales Technical Paper No. 41 *Methods of determining the moisture content of wood*. A faster, non-destructive but less accurate method is to use a battery operated moisture meter which, in the range below about 30%, is sufficiently accurate for boatbuilding purposes. This meter measures the resistance of the wood to an electric current and indicates its moisture content. The relationship between electrical resistance and moisture content is not the same for all timbers so it is necessary to apply species correction figures; they are given in State Forests' Technical Paper No. 41 referred to above. The electrodes fitted to meters are usually intended for the testing of nominal 25 mm thick stock. Thicker material can be tested by using a special hammer-probe with insulated 'needles' or probes.

Timber may be seasoned by air-drying or kiln drying, or by a combined process of air and kiln drying. For the drying process the timber must be stacked so that there is good air circulation around each piece in the stack. To obtain this circulation the timber must be spaced by placing 20-25 mm square strips between each layer of boards in the stack. These strips must be accurately placed in vertical lines so that the boards will not become distorted. It is recommended that drying stacks be covered to prevent the entry of rain and to minimise splitting or checking of the top layers of boards. Further information on drying procedures is given in Forestry Commission of New South Wales Technical Publication No. 9 *Seasoning of Timber*.

Timber contains free water (that inside the cells) and 'hygroscopic' or 'combined' water (that held in the cell walls). The free water will evaporate first at quite a rapid rate but the combined water will leave the wood much more slowly. When the combined water begins to leave the cell walls, the cells begin to change shape and shrinkage takes place. As the surface of the wood dries more quickly than the centre, shrinkage is not uniform and surface checking and end splitting may occur because of the development of stresses.

End splitting can be reduced by the use of a heavy bodied paint, bituminous paint or wax preparation brushed onto the end of each board to reduce the rate of moisture loss.

Method of ordering timber

The order should be placed in writing and a copy retained by the purchaser. It should state the seasoned condition required, e.g. 10-15% or 15-20% moisture, etc., and refer to the relevant quality description clause in Australian Standard 1738-1975 *Timber for marine craft*.

The order should also state the timber species required, the time and place of delivery and the purpose for which the timber is required so that the merchant can supply accordingly.

State Forests of New South Wales has a timber inspection service available which will, for a fee, check timber for compliance with your specifications. The inspector will grade the timber according to the relevant standards as laid down by Standards Australia or to any other grading rules acceptable to both buyer and seller. The inspector brands each piece and then issues a certificate of compliance. A list of timber inspectors' offices is given at the end of this publication.

Timber species

Because of the wide variety of marine craft it is not feasible to list individual species in order of preference as design considerations must be taken into account when selection is being made. It is presumed the designer will relate the known characteristics of strength, density, bending properties, permeability to preservative treatment and ability to take an adhesive bond when making a selection for a particular purpose.

Some of the more common species listed in Australian Standard 1738-1975 for the various boat parts are in Table 1. However, it must also be appreciated that because of restrictions applying to the harvesting of certain species not all the listed timbers will necessarily be available. Those likely to be obtainable are marked with an asterisk (*). However, not all species will be available from single suppliers and seasoned material may only be available in limited quantities and in certain species. Some unmarked species may also be available but usually only in very limited quantities from specialist suppliers.

Table 1. Some timbers suitable for use in boatbuilding.

Part	Timber	Strength group[a] Green	Strength group[a] Seasoned	Seasoned weight (kg/m^3)	Durability in marine craft[b]
Planking and bulkhead sheathing	Beech, white	S6	SD6	540	High
	* Blackbutt	S2	SD2	900	High
	Cedar, red	S7	SD8	420	High
	* Fir, Douglas	S5	SD5	550	Medium
	* Gum, spotted	S2	SD2	1100	High
	* Gum, Sydney blue	S3	SD3	850	Medium
	Kauri species	S7	SD8	460-540	Low to medium
	Maple, Queensland	S6	SD6	560	Medium
	* Meranti, dark red	S5	SD6	Must exceed-560	Medium
	* Messmate	S3	SD3	750	Medium
	Pine, celery top	S4	SD5	650	High
	* Pine, hoop	S6	SD5	550	Low
	Pine, huon	S6	SD6	540	High
	Pine, King William	S7	SD8	420	High
	Pine, klinki	S6	SD6	450	Low
	* Stringybark, yellow	S3	SD3	900	High
	* Tallowwood	S2	SD2	1000	High
Decking	Beech, white	S6	SD6	540	High
	Bollywood	S5	SD6	500	Medium
	* Gum, rose	S3	SD4	750	Medium
	* Gum, spotted	S2	SD2	1100	High
	* Gum, Sydney blue	S3	SD3	850	Medium
	Kauri species	S7	SD7	460-540	Low to medium
	Pine, celery top	S4	SD5	640	High
	* Pine, hoop	S6	SD5	550	Low
	Pine, huon	S6	SD6	540	High
	Pine, klinki	S6	SD6	450	Low
	* Pine, white cypress	S5	SD6	700	High
	* Stringybark, yellow	S3	SD3	900	High
	* Tallowwood	S2	SD2	1000	High
Steam bent timbers	Ash, silver	S4	SD5	670	Medium
	* Beech, myrtle	S4	SD5	700	Low
	* Brigalow	S1	SD1	1090	High
	* Gum, spotted	S2	SD2	1100	High
	Oak, tulip	S3	SD3	840	Medium
	Pine, celery top	S4	SD5	640	High
	Pine, huon	S6	SD6	540	High
	Quandong, silver	S5	SD6	460	Low
	Yellowwood	S4	SD3	750	Medium

Table 1. (cont.)

Part	Timber	Strength group[a]		Seasoned weight (kg/m^3)	Durability in marine craft[b]
		Green	Seasoned		
Sawn worked frames	* Blackbutt	S2	SD2	980	High
Floor frames	* Box, grey	S1	SD1	1120	High
Bulkhead frames	* Fir, Douglas	S5	SD5	550	Low
Engine beds	* Gum, grey	S1	SD2	1050	High
	* Gum, mountain grey	S3	SD2	900	High
	* Gum, rose	S3	SD4	750	Low to medium
	* Gum, spotted	S2	SD2	1100	High
	* Gum, Sydney blue	S3	SD3	850	Medium
	* Ironbark, grey	S1	SD1	1100	High
	* Messmate	S3	SD3	750	Medium
	Stringybark, brown	S3	SD3	850	Medium
	* Stringybark, white	S3	SD3	1000	High
	* Tallowwood	S2	SD2	1000	High
	Tea-tree, broad-leaved	S4	SD4	740	High
Straight stems	* Blackbutt	S2	SD2	900	High
Deadwoods	* Box, grey	S2	SD2	1120	High
Keels	* Gum, grey	S1	SD2	1050	High
Keelsons	* Gum, river red	S5	SD5	900	High
Stern posts					
Horn timbers	* Gum, spotted	S2	SD2	1100	High
	* Ironbark, grey	S1	SD1	1100	High
	Mahogany, red	S2	SD3	960	High
	* Mahogany, white	S2	SD3	1000	High
	* Stringybark, white	S3	SD3	1000	High
Stringers	Ash, silver	S4	SD5	670	Medium
Chines	* Blackbutt	S2	SD2	900	High
Gunwales	* Fir, Douglas	S5	SD5	550	Medium
Deck framing	* Gum, spotted	S2	SD2	1100	High
	* Gum, Sydney blue	S3	SD3	850	Medium
	Mahogany, red	S2	SD3	960	High
	* Mahogany, white	S2	SD3	1000	High
	Spruce, sitka	S7	SD6	430	Low
	* Stringybark, yellow	S3	SD3	900	High
	* Tallowwood	S2	SD2	1000	High
Mooring and towing bitts	* Box, grey	S2	SD2	1120	High
	* Gum, grey	S1	SD2	1050	High
	* Gum, spotted	S2	SD2	1100	High
	* Ironbark, grey	S1	SD1	1100	High
	* Mahogany, white	S2	SD3	1000	High
	* Tallowwood	S2	SD2	1000	High

Table 1. (cont.)

Part	Timber	Strength group[a] Green	Strength group[a] Seasoned	Seasoned weight (kg/m^3)	Durability in marine craft[b]
Masts	* Ash, alpine	S4	SD4	650	Low
Spars	Ash, silver	S4	SD5	670	Medium
Derricks	* Fir, Douglas	S5	SD5	550	Medium
	* Gum, spotted	S2	SD2	1100	High
	Maple, Queensland	S6	SD6	560	Medium
	Pine, klinki	S6	SD6	450	Low
	Quandong, silver	S5	SD6	460	Low
	Spruce, sitka	S7	SD6	430	Low
	* Stringybark, yellow	S3	SD3	900	High

a refers to *Strength groups* below
b refers to *Durability* p. 6.

Strength groups

Tables 2(i) and 2(ii) list basic minimum values for modulus of rupture, modulus of elasticity and maximum crushing strength for each strength group within clear green and seasoned timbers.

Table 2 (i). Basic minimum values for clear green timber.

Property	Strength groups S1	S2	S3	S4	S5	S6	S7
Modulus of rupture (MPa)	103	86	73	62	52	43	36
Modulus of elasticity (MPa)	16 300	14 200	12 400	10 700	9 100	7 900	6 900
Maximum crushing strength (MPa)	52	43	36	31	26	22	18

Table 2 (ii). Basic minimum values for clear seasoned (12% m.c.) timber.

Property	Strength groups SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
Modulus of rupture (MPa)	150	130	110	94	78	65	55	45
Modulus of elasticity (MPa)	21 500	18 500	16 000	14 000	12 500	10 500	9 100	7 900
Modulus of crushing strength (MPa)	80	70	61	54	47	41	36	30

Durability

The term 'durability' as used in Australian Standard 1738-1975: *Timber for marine craft*, refers to the natural resistance of non-preservative treated heartwood used in the most extreme conditions and in the most vulnerable applications existing in a craft kept continuously at mooring (Table 3).

Table 3. Durability of non-preservative treated heartwood under extreme conditions.

Rating	Description
High	Indicates that the heartwood should be satisfactory under the above conditions.
Medium and low	Species with such ratings should be treated with more caution and if amenable, preservative treated for rigorous conditions. Timbers of these ratings may be suitable without preservation when used in applications where durability is not particularly called for, as in craft which are usually stored on shore under cover.

All sapwood is non-durable but can be effectively treated against both fungal and insect attack if proper preservative treatment is carried out before its incorporation into the boat.

PLYWOOD FOR MARINE CRAFT

The decay hazard to which marine plywood is subjected will vary greatly depending on the use it is put to. It should be noted that a durable adhesive does not impart its qualities to the wood and cannot prevent its decay. The use of rot-proofed plywood should be considered if boats will be in the water for long periods.

Careful sealing of end grain or panel edges and the provision of good drainage together with good ventilation and the avoidance of damp pockets and excessively high humidities will help to keep decay hazard at a minimum.

In boat building it is often difficult to avoid a construction that will not lead to the growth of wood destroying fungi. In situations where water entry into the plywood cannot be entirely prevented, the use of permeable coatings or the omission of paint on the dry side will allow it to dry out. If decay hazards are relatively low these constructional techniques, combined with the use of suitable brush or spray preservatives, can give protection.

Plywood which has been completely impregnated with approved fixed preservatives in accordance with Australian Standard 1604-1980 *Preservative treatment for sawn timber, veneer and plywood* is very resistant to wood decay.

Scarf joints through the full thickness of sheets are permitted by agreement between the manufacturer and the purchaser. The slope of the bevel of the edges to be joined should be not less than the following:

For sheets under 13 mm in thickness, 1 in 10

For sheets 13 mm and over in thickness, 1 in 8.

Scarf joints should be bonded with an adhesive of quality and type at least equal in durability and strength to that used in the manufacture of the sheets.

Plywood sheets must be stored flat on a level bed, to prevent distortion, in a well-ventilated place and shaded from sunlight that will cause changes in colour, even if shining through windows.

Marine grade plywood should be used for the hull, decking, all stressed components, and any other exposed parts.

Some hints for plywood users

- Buy your plywood from a reputable, well-known dealer or manufacturer whose name depends on selling a quality product.
- All hull and deck cladding must be marine grade plywood - refer Australian Standard AS 2272-1979: *Marine plywood* (Extract is given in Table 4). Exterior plywood with Type A waterproof bond may be used for linings, cabinets, etc., not of primary structural importance - refer Australian Standard AS 2271-1979 *Plywood and blockboard for exterior use.*
- Sound, adequate interior framings are essential.
- A heavily built transom and hull-bracing are 'musts'. Outboard designs should feature a partitioned off motor well, rather than a low cut transom that may ship water in heavy seas.
- Check inside the hull to see that any exposed plywood edges are fully sealed against moisture.
- There is no need, however, for the superstructure to be too heavily built. In fact, lightweight construction helps lower the centre of gravity for improved stability and performance.

Table 4. Permissible timber species for use in marine plywood. (Reference: AS 2272-1979: *Marine plywood*)

Standard trade common name*	Botanical name
Agba	*Gossweilerodendron balsamiferum*
Alder, brown	*Ackama paniculata*
Alder, rose	*Ackama australiensis*
Ash, silver	*Flindersia schottiana* syn *F. pubescens*
Birch, white	*Schizomeria ovata*
Blackwood	*Acacia melanoxylon*
Canarium	*Canarium smithii*
Carabeen, yellow +	*Sloanea woollsii*
Cedar, pencil	*(Palaquium)* spp.
Coachwood	*Ceratopetalum apetalum*
Guarea	*Guarea thompsonii*
Kauri, Fijian	*Agathis vitiensis*
Mahogany, brush	*Geissois benthamii*
Mahogany, brush, northern	*Geissois biagiana*
Makore	*Tieghemella heckelii*
Maple, Queensland	*Flindersia brayleyana*
Maple, scented	*Flindersia laevicarpa var. laevicarpa*
Pine, celery-top	*Phyllocladus asplenifolius*
Pine, hoop	*Araucaria cunninghamii*
Pine, klinki	*Araucaria hunsteinii*
Sapele	*Entandophragma cylindricum*
Silkwood, bolly	*Cryptocarya oblata*
Silkwood, New Guinea	*Palaquium* spp.
Silkwood, red	*Palaquium galactoxylum*
Silkwood, silver	*Flindersia acuminata*
Sycamore, satin	*Ceratopetalum succirubrum*
Sycamore, silver	*Cryptocarya glaucescens*
Teak	*Tectona grandis*
Utile	*Entandophragma utile*
Oba suluk +	*Shorea pauciflora*
Sassafras +	*Doryphora sassafras*
Sassafras, southern +	*Atherosperma moschatum*
Taun +	*Pometia pinata*

* The standard trade common names are those given in AS2543-1983: *Nomenclature of Australian timbers*, or AS 1148-1971: *Nomenclature of commercial timbers imported into Australia*. Where there is no standard trade common name, common names have been used.

\+ These species are permitted for core veneers only.

Note: In general, a far wider range of species is available in plywoods than in solid timber members.

TYPE OF CONSTRUCTION FOR TIMBER BOATS

Strip plank construction

Strip plank construction involves the use of parallel strakes (planks of timber). Material costs are lower and wastage through cutting is less than for orthodox forms of construction. Strakes can be produced ready planed and spindled to size. The strip plank system gives a good appearance, has added strength and, because of the thickness, a good fastening system for deck or covering boards may be planned.

It is usual to spindle mould the strips with a round convex surface on the bottom edge and a corresponding radiused hollow in the top edge. This affords a larger gluing or bedding surface and enables moderate transverse hull curvature to be negotiated without the necessity of lifting plank bevels. Where the curvature is sharp, it is necessary to plane the inside faces of the strakes to fit the timbers and also to modify the concave or convex top and bottom edges so that they are in close contact when fitted.

In addition to edge fastening, the strips are usually bonded to each other with a waterproof adhesive which must be used in accordance with the manufacturer's instructions. These bonds must be kept under pressure while curing.

Serrated fastenings, driven into closely spaced pre-drilled holes as tight as the material will allow without splitting are suitable for this job. They can be obtained in various lengths and diameters and must be of non-ferrous metal.

With any glued-edge form of single skin construction, the problem arises of hull form distortion or frame breakage through stress exerted by the planking swelling when it is wet. To reduce this, material used for planking should not be of lower moisture content than the maximum allowed for satisfactory bonding by the chosen adhesive and the manufacturer's advice on this should be taken. Some boatbuilders prefer to use timber strips at 10 to 14% moisture content so that any increase in moisture content will cause swelling and corresponding compressive stresses in the sheathing which may be more acceptable than cracking due to shrinkage. This strip plank method of construction involves a large area of timber being bonded into one piece and such planking has been known to crack open as much as 3 mm.

Elastic seam-filling compounds may overcome the swelling stress problem where sheathing is used. These compounds may be used instead of other adhesives for underwater joints. The manufacturer's advice should be sought regarding the application of these compounds. Due to the necessity for edge fastenings, strip plank construction is only suitable for shell thicknesses of 12 mm and over. One difficulty in this system is the number of feathered edges that occur at the shear line. This can be overcome if a thicker and wider sheer strake is fitted and rebated out to cover and seal the feathered edges.

Plywood-chine construction

Plywood-chine construction can be used by amateur boat builders without difficulty. The design of a single chine craft can be prepared in such a way that all hull surfaces are conical projections. Conical projection hull surfaces are those designed around portions of cones and cylinders. The practice is that flat sheets (e.g. plywood) can be bent over a cone or a cylinder without double curvature. This means that there is no double curvature ('dishing') required in the plywood. If transverse frames are straight or concave between chines, particularly in the forward sections, that area is not of conical projection and extra work will be required to properly seat the flat plywood sheets onto the frames. One test for a conical projection surface is that it must be possible at any point to run a straight line that extends to the boundaries in any one direction; in the most direct method, frames are erected to hold the chines in place, the plywood bottom is fixed and finished flush with the chine, then the side plywood is added, capping the plywood of the bottom. A strip is then added at the chine to seal the end grain of the side plywood. Plywood decking is laid over the beams in the normal way. The frames can be left in as bulkheads, buoyancy compartments, etc.

Double chine and three-strake clinker constructions were developed to improve the performance of timber sailing dinghies and runabouts. Here a third flat sheet of plywood is added as a conical projection so that the sides are made up with more shape, but the principle is the same. On some craft a third sheet is added at the chine, as for clinker planking, giving a more curved effect to the midships section but adding very little to the difficulties of construction. The centre plank is relatively narrow compared with the upper and lower strakes.

Double or multi-diagonal planking

Double or multi-diagonal planking consists of two or more skins fastened at varying angles to each other. Synthetic resin glues make it possible for planking to be glued together on faces and edges to form a uniform construction, eliminating the use of oil fabric between the skins. Only gap filling adhesive should be used and sufficient pressure must be applied to ensure that the faces of the planking are held in contact until the bond cures.

Hot moulding by vacuum pressure

The hot-moulded veneer hull sprayed with polyester resin paint is said to require a minimal maintenance. A timber mould, mounted on a trolley with a flat metal plate top, is used to form the hull.

Leaves of veneer about 150 mm wide x 2.5 mm thick are layered over the mould. Wads or bundles of leaves are cut to templates and stored in racks ready to use. The first layer is put on dry and subsequent layers are glued, on one side only, by passing them through the rollers of a glue spreading machine. As the second and subsequent skins are applied the staples holding each previous skin are removed.

Stem, hogs, keels and transoms of preformed, laminated construction may be integrally moulded into the hull.

A rubber bag is then lowered over the hull and secured and a vacuum applied to stretch it tight. The whole assembly is wheeled into an autoclave where steam heat of over 100°C and 350 kilopascals of pressure are applied. After about half an hour the hull is removed and allowed to cool and is then ready for further construction work. This method is suitable for quantity production but involves considerable capital investment for tooling, jigs and autoclaves.

Cold moulded construction

This is a comparatively simple method of construction using temporary fastenings for applying pressure to the skins during setting of the adhesive.

The advantages of this method are:

- The mould is simple to construct as little pressure is required.
- Although it is an advantage to use a close planked mould, good hulls can be constructed by using stringers spaced at about 75 to 100 mm centres.
- Because of the simplicity of the mould, alterations to the shape and design of the hull are easily made.

Pressure to hold the skins together while the adhesive is setting is obtained by the temporary use of staples or panel pins. Since pressure is localised, the width of the strip to be glued must be limited to allow even distribution of the adhesive and dispersion of any air pockets between the panels. Although the width of the strips is largely controlled by the curvature required, it is recommended that they should not be more than 100 to 125 mm wide.

A fast setting combination of adhesive and hardener can be used as the closed assembly time required is comparatively short. Each skin, however, must be cleaned before the next skin is bonded to it.

In general, three skins of veneer are used but it is possible to use two skins of plywood or a combination of plywood and veneer. The thickness of the veneer ranges up to 2.5 mm and the plywood from 1.5 mm to 3 mm. Except in special instances, the final skin thickness should not be less than 6 mm.

The following recommendations are given for the laying of skins.

1. Using three skins, either:

   (a) Three layers of diagonal planking - the inner and outer skins laid in the same direction or,

   (b) The inner and outer skins laid diagonally and the middle skin fore and aft, or

   (c) The inner and middle skins laid diagonally and the outer skin fore and aft.

2. Using two skins, either:

   (a) Both diagonally laid, crossing at an angle of about 45°; with this construction the use of plywood only is recommended.

   (b) The inner skin laid diagonally and the outer skin fore and aft, the inner skin being plywood and the outer skin veneer.

Cold moulded construction using a bag for applying pressure by vacuum

For this method of construction:

- The mould must be more robust than the type used when pressure is applied only by temporary fastenings.

- The surface of the mould must be close planked.

In some instances wider strips can be used and the number of temporary fastenings can be reduced considerably as they are only required to hold the skins in position before final pressure is applied under vacuum.

Since the pressure is applied only after all the skins have been laid, it is necessary to use an adhesive with a reasonably long assembly time.

In either process, adhesives must conform to British Standard 1204, *Synthetic resin adhesives (phenolic and aminoplastic) for wood. Pt. 1 Gap-filling adhesives.* Refer to 'Adhesives' (p. 13) for further information on adhesives.

TIMBER BENDING

The principal considerations when bending timber are:

- Selection of suitable stock.
- Softening the timber.
- Reaction of the timber to the stresses arising from the bending process.
- Drying after bending so that the bent piece will retain its shape without failure.

Selection and preparation of suitable stock

Choose stock from a species known to have good bending properties and which, in addition, is straight-grained and free from failure producing defects such as knots, checks, shakes and brittle wood.

Brittle wood may be detected by digging into the surface with a sharp pointed instrument. A tough timber will yield a strong splinter which tends to run along the grain. If the timber is brittle, the splinters will be short and "carroty".

The timber should be reduced to the smallest possible size before bending and should be dressed all round. Saw marks on the surface of a piece of timber will assist failure and, therefore, should be removed by planing.

Too high a moisture content may cause crumpling on the compression side of the timber and will also make it more difficult to dry after bending. On the other hand, if the moisture content is too low more force will be required to make the bend, in which case the strapping must be very efficient if failure on the tension side of the curve is to be prevented.

It is generally considered that timber dried to a moisture content of 15-20% is best for bending but suitable moisture content for dense, hard, strong timbers can be in excess of 20%.

Softening

The most common method for softening timber before bending is to steam it. This is most frequently carried out at atmospheric pressure, although higher pressures are sometimes used.

For steaming at atmospheric pressure the usual time allowance is up to one hour per 25 mm of thickness. Steaming at 70 to 110 kilopascals reduces steaming time but the necessary equipment is more expensive and there is an inevitable loss of time while the pressure is released.

Steam chambers for steaming at atmospheric pressure can be made of wood, sheet metal, concrete, brick, or fibre cement sheeting, depending on the working life required. All chambers should be built so that condensed moisture can drain away. The steam chambers, if other than temporary, should be painted inside with a bituminous paint.

A simple steam chamber of a temporary nature could consist of a 20 litre can to boil the water, connected by a hose to a length of 75 mm (inside diameter) galvanised iron or fibre reinforced cement pipe. The wood to be bent is placed in the pipe and the exhaust end of the pipe is partially closed, to reduce the rate at which the steam can escape. The exhaust end of the steam chamber should be slightly lower than the inlet end, to drain the condensed moisture.

Drying after bending

The bent piece must be allowed to set and dry before it is used. Setting is usually completed by the time the timber has cooled to atmospheric temperature but drying will take much longer. Individual pieces should be supported and stacked so there is uniform circulation of air throughout the stack.