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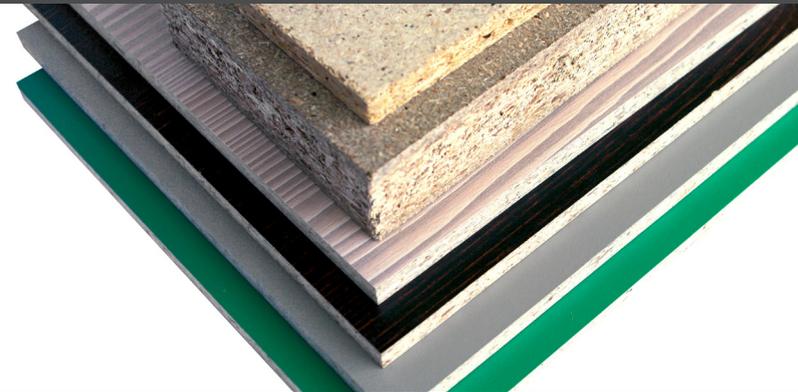


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WOOD  
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# Panel Guide

Version 4



## Annex 2D: Plywood

### Description

Plywood is a versatile product that can combine attractive surface appearance with superior performance under hazardous conditions while retaining comparatively high strength-to-weight ratios. It is available in a range of wood species, including hardwood and softwood species and combinations of the two, and a range of resin types for interior, high humidity and exterior conditions. It was developed to provide panels with dimensional stability and good strength both along and across the panel.

The term 'plywood' includes both the true 'veneer plywood' and also 'core plywood' of which 'blockboard' and 'laminboard' are examples. Typical examples of these products are shown in *Figure A2.4*.



**Figure A2.4** Various types of plywood

Veneer plywood, the official term for what is usually called plywood, is defined as plywood in which all the plies are made of wood veneers orientated with their plane parallel to the surface of the panel. In such products the direction of the grain in adjacent plies is normally at right angles, with the outer and inner plies placed symmetrically on each side of a central ply or core. However, as long as veneer plywood is 'balanced' about its centre line, plies may consist of two adjacent veneers bonded with their grain parallel. This structure usually results in plywood having higher mechanical properties in the direction parallel to the grain of the face veneer.

Core plywood, such as blockboard or laminboard, is an assembly of plies bonded together, some or all of which are wood, in the form of veneers, solid strips or battens. Materials other than wood may also be included in various forms to confer specialist properties or performance.

Plywood is produced with resin bonds which range from those suitable only for interior use to those which will withstand elevated levels of humidity in external exposure. Typical adhesives used are:

- urea-formaldehyde (UF)
- phenol-formaldehyde (PF)
- melamine-urea-formaldehyde (MUF).

Plywood is produced on a worldwide basis using a wide range of timber species including softwoods and temperate or tropical hardwoods. These species may be grown in natural forests or increasingly as part of regeneration or plantation forest management systems. Many different species can be used for plywood manufacture with the principal qualification criteria that the log can be reliably peeled or sliced into veneer. Softwood species commonly used include spruce, pine and fir. Hardwood species used include birch, beech, poplar and eucalyptus. The quality of the finished plywood depends both on the quality, species and lay-up of the veneers, as well as on the resin type and bonding quality.

Blockboard and laminboard are 'core plywood' having a core made up of strips of wood, each not more than 30mm wide, or strips of 'on-edge' veneer, laid separately and bonded or otherwise joined together to form a slab, to each face of which is bonded one or more veneers, with the direction of the grain of the core strips running at right angles to that of the adjacent veneers.

### Composition

#### Veneer plywood

Standard plywood veneer is produced using a lathe, which peels a log in a similar manner to a blade pencil sharpener, but with the blade parallel to the log. Most decorative veneer is sliced from flitches after the log is cut into quarters. Prior to peeling or slicing, the logs are normally soaked or steamed in order to increase the moisture content. This helps to produce a smoother veneer. The veneers are then dried to a moisture content of about 4%–8%. In some cases, small strips of veneer may be jointed into full-size sheets by edge gluing, stitching or using perforated paper adhesive tape. Open defects, such as knot holes, may be repaired using plugs or filler to upgrade the panel in accordance with grading rules. The dried, clipped or reconstituted veneers are sorted into grades, usually by visual inspection.

Synthetic resin adhesive is applied to the veneers by roller spreader, spray, extrusion or curtain coating and veneers are assembled with the grain of each normally at 90° to the adjacent veneer. Plywood with special characteristics is produced when this rule of bonding at right angles is not followed. The resultant assembly is known as a lay-up.

The main types of resin used for plywood manufacture are:

- Urea-formaldehyde (UF): panels made with this type of resin are normally only suitable for interior use.

Some panels may also be suitable for use in humid environments but not for use in exterior situations.

- Phenol-formaldehyde (PF): this type of resin produces bonds which have greater moisture resistance and therefore panels made with this type of resin are normally suitable for use in humid or in exterior situations. The durability of the veneer species must also be taken into account when selecting plywood for uses where it may be exposed to prolonged high moisture content (see *DD CEN/TS 1099 Plywood. Biological durability. Guidance for the assessment of plywood for use in different use classes*<sup>1</sup> for guidance on plywood durability).
- Melamine-urea-formaldehyde (MUF): this third type of adhesive, urea-formaldehyde fortified with melamine and known as 'MUF', is used in some types of plywood. Bonds traditionally tend to be between UF and PF in resistance to moisture/weather. However, resin technology is constantly evolving with some manufacturers able to make exterior or even marine plywood using a melamine-based adhesive.

The lay-ups are then subjected to pressure and heat in batches, most commonly in a multi-opening (multi-daylight) press. This results in a compressed and cured panel which, after cooling, is trimmed to size and, if necessary, sanded.

In some forms of plywood, particularly those from China, further face and back veneers may be added later in a separate processing operation. Such veneers are generally very thin in nature but will normally be of a high quality in order to retain their form and integrity. Because of their thin nature, the resins used to bond these outer veneers may be of a different type to those used to bond the main structure of the panel.

### **Core plywood (blockboard/laminboard)**

The technique of manufacturing blockboard and laminboard developed alongside the plywood industry from the turn of the last century. Blockboard uses strips of wood about 25mm wide for its core, while laminboard cores are composed of strips of veneer on edge (or occasionally strips cut from plywood). Plywood mills may introduce block or laminboard manufacturing facilities to use residues and to produce lower cost utility types of panels suitable for some interior purposes. The method of production is similar to that for plywood and the 'wet' stages of veneer manufacture are identical. The resins used to bond the plies are also potentially the same. However, as utility panels, most will use the lower cost UF resins and therefore such products are generally only suitable for interior applications.

## **Appearance**

### **Surface appearance**

The surface appearance of plywood depends upon the species and grade of veneer used for the surface layers. The classification of surface appearance is covered in the five parts of *BS EN 635 Plywood – Classification by surface appearance*, as follows:

- *BS EN 635-1 Plywood. Classification by surface appearance. General*<sup>2</sup>.
- *BS EN 635-2 Plywood. Classification by surface appearance. Hardwood*<sup>3</sup>.
- *BS EN 635-3 Plywood. Classification by surface appearance. Softwood*<sup>4</sup>.
- *DD CEN/TS 635-4 Plywood. Classification by surface appearance. Parameters of ability for finishing, guideline*<sup>5</sup>.
- *BS EN 635-5 Plywood. Classification by surface appearance. Methods for measuring and expressing characteristics and defects*<sup>6</sup>.

The characteristics listed in *BS EN 635-1, 2 & 3* include:

- knots
- splits
- insect holes
- bark and resin pockets
- decay
- veneer joints
- repairs
- edge defects.

Limits are set for five different grades of veneer, with the best grade 'E' being virtually clear of all defects. The limits vary between softwood (*BS EN 635-3*) and hardwood (*BS EN 635-2*), so care has to be taken to select the correct definition of the grades. The final colour of the panel is also affected by any finish applied and by the effects of weathering and ageing. These factors are also affected by the species of veneer used.

*DD CEN/TS 635-4* deals with parameters that affect the surface finishing/coating of plywood and includes factors such as:

- surface, eg sanded
- minimum appearance class
- thickness of face veneer
- defects in first inner ply
- bonding class.

Although the quality of veneer used in the manufacture of plywood will affect its mechanical properties, the veneer classes given in *BS EN 635* are intended only for use in determining the visual appearance of the panel. They are not intended to be used as a basis for defining a structural grade of plywood, as the inherent strength of the species being used will be a significant determining factor.

### **Edge appearance**

An examination of the edges of plywood panels can quickly distinguish between veneer plywood and core plywood. Veneer plywood will be seen to be constructed from a series of veneers laid with their plane parallel to the panel surface. In core plywood, the core material (solid strips or strips of veneer glued face to back and laid on edge) can normally be clearly seen beneath the surface veneers.

## Density, weight and sizes

The density of plywood is not normally controlled as part of the product specification but is a function of the species of timber used. Most construction plywood will have a density in the range of 400 kg/m<sup>3</sup> to 700 kg/m<sup>3</sup>. Thus a 2400mm × 1200mm × 12mm panel could typically weigh between 14kg and 24kg. However, as most plywood is manufactured from a single species or a limited range of species, the production from a particular manufacturer will fall within a defined density range and therefore reference should be made to the manufacturer's documentation or packaging for further information and handling data.

Some highly compressed, specialist plywood can have densities in excess of 1000 kg/m<sup>3</sup> and some may even be designed with 'bullet resistant' qualities.

Plywood is available to order in thicknesses ranging from 1.5mm to 40mm or greater but the most commonly available nominal thicknesses generally held in stock in the UK will be:

3mm, 4mm, 6mm, 9mm, 12mm, 15mm, 18mm, 22mm, 25mm, 32mm.

Common panel sizes are:

- 2440mm × 1220mm
- 2440mm × 610mm (normally T&G)
- 2500mm × 1220mm
- 3050mm × 1525mm
- 3050mm × 1220mm

Some specialist plywood products, for applications such as lorry sides, are available to order in much larger sizes of up to 14m × 3m. Some manufacturers and most importers or distributors will offer panel cutting services to meet the customer's specific needs.

The density range of blockboard/laminboard is not significantly different from that of plywood, the density being largely controlled by the species and form of the core material. Some panels with low density cores are available for applications where weight is critical. Panels are available in thicknesses ranging from about 10mm up to 30mm. Common sheet sizes are 2440mm × 1220mm and 3050mm × 1525mm.

## Applications

The range of species and bond qualities means that plywood can be engineered to have specific properties, making it suitable for a wide range of applications. It is the only wood-based panel with established design values that can be used in structural applications under external conditions in accordance with *BS EN 1995-1-1 Eurocode 5. Design of timber structures. General. Structural fire design*<sup>7</sup> or *BS 5268-2 Structural use of timber. Code of practice for permissible stress design, materials and workmanship*<sup>8</sup> (now withdrawn).

Some of the typical 'types' of plywood and their applications are listed below.

### Structural plywood

Plywood for use in construction must meet the requirements of the Construction Products Regulation (CPR). The most straightforward route to demonstrating this is by complying with the requirements of the harmonised standard for wood-based panels *BS EN 13986*, which in turn references *BS EN 636 Plywood. Specifications*<sup>9</sup>. See PanelGuide *Section 2* for further guidance on complying with the CPR.

For structural design in accordance with *BS EN 1995-1-1 (Eurocode 5)*, characteristic values can be taken from *BS EN 12369-2 Wood-based panels. Characteristic values for structural design. Plywood*<sup>10</sup>, if a manufacturer has assigned the product to one of the strength classes included in that standard. Alternatively values can be calculated following testing and calculation in accordance with *BS EN 789 Timber structures. Test methods. Determination of mechanical properties of wood based panels*<sup>11</sup> and *BS EN 1058 Wood-based panels. Determination of characteristic 5-percentile values and characteristic mean values*<sup>12</sup>. Whichever method is used, the manufacturer should provide details of the characteristic values in a Declaration of Performance (DoP) to accompany the product.

Permissible design stresses for a range of plywood types are included in *BS 5268-2*. Although this standard has now been withdrawn, it is still being used by some designers. The products listed are manufactured to national standards that ensure minimum strength properties in the finished product and which are subject to approved quality control procedures. Currently such plywood is available from Canada, Finland, Sweden and the USA. Such plywood will also need to demonstrate compliance with the CPR, by meeting the requirements of *BS EN 13986*, or by other means. If characteristic values are provided for a particular plywood, conversion factors in *BS 5268-2* allow these characteristic values to be converted to permissible stresses.

Common uses for structural plywood are in:

- floor decking
- wall sheathing
- flat roofing
- concrete formwork
- external cladding.

### Marine plywood (BS EN 1088)

Marine plywood to *BS EN 1088* is manufactured using timbers having a durability rating of Class 3 (moderately durable) or better in accordance with *BS EN 350-2 Durability of wood and wood-based products. Natural durability of solid wood. Guide to natural durability and treatability of selected wood species of importance in Europe*<sup>13</sup>. Exceptionally, low density species such as gaboon, with a durability rating of Class 4 (slightly

durable) or better may also be used, but the product must then be marked with 'LW' to signify light weight. In both cases, high quality veneers are used and must be bonded using a resin to meet bonding Class 3 of *BS EN 314-2 Plywood. Bonding quality. Requirements*<sup>14</sup>. In most circumstances this would be a phenolic resin or a modified melamine-formaldehyde resin.

Marine plywood was developed for ship/boat building and has a very high performance under severe exposure conditions. It is also commonly used in construction applications where high performance is required or where the cost of replacement or consequences of failure warrant the additional cost. In the case of construction applications, the plywood must also demonstrate compliance with the CPR. As described in PanelGuide *Section 2* compliance with the CPR requires the inclusion of a CE mark and provision by the manufacturer of a Declaration of Performance (DoP).

### Utility plywood

Utility plywood comprises a range of products specifically intended for non-construction applications which are available in surface appearance grades suitable for joinery, furniture and limited exterior uses. Such plywood has traditionally been available from East and South East Asia, Brazil, France, Israel, Bulgaria, Czechoslovakia, Romania, Spain, Portugal, West Africa and more recently China.

### Speciality plywood

There is a wide range of speciality plywood products available aimed at specific applications and end uses. These range from flexible plywood, which can be bent into complex curves, to highly compressed, 'bullet proof' plywood. Lightweight panels and panels with an aggregate or non-slip finish are also available. All these products should be used in accordance with the manufacturer's specification.

### Blockboard/laminboard

These products are targeted at applications requiring a product similar to plywood in appearance but at a lower cost. They are normally restricted to interior applications such as joinery, door blanks, furniture and shopfitting.

### Specification

Plywood used in the UK is sourced from all over the world and has traditionally been manufactured to overseas standards. While this may still be the case for some applications, plywood manufactured for construction purposes must now meet the requirements of the Construction Products Regulation (CPR) and this means that manufacture must meet the requirements of the harmonised European standard *BS EN 13986* and the specification must be in accordance with the product standard *BS EN 636*. Products claiming compliance with this standard must also carry the specified markings, which include a reference to *BS EN 636*.

The most recent edition of *BS EN 636* retains the designations -1, -2 and -3 from the previous three-part standard to represent dry, humid or exterior conditions of use.

The environmental conditions for which each of these types of plywood are considered suitable are defined according to the parameters laid down for Use Classes in *BS EN 335 Durability of wood and wood-based products. Use classes: definitions applicable to solid wood and wood-based products*<sup>15</sup>:

- Dry conditions: for interior applications with no risk of wetting, defined in Use Class 1, with a moisture content corresponding to environmental conditions of 20°C and 65% relative humidity.
- Humid conditions: for use in protected exterior applications as defined in Use Class 2, with a moisture content corresponding to environmental conditions of 20°C and 85% relative humidity.
- Exterior conditions: for use in unprotected external applications, as defined in Use Class 3, where the moisture content will frequently be above 20%.

*BS EN 636* also introduces bending strength and modulus classes based on bending tests to *BS EN 310 Wood-based panels. Determination of modulus of elasticity in bending and of bending strength*<sup>16</sup>. These give a designated strength (F) and modulus (E) for both parallel and perpendicular to the face grain directions. An example designation would therefore be F10/20, E30/40. *BS EN 636* gives minimum values for each of the classes and *BS EN 12369-2 Wood-based panels. Characteristic values for structural design. Plywood*<sup>17</sup> gives corresponding characteristic values for use with each of these classes. *Table A2.20* shows requirements for plywood defined in *BS EN 636*.

Three bonding classes are defined in *BS EN 314-2*. The bonding classes relate to the use classes laid down in *BS EN 335 Durability of wood and wood-based products. Use classes: definitions, application to solid wood and wood-based products*<sup>18</sup>. Under *BS EN 314-1 Plywood. Bonding quality. Test methods*<sup>19</sup>, samples of plywood are tested to evaluate the glue bond performance following exposure to conditions appropriate to the end-use environment class.

For structural applications, design may currently be carried out in accordance with *BS EN 1995-1-1 (Eurocode 5)* or *BS 5268-2*. For floors, walls and roofs compliance with *BS EN 13986* requires performance tests for point load and soft body impact to be carried out in accordance with *BS EN 12871 Wood-based panels. Determination of performance characteristics for load bearing panels for use in floors, roofs and walls*<sup>20</sup>.

*BS 5268-2* lists a series of plywood types, from North America and Europe, that are considered suitable, are subject to acceptable quality control procedures and for which design stresses are given. The products must also

**Table A2.20: Requirements for plywood as defined in BS EN 636**

Property		Standard	Plywood type to BS EN 636		
			Dry	Humid	Exterior
Dimensional tolerance		BS EN 315	✓	✓	✓
Bonding quality		BS EN 314-2	Bonding Class 1	Bonding Class 2	Bonding Class 3
Mechanical properties	Structural <ul style="list-style-type: none"> <li>• Characteristic values</li> <li>• Bending strength</li> </ul>	BS EN 636/ BS EN 310/ BS EN 12369-2 or BS EN 789/BS EN 1058	✓	✓	✓
	Non-structural <ul style="list-style-type: none"> <li>• Bending strength</li> </ul>	BS EN 310	✓	✓	✓
Formaldehyde emission	Construction	BS EN 13986	E1 or E2	E1 or E2	E1 or E2
	Non-construction	BS EN 636/ BS EN 717-1/ BS EN 717-2	E1 or E2	E1 or E2	E1 or E2

demonstrate compliance with the CPR, by compliance with *BS EN 13986*.

Where characteristic values are available either from testing to *BS EN 789 Timber structures. Test methods. Determination of mechanical properties of wood based panels*<sup>21</sup> or from *BS EN 12369-2 Wood-based panels. Characteristic values for structural design. Plywood*<sup>22</sup>, *BS 5268-2* gives conversion factors to enable them to be used with that standard.

Alternative justification, such as load testing, is another option if plywood is to be used in specific structural applications.

Marine plywood manufactured to *BS EN 1088* is also available in the UK. Marine plywood was developed for ship/boat building and has a very high performance under severe exposure conditions. It is also commonly used in construction applications where high performance is required or where the cost of replacement or consequences of failure warrant the additional cost. Marine plywood must demonstrate compliance with the CPR if it is to be used in construction.

For non-structural/non-load-bearing applications, there are many types/grades of plywood available on the market, from various sources. Where these are to be used in construction, they must meet the requirements of the CPR, which can be demonstrated by the use of the CE mark and provision of manufacturer's Declaration of Performance (DoP). Where these products are not used in construction users should still satisfy themselves that the manufacturing specification, be it a national or industry standard, provides a product suitable for the end use. Particular attention should be paid to the glue bond quality if the product is to be exposed to moisture.

Blockboard and laminboard are not commonly marketed as being in accordance with any particular standard. However, blockboard and laminboard are covered by the definition of plywood and should comply with the CPR if they are to be used in construction.

## Physical properties

### Climate

Like other wood-based panel products, plywood is hygroscopic and its dimensions will change in response to changes in humidity. However, wood tends to shrink/expand much more across the grain than along the grain and the cross-laminated structure of plywood means that the longitudinal veneers in one ply tend to restrain the perpendicular veneers in the adjacent ply. As a result, the dimensional movement of plywood is quite small: typically, a 1% change in moisture content increases or decreases the length and width of plywood by about 0.15mm per metre run. The corresponding change in thickness is likely to be in the region of 0.3% to 0.4% per 1% change in moisture content. These figures should be taken as a guide only as they will vary with the species and lay-up of the plywood concerned.

*Table A2.21* gives approximate moisture contents likely to be attained by plywood in certain environments.

**Table A2.21: Expected moisture content of plywood**

Relative humidity at 20°C	Approximate equilibrium moisture content
30%	7%
65%	12%
85%	18%

Like all wood-based materials, the strength and stiffness of plywood will vary with moisture content. In structural design this is accounted for by applying modification factors to the material properties. Relevant factors are given for plywood in *BS EN 1995-1-1 (Eurocode 5)* and in *BS 5268-2*.

### Biological attack

The overall durability of plywood is a function not just of the glue bond quality, but of the durability of the veneers used and of the lay-up of the plywood.

The risks of biological attack of plywood are given in *BS EN 335* in relation to Use Classes 1, 2 and 3. The use of plywood in Use Class 4 (in contact with ground or fresh water) and Use Class 5 (in contact with sea water)

**Table A2.22: Reaction to fire classification without further testing of untreated plywood**

Product	EN Product standard	End use condition <sup>(5)</sup>	Minimum density (kg/m <sup>3</sup> )	Minimum thickness (mm)	Class <sup>(6)</sup> (excluding floorings)	Class <sup>(7)</sup> (floorings)
Plywood <sup>(1),(2),(4)</sup>	BS EN 636	Without an air gap behind the wood-based panel	400	9	D-s2,d0	D <sub>fl</sub> -s1
Plywood <sup>(3),(4)</sup>	BS EN 636	With a closed air gap behind the wood-based panel	400	15	D-s2,d1	D <sub>fl</sub> -s1
Plywood <sup>(3),(4)</sup>	BS EN 636	With an open air gap behind the wood-based panel	400	18	D-s2,d0	D <sub>fl</sub> -s1
Plywood <sup>(4)</sup>	BS EN 636	Any	400	3	E	E <sub>fl</sub>

(1) Mounted without an air gap directly against class A1 or A2-s1, d0 products with minimum density 10 kg/m<sup>3</sup> or at least class D-s2, d2 products with minimum density 400 kg/m<sup>3</sup>

(2) A substrate of cellulose insulation material of at least class E may be included if mounted directly against the wood-based panel, but not for floorings

(3) Mounted with an air gap behind. The reverse face of the cavity shall be at least class D-s2, d2 products with minimum density 400 kg/m<sup>3</sup>

(4) Veneered phenol- and melamine-faced panels are included for class excl. floorings

(5) A vapour barrier with a thickness up to 0,4mm and a mass up to 200 g/m<sup>2</sup> can be mounted in between the wood-based panel and a substrate if there are no air gaps in between

(6) Class as provided for in Table 1 of the Annex to Decision 2000/147/EC

(7) Class as provided for in Table 2 of the Annex to Decision 2000/147/EC

NOTE: The classes given in this table are for unjointed panels, T&G jointed panels installed according to *DD CEN/TS 12872* and fully supported joints installed according to *DD CEN/TS 12872*

is noted as being appropriate only if the inherent and/or conferred properties of the panels are adequate.

Some guidance on the selection of plywood for use in different environmental conditions, ie use classes, is included in *DD CEN/TS 1099*. The durability of plywood is affected by the wood species used in the plies, the veneer thickness and the type of resin used. In *DD CEN/TS 1099*, for resistance to fungal attack, the durability class of the wood species used in the plies (from *BS EN 350-1 Durability of wood and wood-based products. Natural durability of solid wood. Guide to the principles of testing and classification of the natural durability of solid wood*<sup>23</sup>) is related to the use class in which the plywood is to be used. Recommendations as to whether the natural durability of the plywood is sufficient or whether preservative treatment is advisable or required are included. Ratings for the resistance of plywood to common species of insects, including termites and marine borers are included.

General guidance on the use of preservative treatments for panel products can be found from the WPA Manual *Industrial wood preservation specification and practice. Commodity Specification C11*. This guidance assists with making the right choice of preservatives for the end use and the panel product to be treated, as not all panel products need to be treated for particular end uses or are indeed suitable for some treatments. It also stresses that the preservative and/or the panel manufacturer should be consulted before any treatment is carried out as treatment may alter the physical and/or visual properties of the panel product.

### Water vapour permeability

Water vapour permeability will vary with plywood species, density and structure, but the water vapour resistance factor ( $\mu$ ) will generally be between 50 and 110 when tested in accordance with *BS EN ISO 12572* using test conditions C (the wet cup method). This

equates to a range of 150 to 250 when using test conditions A (the dry cup method). Values of vapour resistance factors for various densities of plywood are given in *BS EN 13986*.

### Thermal conductivity

The thermal conductivity of plywood is dependent on its density and is likely to be in the range 0.09 to 0.24 W/mK. Values for thermal conductivity for various densities of plywood are given in *BS EN 13986*.

### Reaction to fire

*Table A2.22* shows what untreated plywood may be assumed to achieve under the Euroclass system for characterising the reaction to fire performance of materials based on *European Commission Decision 2007/348/EC*.

If the manufactured product does not satisfy any of these minimum requirements and a reaction to fire claim is to be made in a DoP for CE marking purposes, then it must be tested and classified according to *BS EN 13501-1*. However if no claim is made in the DoP for CE marking purposes it is still possible to use the British standard system to make a separate claim.

Further information on the reaction to fire of the various panel products in both the BS and EN systems is provided in *PanelGuide Section 2.2.3*.

### Storage and handling

Correct handling and transportation of wood-based panels is essential to prevent either damage to the panels or injury to the operatives undertaking these operations. It is therefore important that the correct storage, transportation and handling techniques described in *PanelGuide Section 4.2* and *Section 4.3* are employed. Being reasonably durable and resilient, most timber products can withstand considerable wear and tear, but lack of care before and during construction can adversely affect wood products.

Plywood should be stored flat and dry, off the ground, with all four edges flush. Storage in a dry enclosed building is preferable and external storage should be avoided whenever possible, as should stacking on edge. Panels should be stacked on a close-boarded or slatted pallet, or if this is not possible on battens at no more than 600mm centres. The battens should all be of equal thickness and should be vertically aligned with any others in the same stack, in order to avoid distortion of the panels.

Panels should be fully protected by a waterproof covering during transport and the edges properly covered. Edges should also be protected against damage by lashings or other banding, this is particularly important for panels with profiled edges such as tongued and grooved panels. Plywood with 'dry' *EN 636-1* or 'humid' *EN 636-2* bond qualities must be protected from wetting during storage and construction. While 'humid' panels *EN 636-2* may tolerate limited wetting and 'exterior' panels *EN 636-3* will tolerate a high level of wetting, these circumstances should still be avoided as far as possible during transport and construction in order to minimise problems with delamination, distortion and discolouration.

All panels should be installed at a moisture content as close as possible to that which they will attain in service. This is particularly applicable if they are being installed under internal heated conditions or are to be coated following installation. Manufacturers can accept no responsibility for plywood exposed to standing water during the construction process. Allowing 'exterior' plywood to become wet during construction can lead to severe construction delays: the necessary drying out period will be prolonged, as the plywood must return as close as possible to its final in-service moisture content before it is covered or fully enclosed. Failure to meet this requirement will result in discolouration and potentially fungal decay.

Once on site, it is preferable for individual panels to be 'stickered' before installation in order to allow air to circulate and to allow the panels to attain a moisture content as close to their final in-service moisture content as possible.

Further guidance on storage and handling can be found in PanelGuide *Section 4*.

## Working with plywood

### Cutting

Fixed workshop machines are generally most appropriate for cutting and machining wood-based panels, as they provide a better quality finish and allow health and safety requirements to be effectively addressed, particularly in terms of machine guarding, dust extraction and manual handling. Hand-held power tools are generally only appropriate to small volumes of in-situ cutting or final adjustment on site. Satisfactory results on single panels can be achieved using hand tools. When hand sawing, use a cross-cut saw of 10 to 15 TPI for best results.

When a circular saw is used, the saw blade should enter the panel on the good face. A tungsten carbide tipped (TCT) saw will give good performance. The best finish will be obtained using a fast material feed speed in the opposite direction to the saw rotation and with minimum protrusion of the saw above the panel surface. The panel should be supported as close as possible to the blade. To minimise the risk of splintering the corners of the panel, it is best if the cuts at right angles to the face grain are made first and those parallel to the face grain are made afterwards.

When using a band saw, the best results are achieved with the maximum saw speed and a slow feed speed.

Where material routing or moulding is required, the cutter type, tool and material feed speed all affect the quality of the finish. Trials may be required to establish the optimum conditions.

### Fixing

Plywood normally has higher mechanical properties in a direction parallel to the face grain; this means the direction in which the panels are to be laid must normally be specified. This is particularly so in structural applications, such as floors, walls and roofs where the direction of installation must be as assumed in the design calculation.

If panels are laid edge to edge, such as in a floor, it is essential that suitable expansion gaps are provided to allow for any (moisture related) dimensional movement during service. Guidance on the necessary allowances can be found in PanelGuide *Section 4.5.3*.

Plywood can be fixed by nails, screws and staples or by gluing, depending upon the application and requirements.

The structure of plywood makes it possible to use nails and other mechanical fastenings quite close to the panel edges without the risk of pull out. While pre-drilling is required for screws and larger connectors, nails can normally be driven without pre-drilling. When fastening plywood to timber, ring shank nails give improved performance over plain wire nails. More guidance on fastener sizes and spacing for specific applications can be found in PanelGuide *Section 2*.

Glued joints provide stiffer joints than ones made with mechanical fixings alone. A wide range of adhesive types is available but care should be taken to ensure that the adhesive used is suitable for the environmental conditions of the end use.

### Finishing

The quality of the surface finish of plywood is affected by the species and the grade of the surface veneer. Manufacturers may produce either sanded or un-sanded products according to their manufacturing needs and end-user requirements. Where sanding is undertaken

only in order to improve the appearance of repairs to the surface veneers, plywood may be described as 'touch sanded'. In such panels areas of the surface will be untouched by sanding operations.

When exposed to weather in an unprotected state, plywood will weather to a dull grey colour at the same rate as would be expected of solid wood of the same species. Further weathering can result in checking and splitting of the surface and the loss of wood fibre. The application of a suitable finish following installation can protect the material and enhance its appearance. The application of a finish to plywood under interior conditions is normally only for decorative purposes.

The surface finish that can be achieved will vary with species. Fine grained species such as birch can have a very finely textured surface, whereas coniferous species tend to be more heavily textured.

A range of paints, stains and varnishes are suitable for use on plywood, but care should be taken to ensure that the finish is suited to the end use. Products used in exterior or other changeable environmental conditions require a flexible coating to accommodate dimensional changes. If the plywood is installed in a heated environment, it is important that the moisture content is allowed to stabilise before the coating is applied.

Plywood with a medium density paper overlay is specially designed to be painted and subjected to fully exposed service. With normal plywood, adequate performance of the finish requires great care with design, surface preparation and application of the finish, if surface checking is to be avoided. Low-build exterior wood stains possess certain advantages over film-forming finishes by being more able to cope with the behaviour of exposed plywood. Exterior wood stains will not prevent surface checking but are less likely to react to it by flaking off than paint. Redecoration with a pigmented product will protect the checked surface and should present an acceptable appearance.

Some water-based acrylic paints show high levels of extensibility and can tolerate the surface movements of plywood. However, dark colours of such paints should not be used in areas sheltered from rainfall as salt efflorescence can appear on the surface. Blockboard and laminboard are not intended for use in exposed exterior applications.

Guidance on the specification of plywood on the basis of surface appearance and its ability for finishing is given in *BS EN 635 Plywood. Classification by surface appearance*. TRADA Wood Information Sheet *WIS 2/3-1 Finishes for external timber*<sup>24</sup> also gives guidance on the use of timber finishes under exterior conditions.

Under exterior conditions, it is important to coat both surfaces of the plywood panel and to effectively seal the panel edges with a suitable sealing compound. There

are many materials that have a potential edge sealing role, including liquids, pastes and hot melts, but none should be relied upon to compensate for poor design or detailing. Designers should seek to ensure that the wetting of panel edges is minimised, for guidance see TRADA Wood Information Sheet *WIS 4-28 Durability by design*<sup>25</sup>.

Ineffective edge sealing can result in dimensional changes/swelling due to water ingress and can lead to staining, failure of the coating, decay, delamination and ultimately to premature failure of the plywood. Further guidance can also be found in TRADA Wood Information Sheet *WIS 2/3-11 Specification and use of wood-based panels in exterior situations*<sup>26</sup>.

## Health and safety

### Dust

In common with other wood products, plywood is safe when it is handled and used correctly. Contact with some species of timber can cause irritation to sensitive individuals, but such species are rarely used in the manufacture of plywood.

When cutting or machining plywood, wood dust is produced and as this can be hazardous, measures must be taken to control the dust. This is normally carried out with the use of suitable dust extraction systems in a workshop environment.

Dust from cutting operations can be controlled by complying with the Control of Substances Hazardous to Health (COSHH) Regulations 2002. Under these Regulations, wood dust has a Workplace Exposure Limit (WEL) of 5 mg/m<sup>3</sup>, which is appropriate to wood dust from the machining of plywood. Exposure must be reduced as far as possible below this limit.

### Formaldehyde

The formaldehyde content of plywood is normally very low and emission of formaldehyde is not often an issue with plywood. Free formaldehyde in the workplace atmosphere has a WEL of 2 parts per million (ppm). However, when machining plywood in mechanically ventilated situations, it is expected that exposure to levels of free formaldehyde would be significantly below this.

Two classes of 'in service' formaldehyde potential are specified in *BS EN 13986*, Class E1 and Class E2, E2 being the higher of the two. The test methods available for determining the formaldehyde potential are *BS EN 717-1*, and for coated plywood, *BS EN 717-2*. Manufacturers claiming compliance under the Construction Products Regulation (CPR) must test and declare formaldehyde emission potential Class E1 or Class E2 for their products. This information forms an element of the CE mark and will appear on the Declaration of Performance (DoP) for the plywood product.

**Table A2.23: Plywood – common hazards and methods of control**

Activity	Hazard	Control
Manual handling of full sheets	<ul style="list-style-type: none"> <li>Large sheet sizes present a risk of strain or crush injuries if not handled correctly</li> </ul>	<ul style="list-style-type: none"> <li>Store carefully in uniform stacks on a flat level base</li> <li>Use mechanical handling equipment</li> <li>Adopt correct manual handling procedures</li> </ul>
Carpentry work Activities likely to produce high dust levels include: <ul style="list-style-type: none"> <li>Sanding by machine and hand</li> <li>Sawing, routing</li> <li>Hand assembling machined or sanded components</li> </ul>	<ul style="list-style-type: none"> <li>Wood dust in general (including dust from plywood) may cause dermatitis and allergic respiratory effects</li> <li>Wood dust is flammable</li> </ul>	<ul style="list-style-type: none"> <li>Off site: preparation under exhaust ventilated plant</li> <li>On site: enclosure and exhaust ventilation</li> <li>Dust extraction on portable tools</li> <li>Good ventilation</li> <li>Respiratory protection equipment (RPE)</li> </ul> <p>Note: Any health hazards arising from the use of plywood at work can and should be controlled by compliance with the requirements of the Control of Substances Hazardous to Health (COSHH) Regulations 2002</p>

As with all wood-based panels, there may be manual handling hazards and COSHH Regulation 6 requires an assessment to be made, and recorded, of health risks associated with wood dust and handling. Common risks and control measures are shown in *Table A2.23*.

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