Section A *Design Guidance*

A1 Structural form and function

Timber is a versatile building material that has been used for centuries as a structural material. Solid timber is widely used in domestic housing but engineered products are also widely available (used mainly for engineering solutions in many buildings). Products include laminated veneer lumber (LVL), parallel strand lumber, glulam, I beams, box beams, steel web beams and numerous board materials such as plywood, chip board, fibre board and orientated strand board (OSB).

The many products available give the engineer the versatility to design unique timber structures capable of meeting the client's requirements (e.g. safety, cost, functionality, fire performance, durability and aesthetic appeal). Structural forms and concepts are dictated by end use, space requirements and cost. At the preliminary design stage there are many criteria to be considered.

For example:

Building Usage
- Function
- Size
- Space division
- In-plan organisation

Special Considerations
- Fire protection
- Acoustics
- Surrounding properties
- Environment

Site
- Ground conditions
- Access
- Topography

Service Installations
- Ventilation
- Heating
- Acoustics/Lighting
- Water supply
- Waste removal

Loading
- Dead load
- Live load
- Snow/wind
- Impact

The building shape is influenced by many factors including how it fits into its surroundings, the creativity of the designer, its functionality, the economics of construction and its capability to meet the structural requirements.

Timber used structurally must be strength graded by qualified personnel under the supervision of an accredited certification body such as the National Standards Authority of Ireland (NSAI) or the Timber Research and Development Association (TRADA). Timber must be strength graded in the dry state with a moisture content of approximately 20% but its moisture content, treatment (perhaps with preservative or flame retardant) and finish (planed or sawn) can be further specified by the designer. Timber can be an efficient structural material as well as durable, fire resistant, environmentally friendly and aesthetically pleasing.

Solid timber is widely used in domestic housing mainly for roof rafters, trussed rafters, ceiling joists, purlins and floor joists. Timber frame construction has become increasingly popular in Ireland due to its thermal efficiency, rapid construction times, cost and its environmental image. Traditional timber frame construction is almost identical in appearance to masonry construction, essentially the only difference being the inner leaf of the external wall being constructed mainly of timber. The thermal insulation is contained within the external wall inner leaf and is protected and sheltered and therefore performs extremely well. Timber frame is a system that can be designed to easily give increased performance in sound, fire and thermal parameters.

Engineered wood products, the most common ones probably being glulam, LVL, parallel strand lumber and I-beams are used in a wide range of building types; apartments, offices, factories, shopping centres, sports halls as well as housing. The engineering of the timber enhances the performance of the timber and maximises its use. Glulam can be made in almost any size and is capable of carrying heavy loads and spanning large distances. LVL and parallel strand lumber tend to go into products such as I-beams or to be used as part of an I-beam floor system. I-beams and similar engineered systems are increasingly being used especially in timber frame buildings in apartments and housing. Refer to building regulations for thermal performance.

Developing the building
- Will connections be exposed and used aesthetically
- Joints can affect the structure, e.g. with bolted trusses the number of timber members is usually increased to accommodate the number of bolts
- Will loads, spans and performance dictate the material used, e.g. solid timber, I-joists, glulam, steel
- Will other material be used and how will these interact with the timber
- The size of components, this can affect appearance and can raise difficulties in transport and erection
- Manufacturing of components on site is usually to be avoided but on occasions there may be no alternative

Structural considerations
- Stability
- Strength
- Deflection
- Cost effectiveness
- Buildable
- Durability
- Fire resistance
- Layout of structural members
- Connections
- Materials

Architectural considerations
- Use of structure as a visual medium
- Geometry and shape
- Use of colour and texture
- Selection of timber species
- Layout of structural elements

A2 Strength

Wood is an anisotropic material with different strength properties in different directions. Its strength is directly dependent on the grain direction; axial, radial or tangential. Its properties also change with environmental conditions. The properties not only vary from species to species but even within the same species. To be able to design timber structures successfully, the practising engineer needs to be aware of the particular properties of the timber being specified.

To assist the designer, species with similar strength properties are grouped together in the same strength class and are thus inter-changeable in the design process. This simplifies the selection process and extends the range of materials available to the designer/specifier.

Factors influencing properties of timber:

General:
- Species
- Source (geographical)

Natural characteristics:
- Density – this can affect the joint design
- Knots – some species are naturally knotty
- Slope of grain - knots can affect the grain and some species are more prone to spiral grain
- Ring width – these are usually wider in the heartwood (the inner portion of the tree)
- Anisotropy – the properties are different in different directions
- Distortion – timber can distort if drying is not controlled, spring, bow and twist can affect timber grading
- Moisture content – in its natural state timber can have a moisture content in excess of 100%. The fibre saturation point is usually around 28%.

Service conditions
- External use will result in high moisture contents and dictate the timber species
- Internal use may result in low moisture contents and may dictate the use of controlled drying
- Treatments might affect metal components

Timber grading

All structural timber must be strength graded and this process should be carried out by trained graders in a quality control scheme overseen by a suitable third party. In Ireland the NSAI is the main timber certification body while in the UK TRADA, BRE, BSI and others operate timber certification schemes some of which are available in Ireland.

There are two methods of grading timber; visually or by machine, both require trained personnel.

The main standard covering strength grading is EN 14081 which has 4 separate parts. Part 1 covers timber marking (for both visual and machine graded timber) and requirements for visual strength grading standards while parts 2, 3 and 4 cover machine grading. Part 4 gives machine settings for a range of different machines, timber species and timber sources; the settings are dependent on the timber size and the strength class combination that the grader requires. There are a number of different machines on the market using different principles and providing the machines (along with their settings) are referred to in EN 14081 then these machines should be satisfactory for use. Strength grading machines are capable of directly grading timber into a strength class (a grouping of timber with similar strength properties).

Grading

Visual strength grading
- IS 127 or BS 4978 (softwoods)
- BS 5756 (hardwoods)

Machine strength grading
- EN 14081-4 Machine grading-grading machine settings for machine control systems.

EN 14081-1 gives some requirements for visual strength grading but is not actually a strength grading standard; it really gives general requirements that a visually strength grading standard should contain e.g. a standard should have some method of assessing the area of knots in a timber section.

The main visual strength grading standard in Ireland is I.S. 127 while in the UK it is BS 4978; however, these standards are almost identical. There are two main visual grades in these standards GS (General Structural) and SS (Special Structural); the grading rules for these 2 grades are the same in both standards and these grades (and standards) are referred to in EN 1912.

Timber properties
- Timber exhibits different mechanical properties in different growth directions. Generally the strength properties of timber are highest parallel to the grain or the longitudinal axis.
- The mechanical properties of timber change with changes in moisture content and timber should generally be installed at a moisture content close to the equilibrium moisture content likely to be achieved in service.
- Timber generally has a high strength to weight ratio compared to other materials

In terms of visual strength grading, EN 1912 is an important standard, as it allocates a strength class to a particular timber grade based on the timber species and source (where it was grown). It references the strength grading standard used for the grades i.e. in Ireland I.S. 127, in the UK BS 4978).

Once the graded timber has been allocated a strength class from EN 1912 then the characteristic strength properties can be obtained from EN 338. Eurocode 5 (the main part for general design is EN 1995-1-1) uses characteristic stress values in design rather than the permissible stress values used in BS 5268. If the timber grade, species and source are not referenced in EN 1912 then it is very doubtful if it can be used for designs to Eurocode 5.

Design parameters
- Strength class/grade & species
- Moisture content
- Movement
- Joints
- Lateral restraints
- Stability
- Durability
- Fire resistance
- Supports
- Loading

Timber marking

All timber must be strength graded but it must also be properly marked. EN 14081-1 specifies two marking criteria; one where the timber is not CE marked and one for CE marking (which also has specific requirements for factory production control). At the time of writing, Ireland and the UK do not have a requirement that timber must bear a CE mark but some other countries require a CE mark. The Construction Products Requirements will require all construction products to bear a CE mark by July 2013.

The marking requirements set out in EN 14081-1 are summarised below:

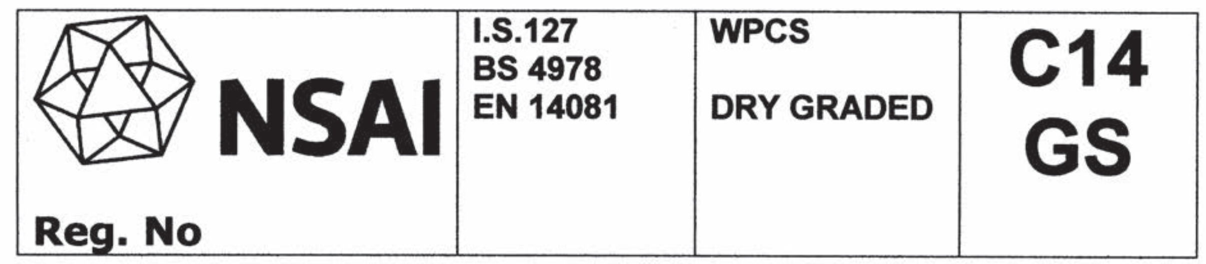
a) Producer's identification mark
b) If visually graded, the strength class as assigned in EN 1912 or the strength grade and grading standard if not included in EN 1912
c) The words 'Dry Graded' if appropriate
d) If machine graded the letter 'M'
e) The following information or reference to a document that contains it:

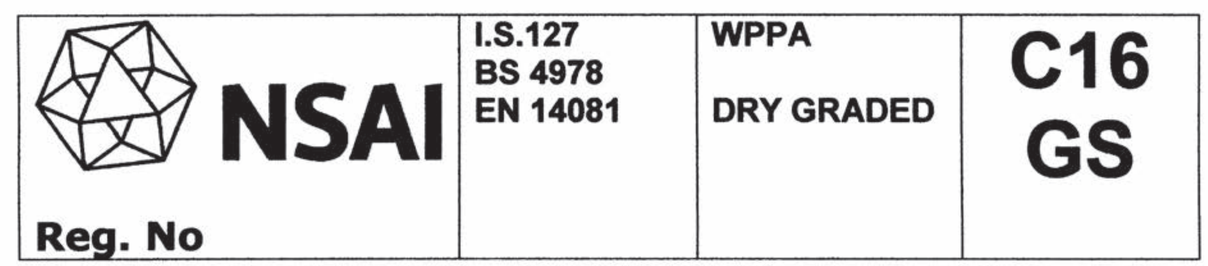
    1) If a single species, the species code in accordance with EN 13556
    2) If a combined species, the species code from Table 4 EN 14081-1
    3) If machine graded, the code identifying the country or region of origin in accordance with EN ISO 3166-1
    4) If visually graded and marked with a strength class, the grade and grading standard.

Information can be omitted for aesthetic reasons and the above information can be placed on accompanying documentation. The standard (EN 14081-1) also refers to timber that has been treated with a preservative being marked according to prEN 15228 but any marking related to this standard is unlikely to be placed by the timber grader. There are also additional marking requirements visually strength graded timber set out in I.S. 127 and BS 4978.

EN 14081-1 allows visually graded timber to be package marked, that is the individual timber pieces do not necessarily have to be stamped and that accompanying documentation may contain the required information on the timber. The standard allows national grading standards to make a national choice on timber marking and both Ireland and the UK require individual pieces of timber to be marked. However, it appears that timber graded in a member state that permits package marking may have to be accepted in Ireland and the UK.

A few examples of timber marks which comply with EN 14081-1 are given below.





The "Reg. No" is the company registration number allocated by the certification body, in this example NSAI. In some cases there may be a second number giving the registration number of the strength grade.

CE marking

To CE mark timber, there must be a factory production control system in place which is monitored by a notified body. The marking requirements in Annexe ZA (annexes dealing with CE marking all have the designation ZA) call for a level of attestation of 2+ which requires a notified body to oversee the strength grading operation.

Additional marking requirements for CE marking (in addition to those above) include the identification number of the notified body and the year when the mark was affixed.

STRENGTH CLASSES

European Standard EN 338 Structural Timber Strength Classes outlines the characteristic strength and stiffness properties for softwoods and hardwoods. The strength classes for softwoods range from C14 to C40 and for hardwoods they range from D30 to D70. The timber visual strength grades and strength classes for some commonly used softwood species are shown below. The most commonly available strength class for general carcassing work is C16.

Table A 2.1.1 *Softwood grades and strength classes.*

Origin	**Timber species**	**Strength grade IS 127/ BS 4978**	**Strength class (EN 1912)**	
			IS 127[+]	**BS 4978**
Ireland	Sitka spruce and	GS	C14	
	Norway spruce	SS	C18	
				C14
UK	Douglas fir	GS		C18
		SS		
				C16
	Larch	GS		C24
		SS		
				C14
	British pine[1]	GS		C22
		SS		
				C14
	British Spruce[2]	GS		C18
		SS		
				C16
Europe	Whitewood/	GS		C24
(CNE)	Redwood	SS		
				C16
Canada/USA	Douglas fir/Larch	GS		C24
	Hemlock/Fir	SS		
	Spruce-Pine-Fir			

[+]Generally Irish and British grown timber have the same properties and therefore can be considered as synonymous. While EN 1912 does not contain a reference for Ireland for many of the Irish/UK grown timber species and readily available imported timbers, a submission is being made to CEN to correct this.

[1]This includes species Corsican pine and Scots pine
[2]This includes Sitka and Norway spruce; it is recognised that there is no difference between these species grown in Ireland and the UK.

The grading rules for GS and SS in IS 127 are identical to those in BS 4978 and therefore the standards can be considered to be interchangeable for these grades. The above timbers are some of the more common ones used in Ireland and the UK. EN 1912 contains a greater number of timbers and grading standards than those referred to above.

Europe refers to CNE; that is Central, Northern or Eastern Europe.
For designs to BS 5268 Part 2; timber grades can be allocated to a strength class using that standard.

Timber can be machine graded directly into a strength class.

Table A 2.1.2 *Some hardwood grades and strength classes*

Origin	Timber Species	Strength Grade BS 5756	Strength Class EN 1912
Ireland/U.K.	Oak	TH 1	D 30
	Oak	TH 2	Not Listed
	Oak	TH A	D 40
	Oak	TH B	D 30
USA	Am. White oak	TH 1	D 50
	Am. Red oak	TH 1	D 40
	Am. White ash	TH 1	D 35
	Am. Tulipwood.	TH 1	(D 40)*
Tropical	Balau	HS	D 70
	Greenheart	HS	D 70
	Ekki	HS	D 60
	Keruing	HS	D 50
	Iroko	HS	D 40

Notes.
1. *Strength Class allocation for Irish/UK oak from values given in Table 7 of BS 5268 Pt2 for designs to that standard.*
2. *Strength Class allocation for USA species from tests carried out at BRE in accordance with EN 408 & EN 384. * Tulipwood meets the requirements for strength & stiffness of D 40 but not for density.*

Published in "*Structural Design in American Hardwoods*".

Strength classification

The classification of timber into a particular strength class is undertaken on the basis of:
- a combination of the species and visual strength grade as shown in table A 2.1.1 or A2.1.2
- directly by use of a machine.

Characteristic stresses

For designs to Eurocode 5, characteristic stresses and moduli of elasticity values for the appropriate strength classes (softwoods and hard woods) are given in EN 338 Structural timber – strength classes; some of the characteristic values for the common strength classes are given in Table A2.2.1

Table A 2.2.1 *Characteristic values for designs to Eurocode 5 – Softwoods.*

		Softwood species						
		C14	C16	C18	C20	C22	C24	C27
Strength properties (in N/mm²)								
Bending	$f_{m,k}$	14	16	18	20	22	24	27
Tension parallel	$f_{t,0,k}$	8	10	11	12	13	14	16
Tension perpendicular	$f_{t,90,k}$	0,4	0,4	0,4	0,4	0,4	0,4	0,4
Compression parallel	$f_{c,0,k}$	16	17	18	19	20	21	22
Compression perpendicular	$f_{c,90,k}$	2,0	2,2	2,2	2,3	2,4	2,5	2,6
Shear	$f_{v,k}$	3,0	3,2	3,4	3,6	3,8	4,0	4,0
Stiffness properties (in N/mm²)								
Mean modulus of elasticity parallel	$E_{0,mean}$	7	8	9	9,5	10	11	11,5
5% modulus of elasticity parallel	$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4	7,7
Mean modulus of elasticity perpendicular	$E_{90,mean}$	0,23	0,27	0,30	0,32	0,33	0,37	0,38
Mean shear modulus	G_{mean}	0,44	0,5	0,56	0,59	0,63	0,69	0,72
Density (in kg/m³)								
Density	ρ_k	290	310	320	330	340	350	370
Mean density	ρ_{mean}	350	370	380	390	410	420	450

Notes:

Values are often given in terms of MPa= 1 N/mm².
Strength classes C 20 and C22 are not common in Ireland.
The values are taken from EN 338 and that standard should always be consulted in case of updates.

TR26 while referenced in EN 14081-1 has not yet been included in EN 338; however that standard gives a method of determining characteristic values from test. Characteristic values for TR26 should be available from BRE or TRADA.
For permissible stress designs to BS 5268, the design values for different strength classes should be taken from that standard.

Table A 2.2.2 *Characteristic values for designs to Eurocode 5 – Hardwoods.*

	Hardwood species							
	D18	D24	D30	D35	D40	D50	D60	D70
Strength properties (in N/mm²)								
Bending	18	24	30	35	40	50	60	70
Tension parallel	11	14	18	21	24	30	36	42
Tension perpendicular	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
Compression parallel	18	21	23	25	26	29	32	34
Compression perpendicular	7,5	7,8	8,0	8,1	8,3	9,3	10,5	13,5
Shear	3,4	4,0	4,0	4,0	4,0	4,0	4,5	5,0
Stiffness properties (in N/mm²)								
Mean modulus of elasticity parallel	9,5	10	11	12	13	14	17	20
5% modulus of elasticity parallel	8	8,5	9,2	10,1	10,9	11,8	14,3	16,8
Mean modulus of elasticity perpendicular	0,63	0,67	0,73	0,80	0,86	0,93	1,13	1,33
Mean shear modulus	0,59	0,62	0,69	0,75	0,81	0,88	1,06	1,25
Density (in kg/m³)								
Density	475	485	530	540	550	620	700	900
Mean density	570	580	640	650	660	750	840	1080

Target size

The target size is really the only relevant term that should be used for specifying timber; terms like planed or regularised can be used but they apply to a process rather than size. Target size is defined in EN 336 and is where the applied tolerances on the dimensions would ideally be zero at the reference moisture content of 20%; where the timber moisture content is different to 20% a formula is given in EN 336 to relate the timber size to 20%. The target size can therefore be thought of as a minium average size while the relevant tolerances given in EN 336 represent the limits on the measurements taken to determine the average size.

Tolerance class

Timber should be specified by tolerance class in accordance with EN 336. There are two tolerance classes TC1 and TC2; TC2 has tighter tolerances and usually applies to factory produced timber components such as timber frame and roof trusses. TC1 with its higher tolerances usually applies to sawn timber products.

Different tolerances could be specified in a specification but this would be unusual for structural timbers. However, CLS sizes used in timber frame construction are usually the actual finished sizes with effectively zero tolerance on the dimensions.

Tolerances to EN 336

Tolerance class	<=100mm	>100mm	Typical uses
TC1	-1/+3	-2/+4	Floors, cut roofs
TC2	-1/+1	-1.5/+15	Timber frame, roof trusses

Load span tables

Swift 6 is a Non-Contradictory Complimentary Information (NCCI) and gives load span tables for designs based on Eurocode 5 and the Irish National Annex. Swift 6 should be consulted for the precise design criteria as the load span tables in *Woodspec* are for information only.

The use of Swift 6 is voluntary and although it is not a standard, in the future it may become one. Swift 6 is expected to be pu blished in 2012. The tables in Swift 6 include floor joists, ceiling joists, roof rafters and purlins for a number of different loadings as well as a method of selecting the design wind loads for a building in Ireland. For buildings where Swift 6 may not be applicable then the design should be undertaken by an experienced structural engineer.

In the UK for designs based on BS 5268-2, load span tables are given in BS 8103-3 and BS 5268-7, TRADA did produce tables which may be concurrent. If designs are to be based on BS 5268-2 then it should be ensured that the document giving the load span tables complies with current practice and regulations as some standards may have been superseded by newer editions or may have been withdrawn (such documents may be satisfactory for design but a check should be carried out to ensure that this is the case).

For designs to Eurocode 5 in the UK TRADA have produced load span tables but these should be checked to ensure that the design criteria meet the requirements of the building and the specification.

A NCCI (PD 6693) is being produced in the UK which will give additional information for designs to Eurocode 5 but it will not include load span tables. It is likely that load span tables will be produced in the UK than also comply with PD 6693 but this is by no means sure.

As Ireland and the UK have different design requirements in their National Annexes (not just for Eurocode 5 and EN 1990 but also for the loading standards and other supporting standards) any load span tables produced by the two countries should not be considered interchangeable.

Floor joist load span tables

The load span tables below are taken from Swift 6 and are based on the Irish National Annexes to Eurocode 5, EN 1990 and EN 1991-1-1 as well as criteria specified in Swift 6.

The spans in Swift 6 are less than those in I.S. 444 especially where a full vibration check is undertaken. I.S. 444 was based on permissible stress design as outlined in BS 5286-2 and there are considerable differences between the design loads and the deflection criterion between the BS 5268-2 and Eurocode 5.

Swift 6 allows a limited check for vibration to be taken for floors in housing while for other purpose groups a full vibration check should be undertaken. Table A 2.2.3 shows allowable spans for housing while Table A 2.2.4 shows allowable spans for floors with the same design load but would be appropriate to apartments.

Table A 2.2.3 *Domestic housing – Floor joists to Eurocode 5; Part vibration check*
(Dead 0,30kN/m^2 Imposed 1.50kN/m^2 Point load 2.00kN).

TARGET SIZE mm		C14			C16			C18			C24			C27		
b	**h**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**
38	100	1,56	1,55	1,54	1,73	1,71	1,70	1,84	1,82	1,80	2,03	2,00	1,98	2,07	2,05	2,02
38	115	1,98	1,96	1,94	2,12	2,09	2,07	2,24	2,21	2,19	2,47	2,44	2,41	2,52	2,49	2,45
38	125	2,23	2,20	2,18	2,38	2,35	2,32	2,52	2,49	2,46	2,77	2,73	2,68	2,82	2,78	2,72
38	150	2,88	2,84	2,76	3,06	3,02	2,89	3,23	3,14	3,01	3,54	3,36	3,22	3,59	3,41	3,26
38	175	3,54	3,36	3,22	3,70	3,52	3,37	3,85	3,67	3,51	4,04	3,90	3,75	4,08	3,94	3,81
38	200	3,99	3,84	3,68	4,12	3,98	3,85	4,24	4,10	3,98	4,45	4,30	4,17	4,49	4,34	4,21
38	225	4,35	4,20	4,08	4,49	4,34	4,21	4,63	4,47	4,33	4,85	4,69	4,55	4,89	4,73	4,59
44	100	1,74	1,72	1,71	1,86	1,84	1,82	1,97	1,95	1,93	2,17	2,15	2,12	2,22	2,19	2,17
44	115	2,13	2,10	2,08	2,27	2,24	2,22	2,40	2,37	2,34	2,64	2,60	2,57	2,69	2,66	2,62
44	125	2,39	2,36	2,33	2,55	2,52	2,48	2,70	2,66	2,63	2,96	2,92	2,81	3,01	2,97	2,85
44	150	3,07	3,03	2,90	3,27	3,17	3,03	3,45	3,30	3,16	3,71	3,53	3,38	3,76	3,58	3,43
44	175	3,71	3,53	3,38	3,86	3,69	3,54	3,98	3,84	3,68	4,17	4,03	3,91	4,21	4,07	3,95
44	200	4,13	3,99	3,86	4,26	4,12	3,99	4,39	4,24	4,11	4,60	4,45	4,31	4,64	4,49	4,35
44	225	4,50	4,34	4,22	4,64	4,49	4,35	4,78	4,62	4,48	5,01	4,84	4,70	5,05	4,88	4,74
47	100	1,80	1,78	1,76	1,92	1,90	1,88	2,04	2,01	1,99	2,24	2,21	2,19	2,29	2,26	2,23
47	115	2,20	2,17	2,14	2,34	2,31	2,28	2,48	2,45	2,42	2,72	2,68	2,65	2,77	2,74	2,68
47	150	3,17	3,09	2,96	3,36	3,24	3,10	3,54	3,37	3,23	3,79	3,60	3,45	3,82	3,65	3,50
47	175	3,79	3,61	3,45	3,92	3,77	3,61	4,04	3,90	3,76	4,24	4,09	3,97	4,27	4,13	4,01
47	200	4,19	4,05	3,92	4,32	4,18	4,05	4,45	4,30	4,17	4,66	4,51	4,38	4,70	4,55	4,42
47	225	4,56	4,41	4,28	4,71	4,55	4,42	4,84	4,68	4,55	5,08	4,91	4,77	5,12	4,95	4,81
75	175	4,21	4,07	3,95	4,34	4,20	4,08	4,47	4,32	4,20	4,68	4,53	4,40	4,71	4,57	4,44
75	200	4,63	4,48	4,35	4,77	4,62	4,49	4,91	4,76	4,63	5,14	4,98	4,85	5,18	5,02	4,89
75	225	5,03	4,87	4,74	5,19	5,03	4,89	5,34	5,17	5,03	5,58	5,41	5,27	5,62	5,46	5,31

Table A 2.2.4 *Domestic housing – Floor joists to Eurocode 5; Full vibration check*
(Dead 0,30kN/m^2 Imposed 1.50kN/m^2 Point load 2.00kN).

TARGET SIZE mm		C14			C16			C18			C24			C27		
b	**h**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**	**300**	**350**	**400**
38	100	1,56	1,55	1,54	1,73	1,71	1,68	1,84	1,82	1,75	2,03	1,95	1,87	2,07	1,98	1,90
38	115	1,98	1,93	1,85	2,12	2,02	1,94	2,21	2,10	2,02	2,36	2,25	2,16	2,40	2,28	2,20
38	125	2,21	2,10	2,02	2,31	2,20	2,11	2,40	2,29	2,20	2,57	2,45	2,36	2,61	2,48	2,39
38	150	2,66	2,53	2,43	2,78	2,64	2,55	2,89	2,75	2,65	3,10	2,95	2,84	3,15	2,99	2,88
38	175	3,11	2,96	2,85	3,25	3,09	2,98	3,38	3,22	3,10	3,62	3,45	3,32	3,68	3,50	3,37
38	200	3,56	3,39	3,26	3,72	3,54	3,41	3,88	3,69	3,55	4,09	3,95	3,80	4,14	3,99	3,86
38	225	4,00	3,82	3,67	4,13	3,98	3,84	4,25	4,10	3,99	4,47	4,31	4,19	4,52	4,35	4,24
44	100	1,74	1,72	1,69	1,86	1,84	1,77	1,97	1,91	1,84	2,15	2,05	1,97	2,19	2,08	2,00
44	115	2,13	2,03	1,95	2,23	2,12	2,04	2,32	2,21	2,12	2,48	2,36	2,27	2,52	2,40	2,31
44	125	2,32	2,21	2,12	2,43	2,31	2,22	2,53	2,40	2,31	2,70	2,57	2,48	2,75	2,61	2,51
44	150	2,79	2,66	2,56	2,92	2,78	2,68	3,04	2,89	2,79	3,26	3,10	2,98	3,31	3,14	3,03
44	175	3,27	3,11	2,99	3,42	3,25	3,13	3,56	3,38	3,26	3,81	3,62	3,49	3,86	3,68	3,54
44	200	3,74	3,56	3,43	3,91	3,72	3,58	4,04	3,87	3,73	4,24	4,09	3,98	4,29	4,14	4,02
44	225	4,14	3,99	3,86	4,28	4,13	4,02	4,41	4,25	4,13	4,63	4,47	4,34	4,68	4,51	4,39
47	100	1,80	1,78	1,73	1,92	1,88	1,81	2,04	1,96	1,88	2,20	2,09	2,02	2,24	2,13	2,05
47	115	2,18	2,07	1,99	2,28	2,17	2,09	2,37	2,26	2,17	2,54	2,42	2,33	2,58	2,45	2,36
47	150	2,86	2,72	2,62	2,99	2,84	2,74	3,11	2,96	2,85	3,33	3,17	3,05	3,38	3,22	3,10
47	175	3,34	3,18	3,06	3,50	3,32	3,20	3,64	3,46	3,33	3,89	3,70	3,57	3,95	3,76	3,62
47	200	3,83	3,64	3,50	3,99	3,81	3,67	4,10	3,96	3,81	4,31	4,16	4,05	4,36	4,21	4,09
47	225	4,21	4,06	3,95	4,35	4,20	4,08	4,48	4,32	4,20	4,71	4,54	4,41	4,76	4,59	4,46
75	175	3,91	3,72	3,58	4,05	3,89	3,75	4,17	4,02	3,90	4,39	4,23	4,11	4,43	4,28	4,16
75	200	4,33	4,18	4,06	4,48	4,32	4,20	4,61	4,44	4,32	4,84	4,67	4,54	4,89	4,72	4,59
75	225	4,72	4,56	4,43	4,88	4,71	4,58	5,03	4,85	4,71	5,28	5,09	4,95	5,34	5,15	5,01

Bridging and Strutting

Bridging between joists is used to stiffen the whole floor and is inserted at intervals according to the joist depth to breadth ratio and depending on the span, either one, two or multiple rows of bridging may be required. For joists with spans over 2.7m intermediate bridging shall be provided at 1.35m spacing. Bridging may be achieved by using:

(a) solid timber, or
(b) timber herringbone strutting.

It is important to note that, at the end of the lines of bridging adjacent to a wall, solid packing pieces will be required between the last joist and the wall.

The use of strutting and bridging can be influenced by design; however in the past much of their requirements were based on empirical experience. Herringbone strutting works well when floor joists are placed in position with slightly higher moisture contents and then as they dry out, shrinkage tightens up the herringbone and the floor joists so that the whole floor acts together.

Bridging should be a minimum of 0.75 times the joist depth.

Bridging should be placed so as to restrain the ends of the floor joists at points of support and can also give support to plasterboard edges. Where joists are built into masonry walls, restraint bridging is normally not necessary but the plasterboard edges will still need to be supported.

Where spans exceed 2.7m, Swift 6 recommends for joists spans over 2.7m that bridging should be at centres not exceeding 1.35m.

Bridging can be used to pick up plasterboard edges (typically at 1.2m centres). However these values do not preclude a designer specifying different requirements.

It is important to note that at the end of the lines of bridging adjacent to a wall, solid packing pieces will be required between the last joist and the wall.

Notching of joists

In normal situations, services in floors will either run parallel to joist spans or, when this is not possible, through the joists themselves. Obviously the reduced depth due to notching or by the provision of holes must be taken into account. Joists may be notched or drilled as shown below; joists must be designed where notching or drilling is outside the limits shown.

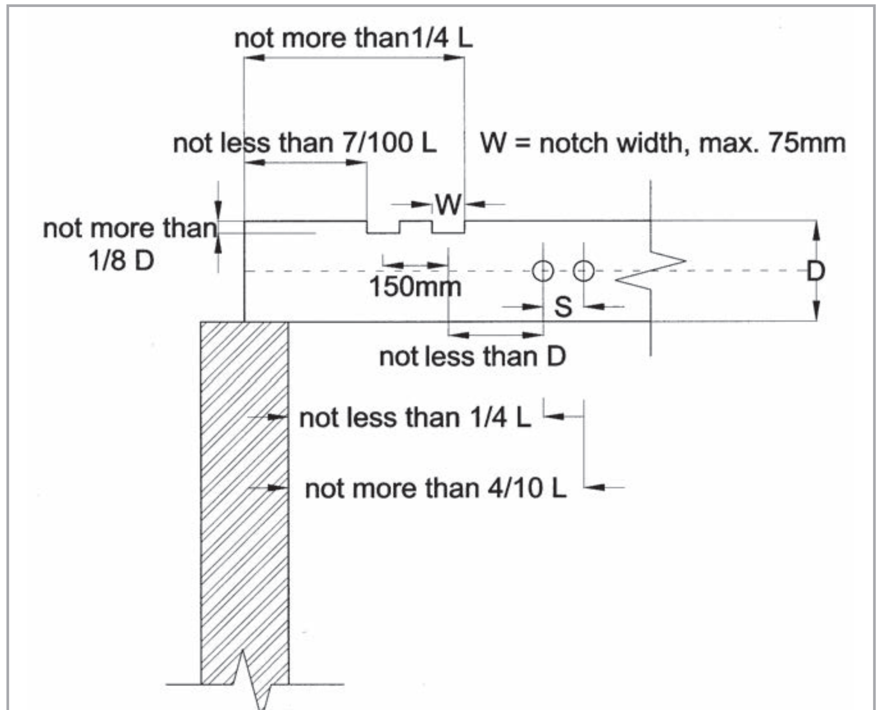


Fig. A 2.1 Notching and drilling

Note: Drilling or notching outside these limits should be designed by an engineer.

A3 Overall stability

Stability is referred to in EN 1990 (Basis of design) as equilibrium and the relevant factors of safety (through the use of partial safety factors applied to the relevant loads) are set out in that standard.

These partial safety factors can be modified by individual member states in their National Annex or possibly in a NCCI (Non Contradictory Complementary Information): currently Ireland has adopted the recommended values in Table A1.2(A) in EN 1990.

For timber construction the most obvious and common application of stability lies in roof uplift.

I.S. 444 only covered heavy concrete tiled roofs and therefore gave little consideration to roof uplift, and did not specify a factor of safety for roof uplift. However, Technical Guidance Document A (Structure) gave information on masonry walls to timber roof and floor connections using metal straps which effectively covered stability for housing using masonry construction under the rules laid out in the TGD.

Swift 6 only gives information on rafter spans for a range of wind loads and does not consider uplift.

For masonry construction it is likely that the wall designer will also have to take account of uplift forces, some of which might be localised.

In the UK BS 5268-3 specified a factor of safety of 1.4 for roof uplift on rafter trussed roofs but this was not taken over into any other standard and was therefore not applied to cut roofs.

Stability was essentially overlooked as timber roofs were considered traditional construction and like Ireland strapping arrangements were given in the Approved Document A (Structure).

The factor of safety of 1.4 is less than that required by EN 1990 and this will result in greater holding down requirements for trussed roofs where designed to Eurocode 5.

Timber frame construction when designed to Eurocode 5 will have to conform to EN 1990 and this too will result in greater holding down requirements. Ireland did use BS 5268-6 (covering timber frame wall design) and this standard was referred to in I.S. 440 (Timber Frame) but I.S. 440 is being revised to conform to Eurocode 5 and therefore design references to BS 5268-6 will be removed.

The factor of safety of a racking wall against overturning is defined as the overturning resistance divided by the overturning moment.

For BS 5268-6 each backing wall under its apportioned wind load should have a factor of safety against overturning of 1.2. In addition the factor of safety of the total racking wall resistance, under the total wind load, should be not less than 1.4.

The resisting moment is provided by permanent or dead loads and any fixings such as anchor straps.

The factor of safety required by EN 1990 typically requires the imposed wind load to be factored by 1.5 and the permanent or dead load to be factored by 0.9 – this essentially results in an overall factor of safety of almost 1.7, ignoring any contribution from fixings and arrangements such as anchor straps.

Typical Restraint Arrangements (Taken from TGD 'A')

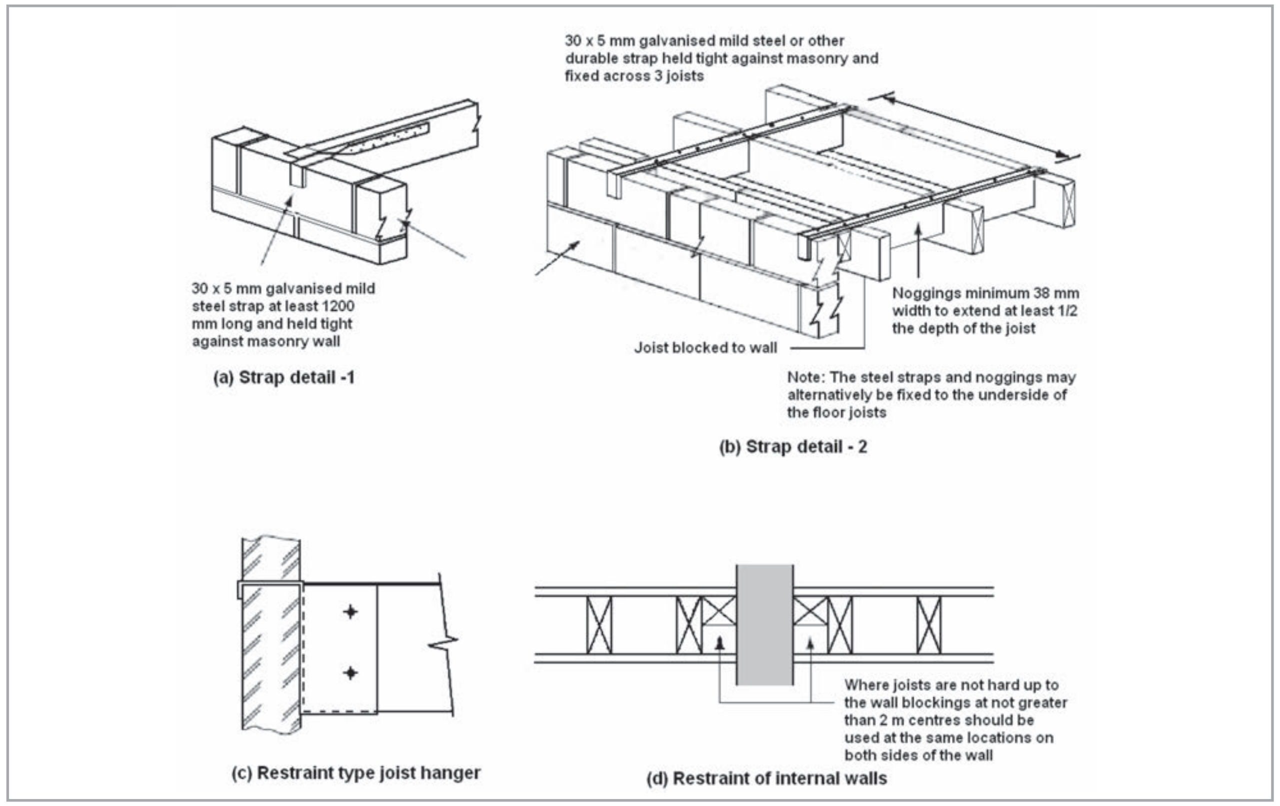


Fig. A 3.1 Lateral support by floors

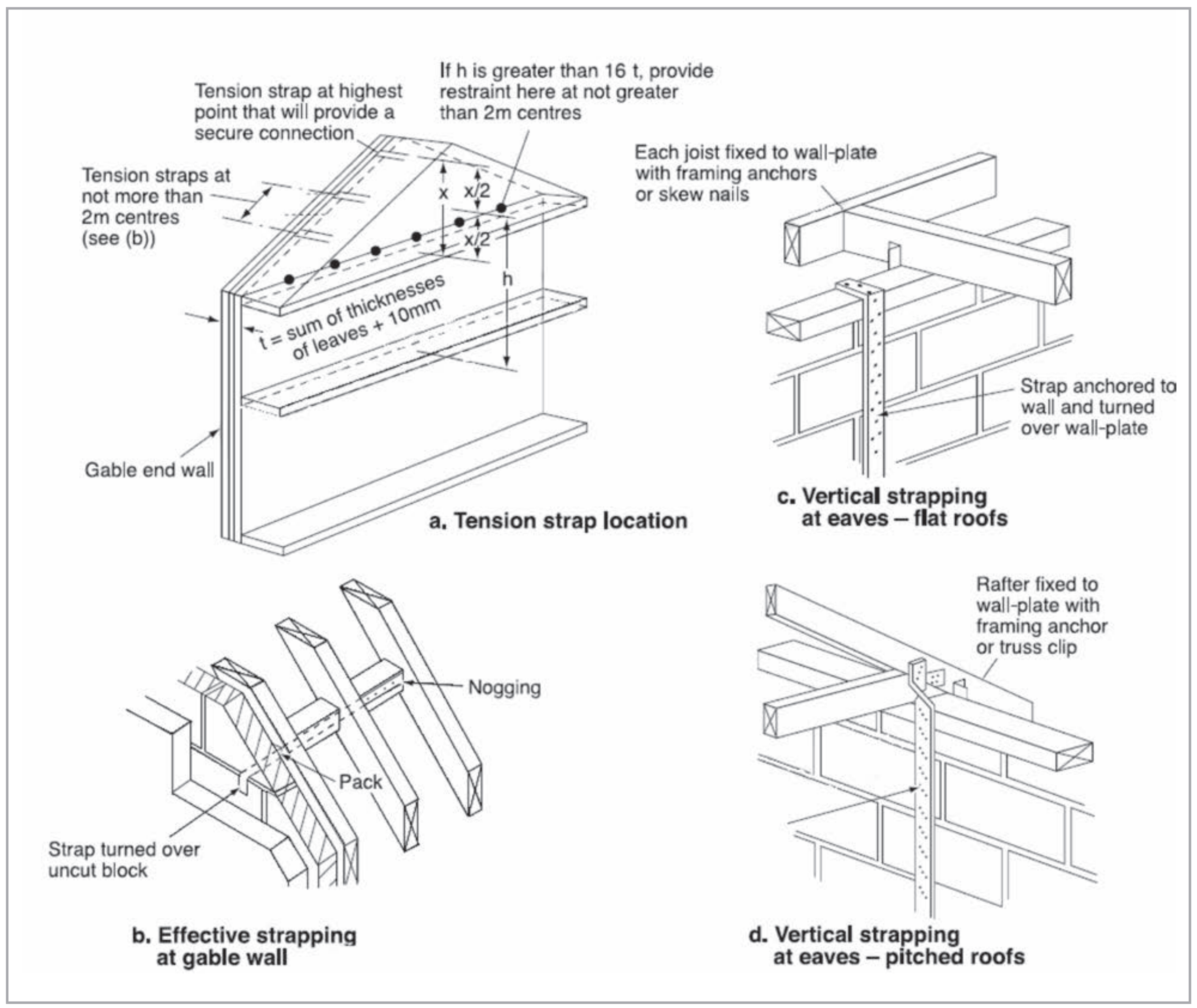


Fig. A 3.2 Lateral support at roof level

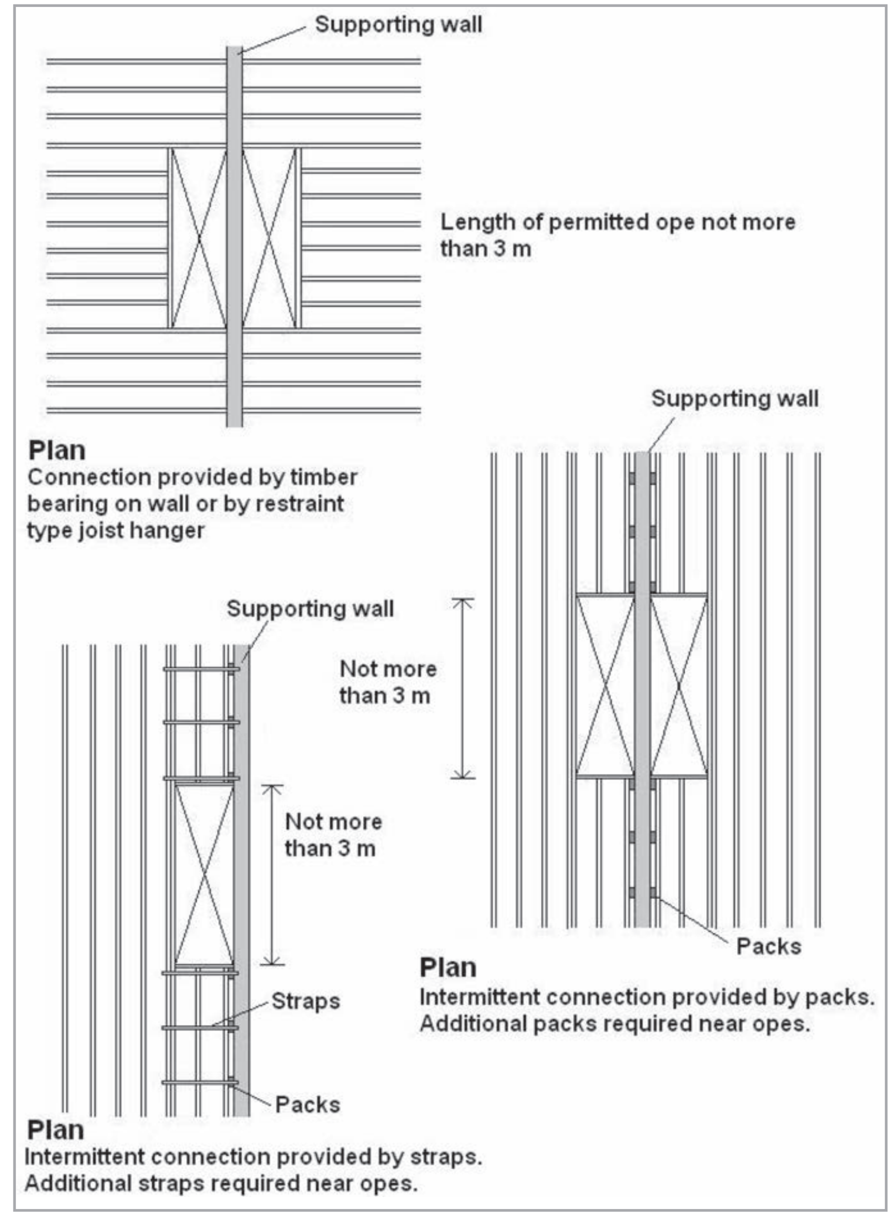


Fig. A 3.3 Interruption of lateral support

Vertical load

In cross wall construction, the floor and roof elements of the structure are supported by the load bearing walls which usually run perpendicular to the front/rear walls, (Fig. 3.4 A). Alternatively, the horizontal elements may span from front to rear with internal load bearing walls also supporting the load (Fig.3.4 B).

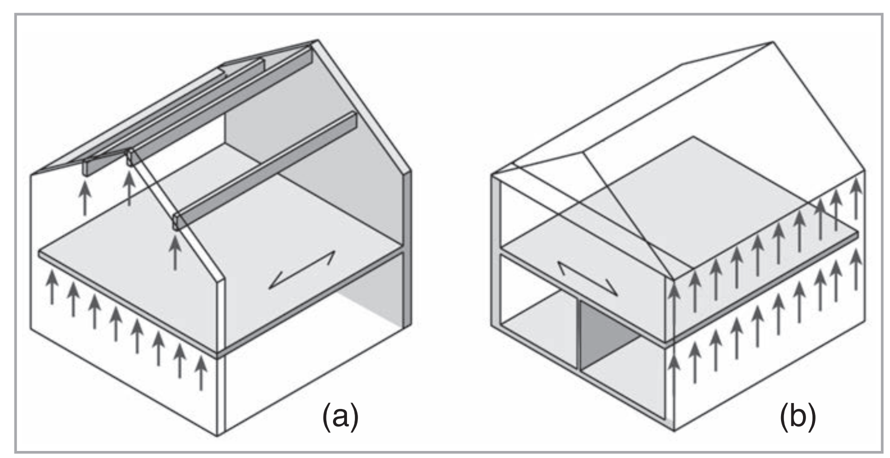


Fig. A 3.4 Vertical Load

Horizontal load

In addition to carrying vertical loads, wall panels may be required to withstand wind forces resulting in shear or racking forces.

Walls subject to horizontal shear or racking forces may need to be restrained from sliding and held down (see fig. A 3.4).

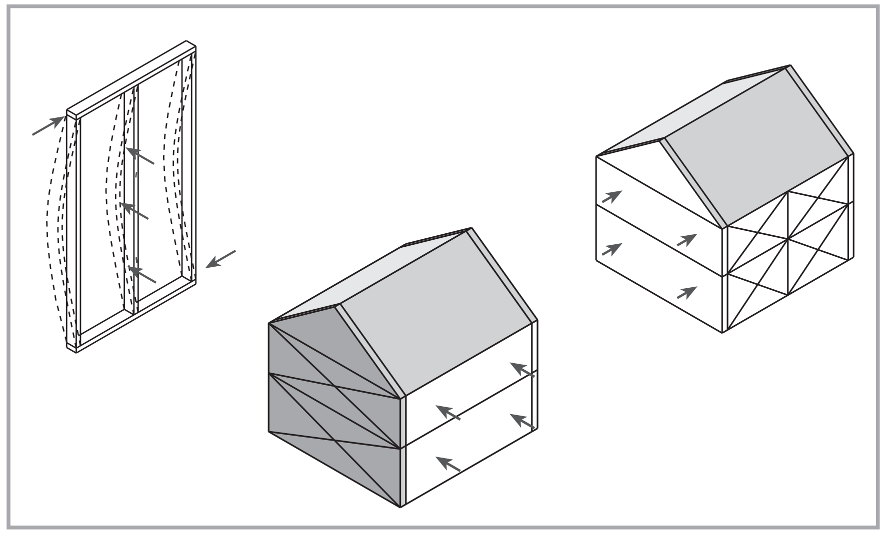


Fig. A 3.4 Horizontal loads

Horizontal diaphragms

Floor, roof and ceiling systems may act as horizontal diaphragms to take loads in their own plane and transfer loads into shear walls.

Figure A 3.5 illustrates such horizontal diaphragms resisting wind loads on a gable wall.

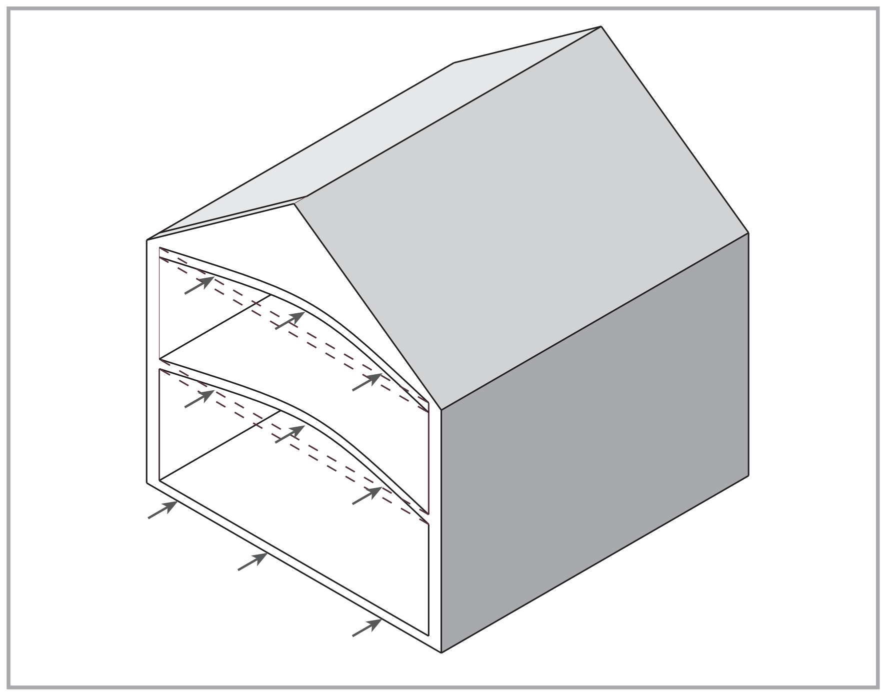


Fig. A 3.5 Horizontal diaphragms

A4 Durability and preservation

Durability relates to the resistance of wood to organisms that cause decay and may be expressed as the time during which wood preserves its usefulness without special protection, such as preservative treatment. The natural durability of a species is greater for the heartwood than for the sapwood; sapwood is rated as perishable or non-durable in both hardwood and softwood species.

In service, fungi and insect attack are the main sources of biological degradation. However, the onset of decay and the rate of decay can be controlled by the correct design and use of wood.

Table A 4.1 *Fungal durability and treatability.ratings*

Species	Durability* (heartwood only)	Treatability (heartwood)	Treatability (sapwood)
Douglas fir (Imported)	3	4	2-3
Douglas fir (Irish)	3-4	4	2
Larch	3-4	4	2
Pitch pine	3	4	1
Redwood (Red deal)	3-4	3-4	1
Norway spruce (Irish)	4	3-4	2
Sitka spruce	4	3-4	2
Western red cedar	2	3-4	3
Whitewood (White deal)	4	3-4	3
Greenheart	1	4	3
Iroko	1-2	4	1
European oak	2	2-3	1
American white oak	2-3	4	1
American red oak	4	2-3	1

The durability and treatability ratings are generally as given in EN 350-2 Part 2. – '*Durability of wood and wood-based products – Natural durability of solid wood.*'
Many other species are also included in this standard. Durability classes (fungi) are rated from 1 (very durable) to 5 (not durable).

Note: this unpreserved durability rating is mainly based on tests for a 50 x 50mm timber section in ground contact. Timber treated in accordance with BS 8417 can achieve a service life of 15-30 years in ground contact - dependent on species and treatment specification. Ground contact should be avoided to further enhance the lifespan of all timbers.

Designing for durability

The main design considerations are to minimise the absorption of water by the wood and to avoid service conditions likely to encourage biological attack. Put simply, wood below a moisture content of 20-22% is immune from decay and is less likely to be attacked by insects.

The end grain of timber absorbs water more readily than side grain. Therefore, the ends of timber should be kept out of situations where water can rise by capillary action. Alternatively, timber should be treated and sealed to reduce moisture uptake. In general, timber should be installed close to the estimated in-service moisture content of the building or structure. Design solutions include:
• Designing to avoid high moisture conditions.
• Selecting timbers that are naturally durable.
• Preservative treating the timber
• Use of metal fixings in accordance with manufacturer's instructions

Why is preservation important?

Except for the heartwood of durable species, wood is not very resistant to attack by fungi or insects; the sapwood of all species is non-durable. Most of the world's old-grown forests have been logged over, and the younger forests or plantations replacing them are being harvested at an early age, resulting in smaller log sizes.

Degradation factors include:
- Plant (bacteria, fungi)
- Animal (insects, marine organisms)
- Climatic
- Mechanical
- Chemical
- Thermal

Degradation can affect wood characteristics such as:
- Appearance
- Strength
- Structure
- Chemical composition

Two types of biological attack:
- Fungal attack which can occur when timber is exposed to high moisture content.
- Insect attack which can occur to a limited extent in fresh timber or to dry timber (mainly sapwood) in service.

Natural durability rating (unpreserved - *applies to heartwood*)

Grade of Durability	Life in Ground Contact (years)
Very durable (1)	>25
Durable (2)	15 - 25
Moderately durable (3)	10 - 15
Slightly durable (4)	5 - 10
Not durable (5)	<5

Design considerations
- End grain shall be typically bevelled and sealed.
- Control condensation by the correct use of insulation and a vapour check.
- Ensure adequate ventilation to avoid the build up of warm damp air.
- Sills, for example, should be adequately bevelled and throated.
- Direct ground contact should be avoided.
- Provide suitable access points for periodic maintenance.
- Where appropriate, utilise corrosion resistant bolts, dowels or steel plate.
- Store all timbers in a manner that avoids prolonged exposure to moisture.
- Avoid water lodgement.
- Take special care at exposed timber joints; design to shed water.

Treatability of wood

Treatability class	Description
1	Easy to treat
2	Moderately easy to treat
3	Difficult to treat
4	Extremely difficult to treat

To maximise the yield from these logs means that it is now an unaffordable luxury to remove all the sapwood, except for a few large-diameter hardwood timbers. Therefore, there is every likelihood that at least some if not all of any parcel of timber will be non-durable or perishable.

Where there is absolutely no risk of fungal decay, i.e. no chance of the timber getting wet and remaining so for some time, then protection from fungal decay is not necessary. Interior timbers, where there is free ventilation and which can be inspected, may be safe, but exposed timbers and interior timbers which are hidden and where ventilation may be limited, or lacking, are not. Woodworm, *Anobium punctatum*, the most common insect species attacking wood in service, will attack dry timber of non-durable species but is more common at higher moisture contents. Modern board materials bound with resin adhesives are generally not attacked. Pretreatment of non-durable species is advised.

How wood preservatives work

For decay and wood-boring insects to thrive requires the basics of food, air, moisture, and warmth. Whereas in normally dry conditions decay fungi cannot survive, woodworm and powder post beetles can. Treating the wood with fungicide, insecticide or a combination of both will render the food source unavailable to these organisms and prevent its deterioration. Application of preservative ranges from brush coating to pressure impregnation. The more comprehensive the treatment the longer and more effective will be the preservative action.

Table A 4.2 *Types of preservatives*

PRESERVATIVE TYPE	DESCRIPTION	PROPERTIES	LIMITATIONS
Tar oil preservative	Consist predominantly of distillates of coal tar, which are commonly known as creosotes.	They are largely water insoluble, are resistant to leaching and are particularly suitable for exterior work. They are not corrosive to metals and can have a protective action on iron or steel. Commonly used for poles and piles.	Has a characteristic odour, which can affect foodstuffs and other materials in their vicinity. Should not be used indoors. May pose a health hazard due to carcinogenic nature of some constituents.
Waterborne preservatives copper-based	These new generation preservatives are copper-based with secondary biocides eg Tanalith E, Copper triazole, ACQ and Celcure AC 500	They are resistant to leaching and therefore the treated wood is suitable for external as well as internal use. After re-drying, treated wood is odourless, clean (albeit coloured grey/green). It can be painted and glued satisfactorily.	Application of waterborne preservatives involves re-wetting the wood being treated, which may cause raising of the grain together with the possibility of distortion, treated timber should be allowed to dry to in service moisture content.
Boron-based preservatives	They are based on water soluble boron compounds such as boric acid, disodium tetraborate (borax), or disodium octaborate, applied by diffusion to green timber.	After application as a simple aqueous solution borate treated wood is clean, non-coloured, non-corrosive and can be stained or glued.	Borates are not fixed in the wood and can become mobile under wet conditions. Not suitable for use in unprotected external or ground contact situations.
Organic solvent preservatives commonly known as light organic solvent preservative (LOSP), and micro-emulsions (water based)	Consist of one or more fungicides or insecticides in an appropriate carrier, i.e. solvent or water-based. May have a dye added for proof of treatment.	Resistant to leaching and usually suitable for both interior or exterior use when coated. When the carrier has evaporated, can usually be painted and glued satisfactorily. LOSP does not cause rising of the grain and can be used without causing movement or distortion.	Not for use in wood in ground contact or below DPC level. Timber intended for external use should receive a surface coating. These solvent based preservatives are only recommended for external joinery protected by a finish. Water based are recommended for internal structural timbers. Allow to dry before painting.

Types of preservatives and their characteristics

Table A4.2 lists preservatives available in Ireland which are grouped into the following categories:

- Waterborne preservatives (EN 599) e.g. Copper triazole or ACQ.
- Organic Preservatives (BS 5707/EN 599), e.g. Prevac, Vac-Vac
- Micro-Emulsion Type Preservatives (EN 599), eg. Prevac, Vac-Vac

The two most widely used methods of preservation are high pressure or low pressure with organic solvent or micro-emulsion preservatives.

High pressure treatment with waterborne preservatives such as Copper triazole and ACQ is required for timbers in ground contact or hazardous locations. In above ground situations pressure treated timber should be allowed to dry to its inservice moisture content. Metal fittings should not be attached to treated timber until the moisture content has fallen to 20% or less.

Organic solvent-based preservation does not affect timber moisture content (no redrying). It does not cause dimensional change to timber sections and has little effect on timber colour. It should be specified for close fitting joinery such as doors and windows. A dye is often added to indicate that treatment has been carried out.

Preparation of timber for preservative treatment

Timber must be sufficiently dry before treatment unless the method is specifically designed to treat freshly felled, green timbers (such methods are the oscillating pressure method and diffusion treatment).

The maximum permissible moisture content for satisfactory preservative treatment has to be below the wood fibre saturation point, generally regarded as 28%. At this point the wood contains the maximum amount of water capable of being held by the wood cell walls without occupying the void spaces which would make it difficult to force preservative fluid into the wood.

For most end uses it is preferable to dry the timber before treatment to the minimum moisture content likely to be achieved in service; this applies especially to such items as exterior joinery where component dimensions and the integrity of the joints can be critical.

Drying the timber is an essential part of the treatment process and checking the moisture content of the timber should always be carried out before impregnation with preservative begins.

The timber must be clean and free of both inner and outer bark, paint and any other surface finish because they are all impermeable to preservation solutions. All cutting, shaping and drilling of timber should, as far as possible, be complete prior to preservative treatment as subsequent working will remove the treated exterior face of timber and may expose untreated timber.

Cut faces should be re-treated. Specifiers should consider timber preservation in a similar light to the protective galvanising of steelwork. No specifier would allow the galvanising to be removed during factory or site work because of the detrimental effect it would have on the steelwork.

The same thought and vigilance should be given to preserved timber. Attempts to rectify this after treatment, for example by brush application, will not necessarily attain the level of treatment originally achieved by the treatment process. This is less important where complete penetration has been achieved, as in the diffusion process.

Sawn timbers, which are thicker than 75mm and resistant to impregnation, will often benefit from an incising pre-treatment if intended for pressure treatment.

Conditioning after treatment

Timber treated with LOSP, or micro-emulsion type preservatives or creosote should be open stacked, preferably under cover in a well-ventilated area to allow the solvent/water to evaporate. The drying process takes 2-7 days or more depending on drying conditions. The EPA requires that low pressure treated timber is held for 24 hours before dispatch. The moisture content should be below 20% before surface coatings are applied.

Timber treated with copper based preservatives require a period of storage before use to ensure fixation of the preservative within the wood (i.e. conversion to water insoluble forms). To allow for this, treated timber should be held under cover at the treatment plant for at least 48 hours to comply with EPA requirements. Pressure treated timber should be allowed to dry to its in-service moisture content before installation.

Table A 4.3 *Treatment processes & effectiveness*

METHODS & PRESERVATIVES	TREATMENT PROCESS	HAZARD CLASS* 1	2	3	4	5	REMARKS
High pressure/vacuum process creosote, copper triazole, copper ammoniacal quaternary ACQ. Also with brown dye. Creosote only in Class 5, or for transmission poles and stud fencing.	The timber is placed in a closed cylinder and immersed in a preservative fluid. A relatively high pressure is applied, usually 10-14 bars for 1-6 hours, which forces the fluid into the wood. This is followed by a vacuum to withdraw excess preservative.	✔	✔	✔	✔	✔	Good penetration of most sapwood but variable penetration of heartwood depending on species. Recommended for use for timbers in ground or water contact especially, and may be used for cladding provided it is redried after treatment. The water base of the preservative can cause raising of the wood grain and possibly some distortion After re-drying the treated wood is odourless but has grey/green colour. It can be painted or stained. Do not fix fittings to the timber until 14 days after treatment — MC is below 20%. If treated timber is liable to become wet and a long service life is required, stainless steel or silicon bronze fastners should be used. For occasionally damp conditions Galvanised or plated fasteners can be used.
Low pressure/double vacuum process LOSP Micro-emulsions	The timber is placed in a treating cylinder and a partial vacuum created and held for several minutes before the cylinder is filled with preservative. The vacuum is released and the timber allowed to remain in the preservative for up to an hour, either under atmospheric pressure or an applied pressure of up to two bar. After the pressure is released and the cylinder drained, a second vacuum is created to recover a proportion of the preservative from the wood and provide a dry surface.	✔	✔	✔ 3A only with a surface coating			Good penetration of most heartwoods. LOSP is suitable for most out of ground locations above DPC level and recommended for fine tolerance joinery. Does not require redrying after treatment or cause raising of woodgrain. It has an odour until solvent evaporates and can be painted or stained. It is colourless. It is critical that all low pressure treated timber receives a surface coating when used in hazard class 3. As with all waterborne preservatives micro-emulsions can raise the grain and cause some distortion so it is recommended to provide for extra drying here with small section sizes.
Diffusion process boron	Applied to 'green' timber which should be well above fibre saturation point. Timber is immersed in concentrated solution of boron compound; then close stacked under cover for several weeks to allow inward diffusion; the timber is then dried.	✔	✔	✔ 3A only with a surface coating			Can be used on 'green' timber above fibre saturation point but requires several weeks to achieve penetration. A disadvantage is that the preservative remains water soluble after drying and where subjected to a regular wetting leaching of preservative will occur. After treatment and drying the wood is non-coloured, non-corrosive and can be painted or stained. Not readily available in Ireland.

*See Table A 4.4

Note: Hazard Classes may also be referred to as Use Classes

European standards for timber preservation

European Standards, covering the production of preservative treated timber have been and are being introduced. They replace the previous process type specification with one based on performance results.

Timber must be fit for the intended purpose. There is a Hazard (Use) Class system which categorises the risk of deterioration to which the timber may be exposed; graded from 1 (insect risk only) to 5 (maximum risk as experienced in a salt water environment).

Table A 4.4 describes these hazard classes and the preservative treatment offered must ensure a good service life when the timber is exposed to the hazard into which it is categorised. Specifiers should check with timber treatment plants and the relevant preservative company's technical departments whether the methods of treatment comply with Irish, British or European standards. Both systems depend on preservative penetration and retention in order to be effective. With either the BS or EN system the specifier must decide:

- the desired durability required;
- the relevant code of practice;
- compatibility with other products.
- the type and method of preservative application.

Table A 4.4 *Hazard (Use) Class and typical service situations*

HAZARD /USE CLASS	HAZARD/USE	PRINCIPAL BIOLOGICAL AGENCY	TYPICAL SERVICE SITUATION	EXAMPLES
1	Above ground, covered Permanently dry. Permanently <18% MC	Insects	Internal, with no risk of wetting	All timbers in normal pitched roofs except tiling battens and valley gutter members. Floor boards; architraves; internal joinery; skirtings. All timbers in upper floors not built into solid external walls.
2	Above ground, covered Occasional risk of wetting Occasionally >20% MC	Fungi/Insects	Internal, with risk of wetting	Tiling battens; *frame timbers in timber frame houses; timber in pitched roofs with high condensation risk; timbers in flat roofs;*ground floor joists; sole plates (above DPC); timber joists in upper floors built into external walls*.
3	Above ground, not covered Exposed to frequent wetting Often >20% MC	Fungi	A- External, above damp proof course (DPC) - coated	External joinery including roof soffits and fascias; bargeboards, etc.; cladding; *valley gutter timbers
			B - External, above damp proof course (DPC) - uncoated	Fence rails; gates; fence boards; agricultural timbers not in soil/manure contact.
4	In contact with ground or fresh water. Permanently exposed to wetting Permanently >20% MC	Fungi	A- Soil contact. Timbers in permanent contact with the ground or below DPC	Fence posts; gravel boards; agricultural timbers in soil/manure contact; poles; sleepers; playground equipment; motorway and highway fencing; sole plates below DPC.
			B - Fresh water contact. Timbers in permanent contact with fresh water.	Lock gates; revetments.
			C - Cooling tower packing Timbers exposed to the particularly hazardous environment of cooling towers.	Cooling tower packing (fresh water).
5	Permanently exposed to wetting by salt water. Permanently >20% MC	Fungi, Marine borers	All components in permanent contact with sea water.	Marine piling; piers and jetties; dock gates; sea defences; ships hulls; cooling tower packing(sea water)

MC = % moisture content of the timber

* These timbers are assigned to a "higher" hazard class than suggested by their location, owing to the potential consequences of failure.

Specification

Specify durability required.

Specify the current Code of Practice.

Specify the type of preservative, and the following:

- Composition of treatment solution
- Condition of timber prior to treatment
- Method of application
- Treatment cycle
- Uptake of preservative

Hazard classes

EN 335:

- Defines five hazard classes with respect to biological attack

Class 1:

- Timber or wood-based product under cover and fully protected from weather and not exposed to wetting

Class 2:

- Timber or wood-based product under cover and fully protected from the weather
- High environmental humidity can lead to some but not persistent wetting

Class 3:

- Not covered
- Not in contact with ground
- Exposed to weather

Class 4:

- In contact with ground or fresh water
- Permanently exposed to wetting

Class 5:

- Permanently exposed to salt water

Penetration Class (mm)	
P1	None
P2	3mm lateral, 40mm axial
P3	4mm lateral
P4	6mm lateral
P5	6mm lateral, 50mm axial
P6	12mm lateral
P7	20mm lateral
P8	Full sapwood penetration
P9	Full sapwood, 6mm heartwood

Guide to specification

The amount of preservative solution absorbed by timber during treatment can vary greatly. Appropriate selection of the preservative formulation and the application process is important for the most effective use of preservative treatment. This in turn depends on the end-use and required performance of the treated component in service (i.e. the appropriate Hazard Class it is subjected to).

European Standards have introduced a system where a defined combination of penetration and retention of preservative must be achieved in the treated wood. The application process is not defined and any process may be used which achieves the desired penetration and retention combination.

The timber species and the environmental service conditions should be assessed with respect to the hazard posed. The classification of service conditions and hazard risk are listed in EN 335, and are shown in table A 4.4. When specifying treatment, identify the hazard class and state that it should comply with it.

A durability flow chart is shown in fig. A 4.1 to assist the designer in the decision making process.

Quality control

The traditional approach to specifying preservative treatment was underpinned by the evidence by the treater (usually in the form of a treatment certificate) that the required treatment schedule has been completed. This will continue to be the case where timber is treated to current standards (at least for the next few years). However, the new European approach will require a demonstration that the treatment used has produced the specified results and this demand can only be achieved through reference to chemical analytical methods.

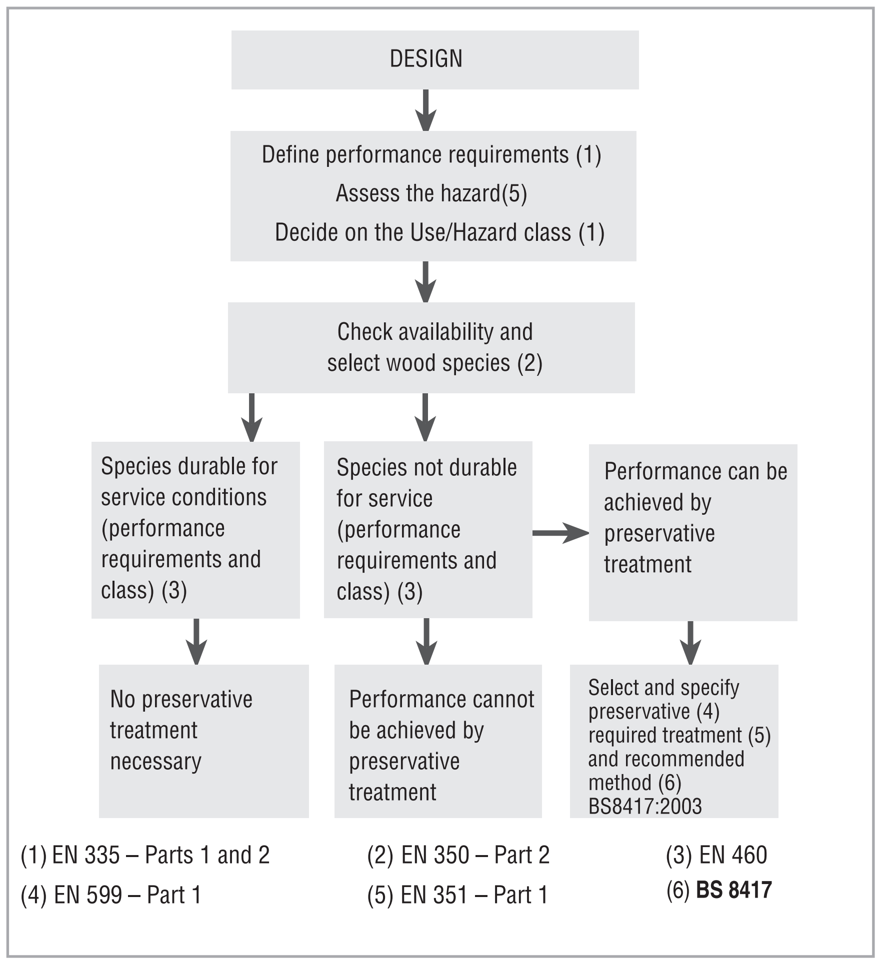


Fig. A 4.1 indicates durability classes and treatability for various timber species.

A5 Fire performance

Timber and its performance in fire can be an emotive issue. In terms of 'spread of flame' and 'heat release' tests, timber performs poorly unless it is treated with flame retardants. However, in one important aspect of performance, namely the maintenance of strength with increasing temperature over time, wood performs well. This is due to the fact that timber chars at a constant rate throughout a fire; the formation of this char protects the un-burnt timber underneath. EN 1995-1-2 (the second part of Eurocode 5) gives charring rates for softwoods and hardwoods (see table A 5.1) and a method of calculating the fire resistance of timber components that is not too dissimilar to that in BS 5268-4. For permissible stress design in the UK BS 5268 Part 4 gives charring rates for softwoods and hardwoods (see table A 5.2) and a method of calculating the fire resistance of timber components that is not too dissimilar to that in BS 5268-4. However the two methods should not be mixed.

How can timber be designed for fire conditions?

Timber is difficult to ignite and once ignited it tends to burn slowly producing a layer of char on the surface. This layer acts as a protective coating for the remainder of the timber, which remains relatively unharmed by the fire. The size and strength of this remaining core can be determined and the section can be designed to carry the load safely for a predetermined period of time.

The main fire performance requirements affecting materials and building elements are Fire Resistance and 'reaction to fire'; similar to the surface spread of flame classification referred to in Technical Guidance Document B (Fire Safety). Technical Document B also refers to limited combustibility and non-combustible materials which are also defined according to fire tests or by reference in the document. It should be noted that the Irish TGD on fire safety is similar to the equivalent UK Approved Documents especially in relation ot fire performance tests but differences do exist but generally the comments here would apply to many buildings in the UK.

Charring rates are related to :

- Density
- Species
- Moisture content
- Shape/Section

Reaction to fire

Technical Guidance Documents B to the Building Regulations classifies buildings according to their purpose group or type of occupancy/usage, for example most domestic dwellings fall into Purpose Group 1a, while apartments fall into Purpose Group 1c. Many of the purpose groups require wall and ceiling surfaces to have a particular performance in relation to reaction to fire (or surface spread of flame classification where BS 476 is referenced) for different locations within buildings. Untreated timber, plywood, particleboard and hardboard usually fall into European Class D-s3,d2 (or approximately surface spread of flame Class 3). However, many timbers can be upgraded by pressure impregnation to meet higher performances but the treatment is expensive and impregnation treatments (as distinct from brush on treatments) are usually only available in the U.K. and on the continent. There are treatments and proprietary boards available from specialist suppliers that meet higher classifications such as European Class B-s3,d2 and Class C-s3,d2 (essentially Class 0 and Class 1). The European Class system is classified using I.S. EN ISO 13501-1 according to test results from I.S. EN ISO 1182 (non-combustibility), I.S. EN ISO 1716 (determination of the gross calorific value) and I.S. EN 11925 (Ignitability when subject to direct impingement of flame). Class 0 is the highest classification and is defined in Technical Guidance Document B (Fire Safety) while Classes 1 to 4 are defined by Fire Test to BS 476 Part 7.

While the two systems are similar they use different test standards. If Technical Guidance Document B is revised and the National System (to BS 476 i.e. Classes 0, 1 and 3) are removed then it probably should not be assumed that a material that was designated under the National System Class 4 automatically meets the European Class.

Fire resistance

Fire resistance relates to three terms, Load-bearing capacity, Integrity and Insulation and in the European standards these three properties are designated by the letters REI. In relation to the specified period of time, load-bearing capacity refers to the ability to carry load, integrity refers to the passage of flame, heat and smoke and insulation refers to the temperature rise on the unexposed face of a wall or floor.

A column would usually only be required to have a fire resistance related to its load-bearing capacity (R) and if necessary the column could be sized to take account of timber lost during fire.

For floors and walls the fire resistance is calculated for the element of construction taking into account the whole construction. Thus plasterboard would protect the timber from fire for a period of time and contribute to all three fire resistance properties (REI); flooring would not contribute to load bearing but (subject to joints being protected) would contribute to integrity and insulation (EI) while the timber member would only contribute to load-bearing (R).

Fire resistance can be determined by testing or by calculation or by assessment if the performance of different materials is known. In most buildings using timber, plasterboard makes an important contribution to fire resistance and not only is the thickness and type of plasterboard important so is its' fixing and it is important that the fixings are properly specified (length and spacing) and checked on site.

Theory of fire

There are two main distinct phases to a fire, the developing phase and the fully developed phase. A material's performance has to be categorised in respect of these two conditions.

The developing phase incorporates a number of separate phenomena, the combustibility of the material, the ease of ignition, the speed of the spread of fire/flame across its surface and the rate at which heat is released.

The ability to resist the fully developed fire is known as fire resistance, in general terms fire resistance relates to an element of construction rather than the material.

The behaviour of solid timber and wood-based materials when subjected to fire is such that it burns, and as such it is termed combustible. This combustible nature of wood and wood-based products can be modified by the use of intumescent coatings. or impregnation with flame/fire retardant salts. While these treatments will not make timber non-combustible, whey will raise the energy level required to cause it to burn.

Ignition of Wood

In general, the higher the density of the wood, the longer it will take the wood to ignite.

Cellulose is one of the main constituents of wood. As the temperature of wood is increased the cellulose begins to decompose, i.e. it is pyrolysed. The first gas produced will be water vapour and as the heating process continues above 100°C, volatile gases are emitted. At 250°C and in the presence of a pilot flame, wood will ignite. However, at a thickness greater than 12mm (approximately) wood cannot support self maintained combustion.

Softwoods contain large quantities of resins and when exposed to heat these resins vapourise rapidly. Softwoods have a more open cellular structure and lower density than most hardwoods, and the combustible vapours are distilled from softwoods at lower temperatures than from hardwoods. This is one of the factors which account for the difference in the ignition temperatures of various woods.

The onset of pyrolysis in timber is marked by a darkening of the timber and the commencement of emission of volatile gases, the reaction becomes exothermic and the timber reverts to a carbonised char popularly known as charcoal (fig. A 5.1).

The volatiles, in moving to the surface, cool and char and are subsequently ejected into the boundary layer where they block the incoming convective heat. This most important phenomenon is known as 'transpirational cooling'. High surface temperatures are reached and some heat is ejected by thermal radiation. The surface layers crack badly both along and across the grain and surface material is continually being lost. A steady state is reached where a balance exists between the rate of loss of surface and the rate of recession of the undamaged wood. Refer to tables A5.1 and A5.2 for common charring rate.

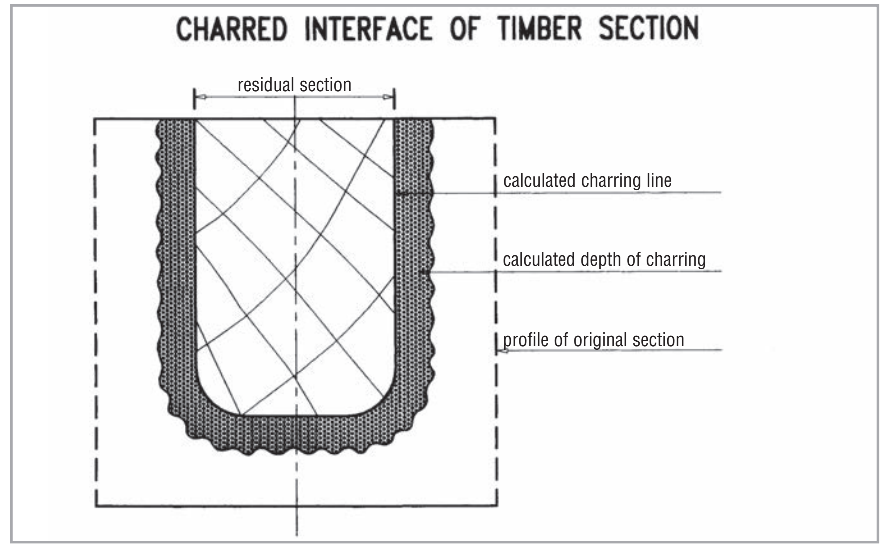


Fig. A 5.1 Charred interface of timber section.

The formation of char:

The formation of char protects the unburnt timber which may be only a few millimetres from the surface. Failure of a beam or strut will occur when the cross-section area of the unburnt core becomes too small to support the load. By increasing the dimensions of timber, it is possible to guarantee structural integrity in a fire for a given period of time. This is sometimes called the 'sacrificial timber' method. The performance of timber in fire is predictable and generally stable compared with for example steel, where sudden buckling failure can occur due to the expansion and softening of steel members in a fire.

Design

The charring rates in tables A5.1 and A5.2 are taken from EN 1995-1-2 and BS 5268-4 and can be used in conjunction with those standards for a relatively simple fire design. A constant charring rate is assumed for calculation of the fire resistance of the section.

It is wise to bear in mind that fire resistance is defined as the ability of an element to carry on performing a building function in spite of being exposed to a fully developed fire. It is thus a property of the elements of building construction, not materials. Different timbers char at varying rates, largely as a function of their density, with the higher density timbers charring more slowly.

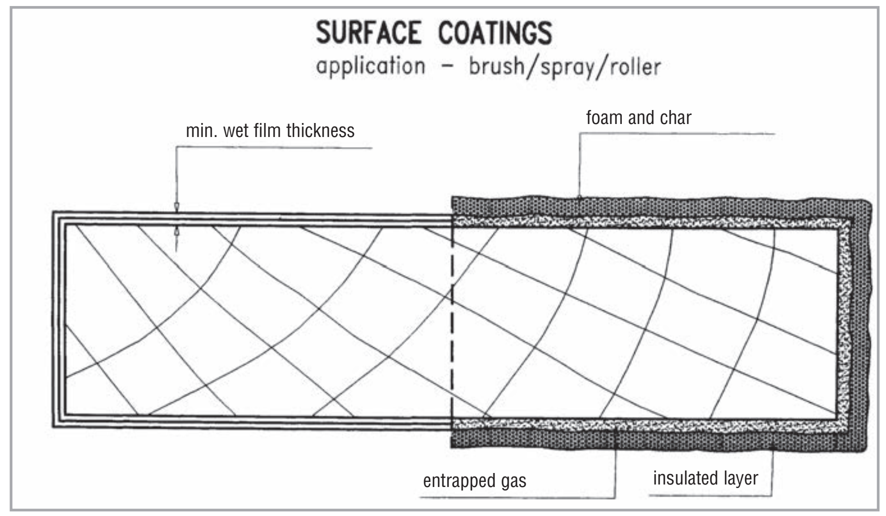


Fig. A 5.2 Effect of fire on treated wood

Flame-retardant treatment

Flame-retardant treatments are utilised to reduce the surface spread of flame which enables timber and wood-based panels to be used for many applications for which they would otherwise not be used in the untreated state.

There are two types of treatment:

(a) impregnation with inorganic salts or leach-resistant chemicals;
(b) surface coating.

Table A 5.1 *Design charring rates β_0 (to be used with EC5 only)*

MATERIAL		β_0 in mm/min
Solid softwood	with $\rho_k \geq 290$ kg/m^3 and min $a_o \geq 35$mm	0,8
Glued laminated softwood	with $\rho_k \geq 290$ kg/m^3	0,7
Wood panels	with $\rho_k \geq 450$ kg/m^3 and $t_p = 20$mm	0,9
Solid hardwood	with $\rho_k \geq 450$ kg/m^3	0,5
Glued laminated hardwood	with $\rho_k \geq 450$ kg/m^3	0,5
Oak		0,5
Solid hardwood	with $\rho_k = 290$ kg/m^3	0,7
Glued laminated hardwood	with $\rho_k = 290$ kg/m^3	0,7
Plywood	with $\rho_k = 450$ kg/m^3 and $t_p = 20$mm	1,0
Wood-based panels	with $\rho_k = 450$ kg/m^3 and $t_p = 20$mm	0,9
Where ρ_k = characteristic density of the material; a_o = width/depth of cross section; t_p = thickness		

Table A 5.2 *Notional rate of charring for the calculation of residual section, (from BS 5268:Part 4).*

Species	Charring. in 30 min. mm	Charring in 60 min. mm	Charring rates mm/min.
(a) Structural timbers listed in BS 5628 Pt 2 other than (b) and (c)	20	40	0.67
(b) Western red cedar	25	50	0.83
(c) Oak, utile, keruing, teak, greenheart, jarrah	15	30	0.50

Specifications for fire-treated timber

A specification for treatment of wood or a timber product should include references at least to the following data:

1. The species of wood or type of timber product;
2. The name of the treatment to be applied;
3. The nature of the treatment – and in the case of a paint – its colour and, where known, the loading and dry film thickness;
4. The method of application of the treatment;
5. The test or regulation to which the treated product must comply.

Fire door sets

Designs for timber fire doors sets are available for periods of 20, 30 and 60 minutes. When specifying a fire door it is essential to check with the manufacturer that the doors comply with EN 1634 Parts 1 to 3 as necessary (for designs to BS 5268 the relevant standard is BS 476 Part 22) for the specified minimum fire resistance. Fire doors are likely to need an intumescent strip to be positioned in the door or door frame (or door lining) to achieve the specified performance.

Any reference to a fire door set is intended to mean a complete door assembly which includes the door leaf, door frame, ironmongery and any seals.

The performance of a fire door critically depends on the correct installation of the complete door assembly, strictly in accordance with the terms of the relevant test certification supplied by the door manufacturer.

All fire doors should be classified in accordance with BS EN 13501-2: 2003, Fire classification of construction products and building elements, Part 2 - Classification using data from fire resistance tests (excluding products for use in ventilation systems). They are tested to the relevant European method from the following:

I.S. EN 1634-1: Fire resistance tests for door and shutter assemblies, Part 1 - Fire doors and shutters;

I.S. EN 1634-2: Fire resistance tests for door and shutter assemblies, Part 2 - Fire door hardware;

I.S. EN 1634-3: Fire resistance tests for door and shutter assemblies, Part 3 - Smoke control doors and shutters;

An additional classification of Sa is used for all doors where restricted smoke leakage at ambient temperatures is needed for tests to BS 476: Part 22.

The method of test exposure in either case is from each side of the door separately, except in the case of lift doors which are tested from the landing side only.

An example of a European specified fire door for 30 minutes is E30, or E30 Sa where resricted smoke is required (E stands for integrity). An example of a similar BS 476 specified fire door is FD 30 and FD 30S.

Manufacturers' product data sheets often provide a suggested wording for a treatment specification relevant to their product.

Note:
It is important to consider the fire resistance of the element as a whole as well as the fire resistance of the materials used to make up the element.

Fire stops
Every joint, imperfection of fit or opening should be fire stopped where required.

Technical Guidance Document B

- B1 Aims to ensure that a satisfactory means of escape is provided for persons in the event of fire in a building;
- B2 Aims to ensure that fire spread over the internal linings of buildings is restricted;
- B3 Aims to limit internal fire spread, that there is a sufficient degree of fire separation within buildings and between adjoining buildings, and to inhibit the unseen spread of fire and smoke in concealed spaces in buildings;
- B4 Aims to ensure that external walls and roofs have adequate resistance to the spread of fire over their external surfaces, and that spread of fire from one building to another is restricted; and
- B5 Aims to ensure that satisfactory access is provided for fire appliances to buildings and facilities in buildings to assist fire fighters in the protection of life and property.

Building regulations
The Irish Building Regulations, Part B sets out the requirements in respect of fire safety in all buildings. Technical Guidance Document B provides general guidance on how these requirement can be complied with (the UK has a similar structure in terms of Building Regulations and Approved Documents). It is divided into five main parts:

- B 1 Means of escape in case of fire;
- B 2 Internal fire spread (linings);
- B 3 Internal fire spread (structure);
- B 4 External fire spread;
- B 5 Access and facilities for the fire service.

Although timber members can be designed for full exposure in a fire situation, it is more common for the timber to be concealed by other building materials (e.g. plasterboard). Where these materials have fire resistance themselves they may be taken into account in determining the fire resistance of the element as a whole.

A fire stop is a seal provided to close an imperfection of fit or design tolerance between elements or components, to restrict or prevent the passage of fire or smoke. Rock fibre as distinct from glass fibre is frequently used as a fire stop. Smoke seals can be provided as required around doors.

Fire safety certificate
In Ireland, the Building Control Act 1990 and the Regulations made subsequently require that the designer shall obtain a Fire Safety Certificate from the Local Authority if the proposed works include the following.

(a) the erection of a building, except a dwelling house (other than a flat);
(b) the material alteration or extension of a building;
(c) a material change of use of a building.

It is a requirement to submit to local Building Control Authority, if requested, calculations, specifications and drawings showing that the buildings or works would comply with the requirements of Part B of the First Schedule to the Building Regulations.

Usually an experienced architect, engineer or fire consultant with specialist knowledge is required to make the application. It is advisable to discuss any proposed upgrading of timber (for both flame retardant and fire resistance) with the Fire Officer when applying for the Fire Safety Certificate and to make sure that the product has been tested to the European Standards if they are the referenced standards.

A6 Architectural criteria

Structural timber (softwoods and hardwoods) can be used to enhance the overall design. Features of timber such as knots, grain, colour and texture can be expressed visually as an integral part of the design.

Specification
Visually expressed timber will require special considerations in the following areas:

- Large solid timber sections will have defects such as knots, splits, checks, and shakes. Limits on their sizes may need to be specified.
- Laminated sections for exterior use generally utilise phenol resorcinol formaldehyde adhesive, which tends to leave a thin black line along the lamination. Clear glues are also available.
- Location of finger joints, scarf joints or butt joints may need to be restricted.
- Concealed joints are typically specified e.g. to hide steel plates in glulam members.
- Recessed connections are commonly plugged with machined timber dowels on the exposed face.

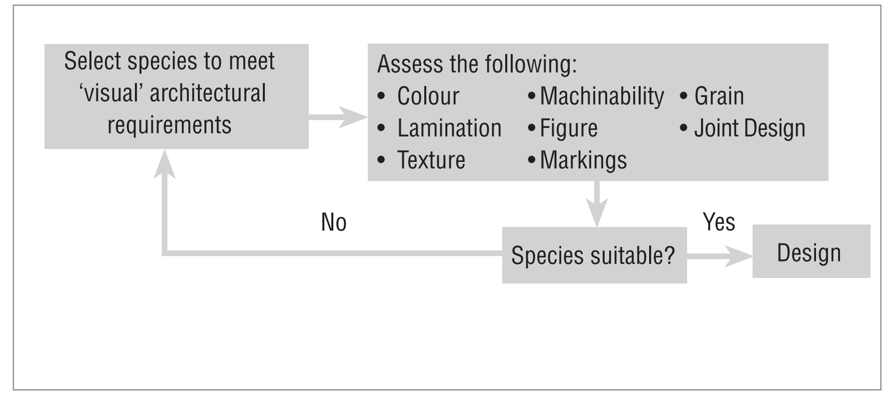


Fig A6.1 Architect's flowchart

Species selection
Certain timbers are noted for specific properties - balsa for lightness, teak for stability, greenheart for resistance to marine borers - but, in terms of suitability for the use identified, it is prudent to ensure that all the relevant criteria are met by the properties of the timber. In identifying these criteria there may be one overriding factor which determines which timber to select, but more often there are a number of criteria which need to be considered.

Table A 6.1 *End-use criteria*

END USE	CRITERIA
Structural timbers	Strength, good strength to weight ratio, toughness, workability, appearance, nail holding properties
Joinery	Workability, good machining properties, stability, good finishing properties, durability, treatability and appearance.
Furniture	Appearance, workability, good machining properties, good finishing properties, good strength to weight ratio.
Flooring	Wear resistance, appearance, good machining properties, stability.
Fencing	Durability or treatability, good nailing properties, strength and appearance stability.
Cladding	Machinability, good finishing properties, durability, treatability, appearance and stability.

Visual Characteristics

Colour
Wood comes in a variety of natural colours and colour differences exist even between individual boards. Wood exposed to the atmosphere frequently darkens. Long exposure of light coloured woods to sun or rain may cause distinct colour changes.

Grain
This generally refers to the direction of the fibres in the wood.

Texture
This is defined as the relative size and amount of variation in size of the cells. It is defined typically as coarse, medium or fine.

Figure
This is used to describe the natural pattern on the wood surface. While the figure of normal wood may be pleasing, more attractive figure may, in some cases, be produced by natural abnormalities, however for structural reasons these are generally not allowed.

Processing Defects
These arise from machining, finishing and handling.

Markings
Where end use requires markings to be omitted for aesthetic reasons each parcel of timber of a single grade should be despatched under the cover of a compliance certificate stating the following minimum information:
- Serial No. and date of certificate
- Both the grading company's and customer's name and address
- The purchase order number
- Timber dimensions and quantities
- Date of grading
- Signature of grader, countersigned by the supervisor
- The standard, strength class and species

- BS 4978, EN 14081-1, and I.S. 127 give specific requirements relating to marked and un-marked timber

Decorative timbers
- Quartered oak
- Flat sawn ash
- Walnut
- Fiddle back sycamore
- Bird's eye maple
- Yew
- Western Red Cedar

Timber ranges from bland to highly figured, from blonde to black. Even timbers of a fairly uniform colour can show attractive figure due to the presence of growth rings. How the wood is presented can affect how its decorative features are displayed. Oak is generally a uniform pale brown but it has very prominent rays so that if quarter sawn or sliced the rays show up as contrasting wavy bars across the vertical stripes of the growth rings and pores.

Decorative timbers can be used in plank or veneer form. Veneers, bonded to a backing panel, are normally used for decorative panels. Furniture and joinery can also incorporate veneered panels. Use of contrasting woods, as laminates or inlay, can enhance items of furniture.

An important aspect of the use of veneers is that when a veneer is bonded to the face of a panel there must be a balancing veneer bonded to the back, otherwise distortion of the panel is likely to take place.

Aspects of the structure of timber which contribute greatly to its decorative value are distortion of grain (walnut forks), waviness of grain (wavy grain, fiddle back), and dimpling of grain (bird's eye).Variation in colour may be caused by soil conditions or even bacterial or fungal infection of the wood (e.g. spalted beech, brown oak) and with some species there can be a plain strong colour, or it may be striped through with a lighter shade (e.g. ebony).

Table A 6.2 *Sample species selection*

Species	**Density kg/M³**	**Texture**	**Moisture movement**	**Working qualities**	**Durability ***	**Colour**	**Common Uses**
Ash	670-710	Medium/Coarse	Medium	Good	5	White-Brown	Interior joinery
Alder	500	Fine	Medium	Good	5	Pale Red-Brown	Interior joinery
Balau, yellow	980	Medium	Medium	Medium	1-2	Yellow-Brown	Marine decking
Beech	720	Fine	Large	Good	5	White-Brown	Furniture
Birch	600	Fine	Medium	Good	5	White-Brown	Furniture
Cherry	580-630	Fine	Medium	Good	3 - 4	Red-Brown	Interior joinery
Douglas fir	530	Medium	Small	Good	3 - 4	Pink-Brown	Exterior joinery
Ekki	1070	Coarse	Large	Difficult	1	Dark-Brown	Marine works
Iroko	660	Medium	Small	Medium	1 - 2	Yellow-Brown	Exterior joinery
Keruing	740	Medium	Large	Difficult	3	Dark-Brown	Vehicle flooring & decking
Larch	560-590	Fine	Small	Medium	3 - 4	Red-Brown	Boats, poles
Sapele	560-650	Medium	Medium	Medium	3	Dark red-brown	Interior & exterior joinery
Maple, hard	740	Fine	Medium	Medium	5	Creamy-White	Flooring, furniture
Maple, soft	650	Fine	Medium	Medium	5	Creamy-White	Furniture
Oak, red	740	Medium/Coarse	Medium	Medium	4	Yellow-Red	Interior joinery, flooring
Oak, white	670-770	Medium/Coarse	Medium	Medium	2 - 3	Yellow-Brown	Exterior and interior joinery
Pine, pitch	670	Medium	Medium	Medium	3	Yellow-Red	Exterior and interior joinery
Pine, Scots	510	Medium	Medium	Good	3 - 4	Yellow-Brown	Joinery
Pine, yellow	420-560	Medium	Medium	Medium	4	Yellow-Brown	Interior joinery
Southern yellow pine**	550	Medium	Medium	Medium	4	Yellow	Joinery
Spruce, Sitka	410	Coarse	Small	Medium	4	Pink-Brown	Studding, pallets
Spruce, Norway	400-500	Medium	Small	Good	4	White-Brown	Interior joinery
Teak	660	Medium	Medium	Medium	1	Gold-Brown	Exterior and interior joinery
Walnut	560-660	Coarse/Medium	Small	Good	3	Dark-Brown	Furniture
Western Red Cedar	390	Coarse/Medium	Small	Good	2	Red-Brown	Exterior cladding
Tulipwood	450	Fine	Medium	Good	5	Yellow-Brown	Furniture and mouldings
Utile	650-690	Medium	Medium	Good	2 - 3	Red-Brown	Joinery
	Note: Oak and western red cedar are acidic timbers and will corrode metals in damp conditions. Use only stainless steel or silicon bronze fitttings externally.						

*** Durability is the resistance of the heartwood to fungal attack as listed in EN 350-2. Durability classes (fungi) are rated from 1 (very durable) to 5 (not durable).**

**** Southern yellow pine is derived from the same species as pitch pine, but is fast grown and contains a high proportion of sapwood. Preservative treatment is needed for exterior applications.**

A7 Building systems

7.1 TIMBER FRAME

Timber-frame construction is a prefabricated factory manufactured building system, which can be transported to site in a flat pack or volumetric units and assembled on site. The NSAI operate the Timber Frame Manufacturers' Approval Scheme and maintain a National Register of approved timber frame manufacturers.

The Irish Agrément Board (IAB) have certified a number of building systems and products that may be suitable for timber frame construction. Similar approval and certification procedures exist in the U.K. through for example TRADA, the British Board of Agrément and BRE. The approval of manufacturers, products and building systems does not necessarily extend to buildings and their design, installation, use and construction as these are often site and workmanship related. The certification of buildings is usually undertaken by project architects and engineers.

Typically a system can be one of four methods;
(a) platform frame
(b) balloon frame
(c) volumetric or
(d) post and beam

The most common method used in Ireland and the UK is the platform method.

Stick building (the cutting of timber and the manufacture of panels on site) is not recommended due to the extended period of exposure to the weather and the difficulty of obtaining the necessary tolerances and workmanship and perhaps more importantly the difficulty of certifying the building.

A system will typically consist of the following structural elements:

Roof: Can be either prefabricated timber trussed rafters or roof panels
Walls: Timber framing. External walls incorporate a breather membrane, sheathing timber studs, insulation, a vapour check and an internal lining such as plasterboard.
Floors: Ground floors can be either concrete or suspended timber floor panels. Prefabricated timber floor panels are usually used for subsequent floors.

In Ireland I.S. 440 (Timber Frame Dwellings) was published in 2009 and covers the main requirements of timber frame construction:

- Responsibilities
- Materials
- Design
- Manufacture
- Construction details
- Site work
- Services

While the standard is applicable to dwellings including apartments much of the standard can be applied to other buildings. Revision on the standard commenced in 2010, mainly to comply with Eurocode 5 but it is proposed to include other building uses in its title and content.

Structural design

Timber frame structural elements should be designed in accordance with IS 440 which refers to Eurocode 5 and BS 5268; however, following its revision it is anticipated that only Eurocode 5 will be referred to. Roof trusses should be designed to Eurocode 5 and when published, Swift 5 will give some further guidance on roof trusses. Swift 6 (due to be published In 2012) contains load span tables to Eurocode 5 and the Irish National Annex for floors, ceiling ties, rafters and purlins amongst other elements.

In the UK, at least for the present, it is likely that designs will continue to be carried out to BS 5268 (Parts 2, 4 and 6) and BS 5268: Part 3 (for trussed rafters). However, designs can be carried out to Eurocode 5 with the UK National Annex and PS 6693 gives some additional guidance on designs to Eurocode 5.

Timber wall panels should be designed for vertical loads (due to roof and floor elements) and for horizontal loads (from wind). The main design criteria are racking resistance, sliding and the overall stability of the walls (overturning). Wind loads are transferred through floors and roofs acting as horizontal diaphragms connected to shear (or racking) walls and on into the substructure. The overall design must be undertaken by a qualified engineer and most timber frame manufacturers usually employ an external consulting structural engineer. The overall design package supplied by the timber frame manufacturer will typically include design calculations, structural drawings, assembly and site details (such as a Site Fixing Schedule) and if required most manufacturers would offer site supervision and certification.

Durability

For designs based on Eurocode 5 reference should be made to I.S. EN 335 (Parts 1, 2 and 3), I.S. EN 350-2, I.S. EN 351-1 and I.S. EN 460, to determine the requirement for preservation treatment.

I.S. 440 requires that timber softwood components in external wall panels (excluding sheathing) should be treated with a suitable timber preservative. These components include:

- timber framing including studs, I-studs, top rails and bottom rails;
- head plates;
- sole plates;
- timber cavity barriers; and
- cladding battens.

Other timber components e.g. header joists may require preservative treatment if so specified.

Where timber treated with preservative is cut on-site, all cut ends shall be liberally brush treated with a suitable preservative.

For designs based on BS 5268-6 reference should be made to BS 8417 for information on the preservation of timber. BS 8417 also gives good advice in relation to timber treatment and durability requirements for designs to Eurocode 5.

The preservative manufacturer's technical recommendations should always be complied with.

Where non-durable timbers are exposed to the weather (e.g. soffit and barge boards) they should be treated with an appropriate wood preservative. External timber cladding has specific requirements and traditionally has been made from durable timbers such as cedar.

Notes:

Softwood timber should usually be considered as perishable due to the presence of sapwood.

In Ireland and the U.K. softwood timbers in the external wall panels and timber cavity barriers have traditionally been pressure treated with a preservative.

The sapwood of all timber species is non-durable.

Some preservative treatments may leach out unless the timber is sealed.

Fire performance

Most building elements (walls, beams, floors etc.) are required to attain a level of fire resistance. Fire resistance is generally achieved by a combination of internal lining materials, the timber structure and in some cases insulation.

In addition it is necessary to provide cavity barriers around openings in the external wall, at the top of external walls, at the ends of party walls and depending on

the purpose group, to limit the cavity distances. In addition continuous vertical fire stops should be placed at the ends of party and compartment walls and horizontal fire stops at floor level within the cavity of any party or compartment wall. For precise requirements for cavity barriers and fire stops refer to I.S. 440 and Technical Guidance Document B (Fire Safety) and for the U.K. the equivalent U.K. Approved Document.

Gaps in a fire resisting component will require fire stopping and suitable materials (preferably ones that have been fire tested) must be used.

It is also necessary to control the spread of flame across surfaces of walls and ceilings and these requirements are set out in TGD B and the equivalent U.K. Approved Document.

Note:

Designs to Eurocode 5 must refer to EN fire test standards; designs to BS 5268 should refer to fire test standards such as the appropriate part of BS 476. The EN fire tests are generally considered to be slightly more severe than the equivalent BS 476 part.

In Ireland compartment floors are required to have a service cavity under the main fire and acoustic linings. A similar requirement exists for party and compartment walls where services are on those walls. It is recommended that a service cavity should be placed on a wall where future services might be installed on that wall.

Quality of materials

Materials sourced by the timber frame manufacturer must be subject to the company's quality control procedures. Timber should be visually strength graded in accordance with IS 127 (or in the U.K. BS 4768) or machine graded to EN 14081-4. Marking should comply with IS 127 and/or EN 14081-1.

OSB and plywood are the most commonly used sheathing materials used in timber frame; OSB 3 should be used and should comply with EN 300 while plywood should comply with EN 636 (type 2 or 3). Other materials can be used for sheathing providing they are suitable; see I.S. 440 and for the U.K. BS 5268 parts 2 and 6. In I.S. 440 attention is drawn to the need to check that the satisfactory performance of wall ties, cavity barriers and fire stops where other sheathing materials to OSB or plywood) are used. Care should be taken about the source of sheathing and that it is properly certified.

Fixings should be corrosion resistant and comply with Eurocode 5 or BS 5268 for designs to that standard.

The breather membrane should have a vapour resistance not greater than 0.6 MNs/g and be suitably durable. Breather membranes should have appropriate certification; membranes conforming to type 1 or type 3 of BS 4016 are considered suitable.

Wall ties, anchor straps and similar products should conform to EN 845-1 (largely in relation to references to testing and the appropriate standards). In terms of durability, these products (and their fixings) should be made from austenitic stainless steel or a material with a similar durability. The products should be marked identifying the manufacturer and the wall tie or strap type. For wall ties the manufacturer should provide information on the wall tie spacing and wind forces which should be related to cavity widths.

Proprietary cavity barriers should have been fire tested (to EN 1364 or BS 476-22 for designs to BS 5268. They should be marked with the manufacturers' name and the range of cavity widths for which they are suitable and be protected by a suitable material from moisture and site damage. More information is contained in I.S. 440. Timber cavity barriers should be treated with a suitable preservative, have a minimum thickness of 38mm and fill the wall cavity (for masonry mortar or another suitable material may need to be used to fill any gaps. Timber cavity barriers will need a DPC between the barrier and the masonry; polythene (made from un-recycled plastic) with a minimum thickness of 0.24mm (1000 gauge) is considered suitable.

The vapour control check (VCL) should have been tested to EN 1931 and EN ISO 12572 and should not be made from recycled materials; where the vapour resistance is less than 250 MNs/g a condensation risk analysis should be carried out to EN ISO 13788. Un-recycled polythene with a thickness of 0.12mm (500 gauge) is considered suitable for use as a VCL.

Generally proprietary materials should be fixed in accordance with the manufacturers' instructions unless specified otherwise (e.g. by the project architect or design engineer).

I.S. 440, Eurocode 5 and BS 5268 give further information on materials,

Thermal insulation

U-values are a measure of the thermal performance of a building element (essentially the building envelope - wall, floor, roof, window or door) and Technical Guidance Document L (TGD L) gives advice on the U-values levels as well as general energy conservation. There are two documents; one dealing with dwellings and one dealing with other building types.

Guidance is given on CO^2 emissions, energy consumption, air tightness (including the air permeability of the building envelop), mechanical ventilation, the use of renewables (e.g. solar power), cold bridging, fabric insulation (i.e. U-values) as well as requirements on the efficiency of gas and oil boilers (a minimum of 86% efficiency). Limits are placed on U-values (for various elements) which are weighted (designated Um); some relaxation is allowed on the weighted values and these values are also given.

Timber frame can provide very high level of thermal insulation by the placement of insulation between the timber framing and the plasterboard lining and the timber sheathing. Typically timber frame manufacturers use a 140mm stud fully filled with glass fibre insulation to achieve the required U value. However, walls can easily be insulated to higher levels by using deeper studs or better performing insulations (such as the polyurethane foams). In addition, as the insulation in timber frame construction is fully covered and is shielded from air movement in the wall cavity, the performance of the insulation tends to be superior to those building methods that place insulation directly in the wall cavity.

Standard timber frame construction usually performs well in relation to air tightness and building fabric air permeability. However, attention is drawn to the need to check that the bottom of walls (especially where they sit on masonry walls) are sealed and that there are no gaps around windows and doors or at upper floor levels between the wall panels and floor panels.

Platform method

The platform method is the most commonly used method for domestic timber frame construction. Each storey is erected as a separate operation with the floor deck of one floor becoming the erection platform of the next. Wall, floor and roof panels are of a size that can be manhandled into position, often with the help of a crane.

The construction details of Section B concentrate only on the platform method. Panels may be continuous, full wall length or shorter separate panels nailed together and tied together with head binders. External walls are usually sheathed with plywood or OSB fixed to the external face of the wall panel frame. The outer face of the sheathing is covered with a breather membrane properly lapped over fixed with austenitic stainless steel staples to the sheathing. This helps to protect the building during erection and later against any wind-driven rain or moisture that might penetrate the external cladding. Glass fibre thermal insulation is usually placed between the timber frame studs and is secured in place in order to avoid sagging. To prevent interstitial condensation a vapour check membrane (also referred to as a vapour control layer) is fixed on the warm side of the insulation behind the internal wall lining; five-hundred gauge un-recycled polyethylene sheeting is normally used for this purpose. The external weather screen can include timber, brick, block, hanging tiles or other suitable materials, details for some of which are shown in Section B. The structural timber framing of external wall panels together with sole plates, timber cavity barriers, cladding battens, counter battens and external timber cladding should all receive appropriate pressure preservative treatment.

Balloon frame

This is similar to the platform method except studs are 2 storeys high.

Volumetric method

Volumetric method involves the factory fabrication of box units which require crane erection. The most common use of volumetric construction is the use of bathroom pods in hotels and apartments. These pods often consist of fully finished bathrooms and include special plumbing and electric fittings that only require to be connected to the main services on site. With domestic buildings a fully assembled house can arrive on site on the back of 1 or 2 trailers. This method or construction is not widespread and due to transport requirements difficulties can arise in transporting the building to site and in accessing the site itself.

Reverse wall construction

This form of timber frame construction is similar to standard timber frame construction. Typically the external structural sheathing (typically OSB or plywood) on the external side of the timber framing is replaced by a wood fibre board with low vapour resistance characteristics which is used mainly for insulation purposes and for support to the breather membrane (although there are some boards that can be used structurally providing they have appropriate certification).

The structural sheathing is usually placed on the inside face of the framing although this can result in difficulties in fixing the wall panels to the sub-structure or soleplate. Often the sheathing stops 300mm or so from the bottom rail to allow fixing into the sub-structure and the final strip of board is site fixed afterwards. Where this is done then there should be bridging pieces between the studs to pick up the edges of the sheathing.

The advantage of placing the relatively high vapour resistant structural board on the inside is that the board contributes to the protection against interstitial condensation provided by the vapour control layer. If the external boards are low density then they might affect the effectiveness of wall ties, holding down straps, cavity barriers and fire stops.

To ensure air tightness it is recommended that the breather membrane always be supported and backed by a board rather than just the thermal insulation.

Breathing walls
Breathing walls rely on a balance of materials with different vapour resistance characteristics with the higher vapour resistance materials being placed on the inside face of the timber frame. The construction usually has no vapour control layer (at least one that has a high vapour resistance) and relies on the construction allowing the water vapour to pass through the structure. There is a rule of thumb often quoted which refers to the internal materials having 5 times the vapour resistance of the layers on the external face of the timber frame. However, it is always advisable to have a robust vapour condensation risk analysis carried out where there is no VCL with a high vapour resistance being used.

This form of construction is not widely used and there is a debate about its suitability and therefore it should be used with care.

The performance of these walls is probably helped if mechanical extraction systems are used.

Single skin systems
Following the widespread failures of single skin systems in Canada and New Zealand there were a number of reports on their use. These systems are not considered suitable for timber frame in Ireland and the UK.

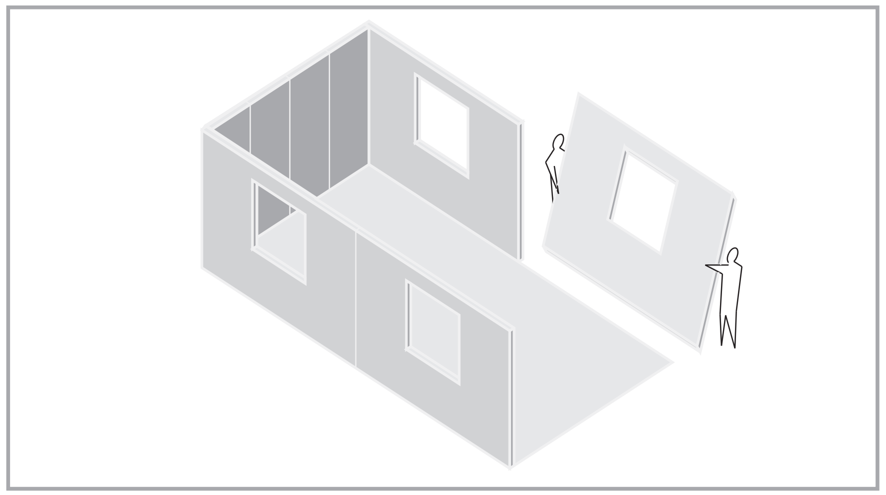


Fig. A 7.1.1 Platform method of construction

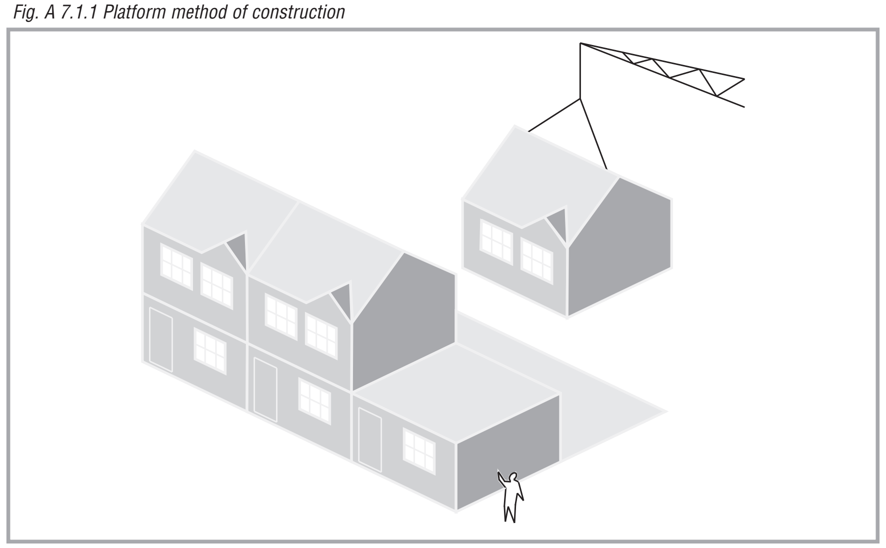


Fig. A 7.1.2 Volumetric method of construction

7.2 POST AND BEAM CONSTRUCTION

The post and beam system consists of a modular framework of heavy section beams and posts which provide the main structure. The system is a three-dimensional load-bearing construction where the floor and roof decks transfer the loads to the beams which in turn transfer them to posts and on to the foundation. There is a clear division between the load-carrying elements and the facade elements. Post and beam elements are larger and spaced farther apart than the studs, joists and rafters of conventional timber frame. Design is governed by many factors including architectural form, layout, wind loads, fire requirements and connections.

Some of the following connections may be suitable to connect the main beam to the column:
- Dowels or bolts
- Toothed plate connections
- Ring and shear plate connections
- Steel brackets
- Joist hangers
- Proprietary fasteners

The selection of the appropriate connection depends on structural considerations.

Foundations
- Pier or continuous
- Connections between foundation and super structure should be designed to remain dry
- End grain of posts should be treated with preservative

Timber Sizes

Some factors influencing material sizes include:
- Span, spacing and loading
- bracing requirements
- connection details

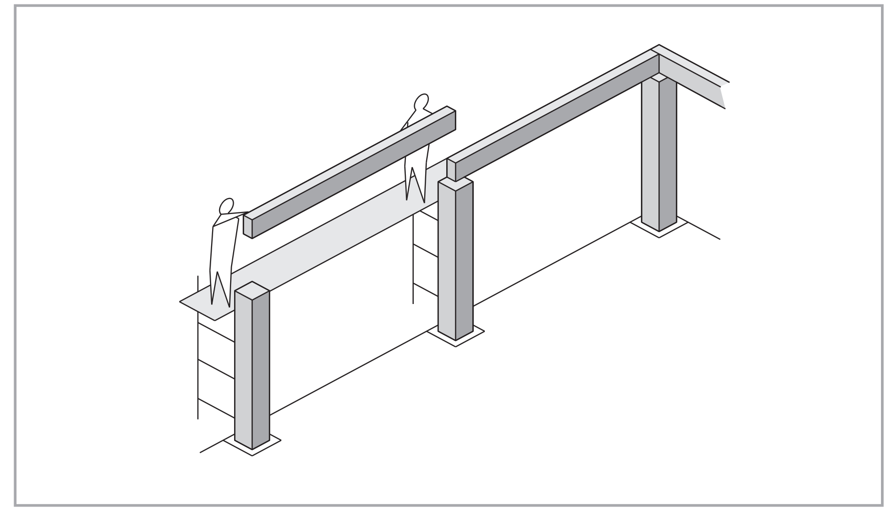


Fig. A 7.2.1 Post and beam

Post and beam can impose restrictions on the location of services which may necessitate advance planning

Decking and roofing
- Exposed planking or standard joist construction
- The finished deck should distribute loads laterally between adjacent planks
- Various proprietary plank and laminated decking systems are available
- Wood-based panels are also used

Partitions
- generally non load-bearing

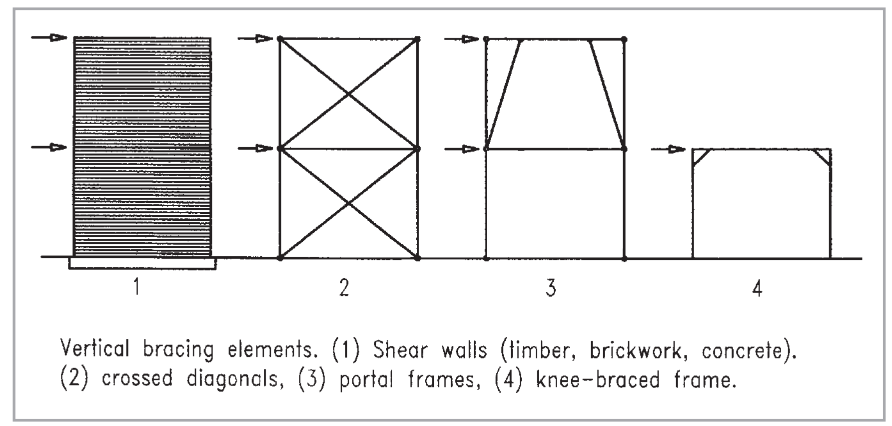


Fig. A 7.2.2 Portal frames – these usually have straight vertical and horizontal members.

7.3 STRESSED SKIN PANELS

General
Stressed skin panels consist of solid timber webs (longitudinal framing members) covered on one or both sides typically with plywood or OSB sheets. The plywood/OSB sheets are glued and nailed to the timber webs so that the assembly acts as a single structural unit. Web spacing and the thickness of the sheathing are dependent on the span and loading and spans typically range from 2.4 to 9.6m. In effect, the panels act like a series of I-joists with the sheathing taking most of the bending stresses.

Panels are generally fabricated in multiples 1200mm wide corresponding to the width of commercially available panel products. However, narrower panels are used when required to make up the difference between the panel width module and the overall length of the building. It is advisable to consider the width of the panels at design stage.

Economic solutions are possible provided the following are taken into account:
- Panel width conforms to commercially available widths (1200 or 1220mm).
- Rectangular plans are generally the most economical for stressed skin panel roofs.
- Stressed skin panels are factory fabricated and delivered as components to site.

Aspects of design, execution and handling not to be ignored are:
- Face grain of plywood/OSB should run parallel to longitudinal web members
- Plywood to web member joints are designed to transmit horizontal shear
- Web members run the full length of the panel, the use of finger joints where permitted should be kept to a minimum.
- Panels over 6m in length may require crane handling

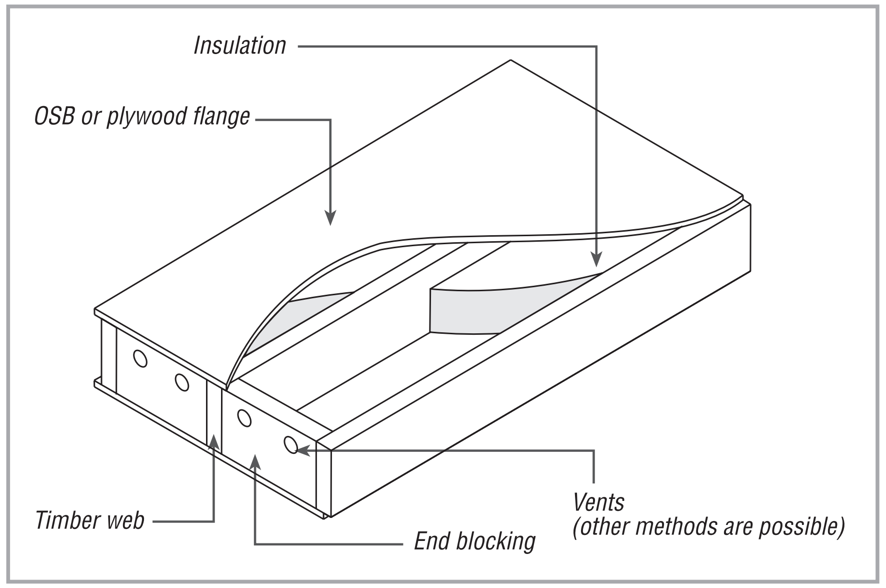


Fig. A 7.3 Typical stressed skin panel

Keywords

Blocking: short lengths of timber placed between web members for alignment and stiffness

Flange: Plywood sheets ranging from 9.5 to 18.5mm thick.

Web: longitudinal solid timber members.

Applications

- Floor panels
- Flat roof panels
- Pitched roof panels
- Wall panels

Typical Dimensions

Panels are normally 1220mm or 1200mm wide with 3 or 4 intermediate web members.

Spans range from 2.4 to 9.6m. For longer spans the plywood flanges are scarf jointed or spliced, while the web members may be extended by use of punched metal plates.

Advantages

- Prefabricated units enable speedy construction.
- Long spans are possible.
- Pitched roof panels can enable a clear roof space with no internal members required.
- Reduced labour costs on site.

Construction

- Webs are typically kiln dried softwood, strength class C16 of Irish origin or imported.
- Flanges are typically plywood or OSB

Where panels are utilised for pitched roof construction a steep roof pitch enables the roof to be erected free from internal members and this allows the occupants to utilise the roof space to their advantage. Intermediate timber blocking stiffeners can be incorporated in the panel during fabrication. Often the horizontal thrust from the panels is transferred into floor panels by specially designed hardwood bearers and fixings.

Where thermal performance is a design criterion, insulation can be incorporated between the timber web members. When used as roofing, it is normal to incorporate a ventilation space above the insulation layer and to incorporate a vapour check to avoid the possibility of interstitial condensation occurring; the ventilation space should be at least 50mm.

Where the roof is a cold deck roof; care should be taken with the overall construction (e.g. BS 5250 recommends that cold deck roofs should be avoided where possible). There is a increased risk of interstitial condensation (which tends to take place under the decking or the weathering membrane) and good through ventilation between the decking and insulation needed is needed as well as a good vapour control layer, properly sealed. Mechanical ventilation can also remove a lot of moisture from the building thereby reducing condensation risk; it is recommended that a condensation risk analysis be carried out for cold roofs.

Roof panel construction

- Dual pitch roof structures - span panels from eaves to ridge and the floor construction restrains the outward thrust at the eaves.
- Floor joists should span in the same direction as the roof panels.
- Monopitch roof structures - provision must be made to restrain the horizontal thrust at bearing points.
- Usable attic space can be provided with spans greater than 5m and pitch angles of 35 to 50 degrees.
- Roof panels can be used with both timber frame and masonry type construction.
- Sometimes used to incorporate a balcony feature into the gable wall.
- Design considerations include structural stability, fire resistance, thermal performance, ventilation and protection against condensation.
- Roof windows or dormer windows can be fitted within the panels to suit design requirements.
- The structural design of roof panels generally does not make allowances for supporting water tanks and these should be supported independently.
- Hips and valleys can be designed where required.
- All blocking should be vented and be the same size as the web members.

Floor panel construction

- For panels with tension flanges, intermittent blocking can be installed at the discretion of the specifier.
- The installation of end blocking between web members is generally recommended.

Load/span tables

Manufacturers produce load span tables to aid the designer in the selection of the most suitable panel. Tables give the allowable load carrying capacity for various panel configurations and common arrangements are outlined in the manufacturer's documentation.

7.4 TRUSSED RAFTERS

Most truss fabricators use punched metal plates, engineering software and design backup provided by a System Owner; the principal System Owners in Ireland are Alpine, Gangnail, Mitek, and Wolf.

Trussed rafters should be manufactured to EN 14250 under a recognised third party scheme. (In Ireland) NSAI operate a scheme to this standard and have a National Register of Approved Roof Truss Manufacturers.

Roof trusses should be designed to Eurocode 5 (and any requirements in the National Annex) while additional advice is given in Swift 5 (to be published). In the U.K. designs can be undertaken to BS 5268 Part 3 (for permissible stress design) or Eurocode 5 taking into account the U.K. National Annex and additional advice is given in PD 6693. Most truss fabricators have engineering software and backup from System Owners and the design can be carried out to Eurocode 5 (for Ireland and Britain) using Non-Contradictory Complimentary Information (NCCI i.e. Swift 5 or PD 6693).

Three dimensional roof stability

To convert a two dimensional trussed rafter design into a three dimensional frame requires a secondary structural system such as a diaphragm or diagonal bracing to transfer and resist horizontal forces.

Truss fabricators usually design the trusses and specify the bracing required by the truss design and any minimum bracing required by the design standards or NCCI (Swift 5 and in the U.K. PD 6693). Most truss fabricators will offer a roof design service (i.e. the overall roof design) while the building designer would be responsible for any bracing needed to stabilise walls.

Rafter stability

There are four common approaches to transmitting the rafter lateral restraint forces to the supporting walls.

- Diaphragm action by timber boarding or sheet material (sarking) to the top plane of the rafters.
- Specific diagonal bracing as designated by the designer and/or in Swift 5. In the UK as per BS 5268 Part 3 and/or as designated by the designer, PD 6693 should be consulted for designs to Eurocode 5.
- The use of timber tiling battens as bracing
- The use of hipped roofs

Attic trusses

Attic roof trusses will have fire resistance requirements and therefore the thickness of the timber should be considered in relation to the fixing of internal fire linings, Designs to Eurocode 5 require a minimum timber thickness of 35mm but this is generally considered inadequate for the fixing of plasterboard; therefore the advice of the truss fabricator (or the System Owner) should be sought as should the advice of the lining manufacturer.

The junction of the ceiling and wall lining should be sealed for air-tightness. The junction of the wall lining and the floor should be sealed for air-tightness; it is recommended that timber noggings be placed between trusses to give support to the bottom of the wall lining at floor level.

Where roofs are designed for future access, the trusses and roof should be designed and framed out for the future conversion so that cutting of trusses is at a minimum and will not compromise the structure.

Gable wall stability

Masonry walls and timber frame walls are required to be adequately restrained in the plane of the rafters and at floor level.

Lateral support to perimeter walls

The ceiling diaphragm provides essential lateral support to perimeter walls. In most domestic scale construction, the plasterboard ceiling provides adequate and proven restraint. In non-domestic applications, an appropriate diaphragm may have to be designed and incorporated into the structure. Where there is a suspended ceiling, diagonal bracing or in-plane boarding or sheeting is required to transfer roof forces back to the shear wall (party wall or wall at right angles to external wall), together with a specific wind girder designed to ensure stability to the perimeter supporting walls.

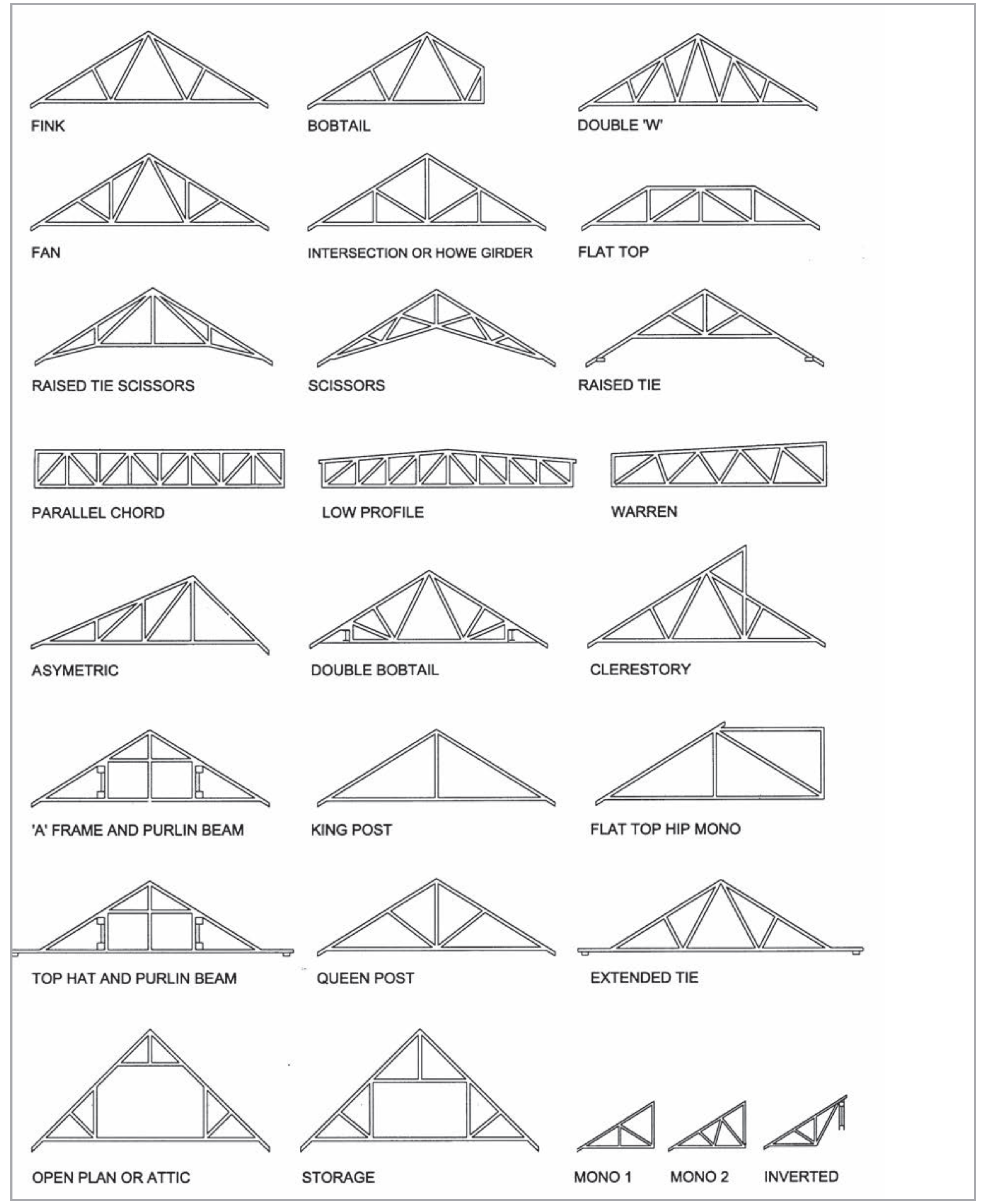


Fig. A 7.4.1 Selection of trussed rafter configurations

A8 Engineered wood products (EWPs)

EWPs can be categorised as:
- Composite (reconstituted fibres, flakes, components using a combination of materials, etc.);
- Laminate (strength graded timber or veneers glued together);
- Panel product* (board materials composed of fibres, chips, veneers or flakes);
- Components or systems (combinations of above)

**Note: Panel products are generally not considered EWPs themselves but are used as components in the production of some EWP systems such as I-joists*

8.1 GENERAL

- EWPs are generally produced from a combination of wood in its various forms, with adhesive (or other type of connection);
- They are typically used for structural applications;
- They are generally stronger, stiffer and more dimensionally stable (uniform MC) than solid timber;
- They are available in a wide variety of lengths and cross sections;
- It is important to check the availability of any EWP and to check the product has been approved for use by an appropriate body such as the Agrément Board
- Can now be manufactured out of American temperate hardwoods – white oak, red oak, ash and tulipwood.

Table A 8.1 outlines the various applications of EWP's:

Table A 8.1 *Summary of engineered wood products.*

Product	Category	Applications
LVL	Laminate	- Beams, columns, vehicle decking, door & window frames, flanges of I-joists. - Industrial, commercial, recreational & institutional.
Parallel strand board (eg Parallam)	Composite	- Beams, columns, truss members, window & door headers, portal frames, post & beam systems. - Industrial, commercial, recreational, institutional & residential.
Glulam	Laminate	- Beams, columns, trusses, bridges, portal frames, post & beam systems, extensions, conservatories. - Industrial, commercial, recreational, institutional & residential.
I-Joists	System	- Floor & roof joists, formwork, ceiling ties, load- bearing stud wall units, available as complete systems. - Residential & commercial.
Box Beams	System	- Beams (one offs) - Residential & industrial buildings.

8.2 GLULAM

Glulam typically consists of a minimum of four timber laminates bonded together. Glulam with no theoretical limits on section size, length or shape is ideally suited for use in structural systems, especially medium to large span roof structures. It is commonly used as roof beams, portal frames, arches, floor beams, shell structures and domes.

Structural use and function

Simple continuous span beams, curved beams, hinged portals and arches are glulam systems which are very applicable to buildings such as churches, schools, hotels, conference halls and leisure complexes. Simple continuous beams can be obtained off the shelf and can span up to 20m depending on their size.

Materials

Glulam laminated timber components are fabricated from carefully selected softwoods of a strength class (or species and grade) specified by the Design Engineer. The timber specified must be in accordance with Eurocode 5 (or where appropriate BS 5268: Part 2) and visually strength graded in accordance with IS127 (or for the U.K. BS 4978) or machine graded to EN 14081-4. Hardwoods may be considered for special strength or appearance requirements and should be strength graded in accordance with BS 5756 and assigned a strength class from EN 1912.

Adhesives

The adhesive used in the manufacture must be fully weatherproof for example phenol resorcinol formaldehyde in accordance with EN 301 Type 1. The adhesive is required to have strength sufficient to provide a joint at least as strong as the timber and be creep free. Where temperatures can exceed 37°C e.g. in insulated roof conditions, urea formaldehyde is not suitable.

Durability - preservative treatments

In external locations where the moisture content exceeds 20%, the timber must be either resistant to decay or preservative treatment is required. As most glulam members are made from softwood timbers with a low durability, consideration should be given to the need for treatment with a suitable timber preservative. For designs based on Eurocode 5 reference should be made to I.S. EN 335 (Parts 1, 2 and 3), I.S. EN 350-2, I.S. EN 351-1 and I.S. EN 460, to determine the requirement for preservation treatment. For designs to BS 5268 reference should be made to BS 8417 which provides good advice on timber preservation some of which would be applicable to designs to Eurocode 5.

If copper based preservative is used, corrosion of metals may be accelerated; therefore the correct choice of metal is imperative. Failure of certain types of stainless steel in the environment of swimming pools under such circumstances has been experienced and due caution is advised.

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8.3 I-JOISTS

General

I-joists consist of flanges made from solid wood, parallel strand lumber or LVL and a web made from OSB, plywood or hardboard. The flanges and web are bonded together to form an ' I ' cross-section shape. I-joists are economical, strong, light and versatile building elements. The geometry makes efficient use of the wood being used by concentrating the timber in the outermost portion of the cross-section where the bending stresses are at their highest. The flanges essentially resist the applied bending moments and the webs the applied shear forces.

I-joists are available as proprietary systems and manufacturers produce supporting literature covering design and their use. This includes information such as load span tables, permitted web hole requirements, hanger details, stiffener requirements, site advice, fixings etc. The manufacturers' literature should be consulted.

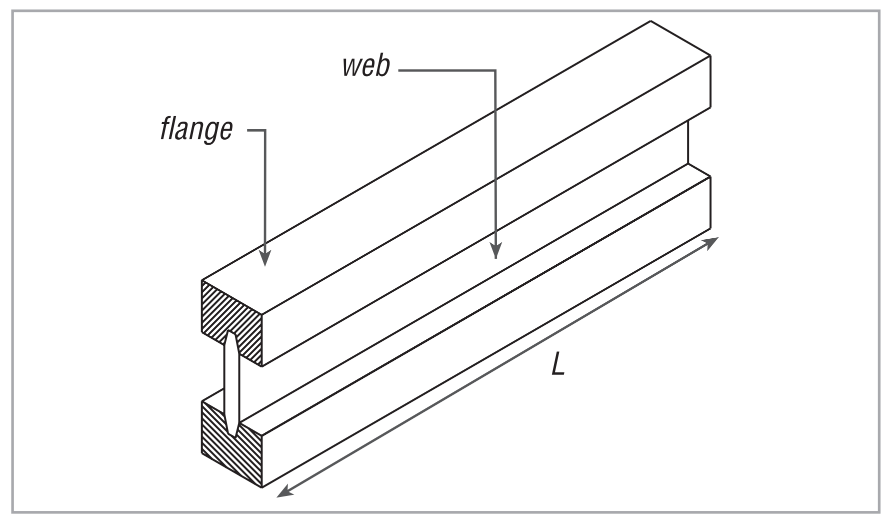


Fig. A 8.3.1 Typical I-joist

Applications
- Floor & roof joists
- Available as complete systems
- Rafter & ceiling ties
- Formwork beams
- Load-bearing stud wall units

Applications
I-joists can be used as structural framing in floors and roofs (flat and pitched). They can also be utilised in wall construction in place of solid timber studding.

Storage
Joists should be stored clear of the ground and stacked vertically (in the plane of the web). Joists should not be stored flat and must be protected from adverse weather. The stiffness of joists about their minor axis is significantly less than that about the major axis and care must be taken to ensure that joists are not damaged during handling and erection.

Installation and fixing
The manufacturer's installation guides should be consulted for specific details. Some general notes are included here:
- I-joists are lightweight and can easily be handled.
- Flanges should not be cut, notched or drilled. Refer to manufacturer's literature for specific requirements.
- Joists are unstable until braced laterally during construction. The structural performance of the joist relies on adequate lateral restraint. To achieve this, restraints should be provided at specified centres depending on joist size and the load being carried. Restraints can be in the form of solid timber blocking, I-joist off cuts or strutting.
- All sheathing must be fully nailed as specified to each joist before any additional loads can be placed on the system
- Reinforcement may be required in cantilever situations. See the manufacturer's details.
- Nailing and other fixings can cause splitting and damage and care should be taken in their use.

Design Tips
- Span joists in one direction
- Run joists over the shorter span
- Maintain a constant depth and centres
- Select deeper joists for longer spans
- Cantilver joists at stair locations to minimise framing

Deflection
Designers should always include shear deflection calculations. This is always included in manufacturers' load span tables and software but it may not be included in third party software.

Note that deflection requirements differ considerably for Eurocode 5 and BS 5268.

Web holes
In standard timber I-joists, openings can be cut in the webs for the passage of utilities such as electrical wiring, SVPs, heating ducts and plumbing and these are often perforated and ready to be knocked out. Manufacturers usually provide clear definite guidelines for the shape, size and position of these holes; they are generally located in areas where shear loads are low

Web Stiffeners
- Glued or nailed to the web.
- Used to increase the bearing capacity and also to reinforce the web against buckling.

Web stiffeners
Stiffeners are generally required at the bearing support. At this location shear forces are high and usually much higher than the flange to web joint shear capacity alone. Stiffeners are usually wood blocks positioned vertically on both sides of the web. If stiffeners are cut too long and are forced to fit, the prying action could damage the flange to web bond; therefore stiffeners should be cut accurately. Stiffeners are usually connected to the web with nails but for some higher capacity I-joists gluing may also be required. Stiffeners also reinforce the joist against buckling and are usually required along the span on deeper joists. At concentrated load points stiffeners also may be required. The manufacturers' documentation should be consulted for further information.

Joist hangers
Many hangers developed for sawn solid timber sections are not suitable for I-joists and proprietary hangers should be used. Generally they use larger nails spaced in a pattern that would split the flanges and web stiffeners. The manufacturers' literature should be consulted for nailing recommendations. Usually hangers provide lateral restraint to the compression flange of the joist and help to resist torsion at the joist ends.

Timber frame walls

I.S. 440 places limits on the use of I-joists as header joists within external, party and compartment walls; refer to that standard for more information. In addition most I-joist manufacturers provide special components (e.g. header joists and LVL beams) to match in with their I-joists

8.4 BOX BEAMS

General
Box beams typically consist of solid timber, parallel stand lumber or LVL flanges with plywood or OSB webs. The webs are glued to the flanges on each side to form a box shape and are very similar to the I joists discussed above. Machine driven nails can be used to aid fabrication but should generally not be used on their own. All joints should be glued over the full contact area.

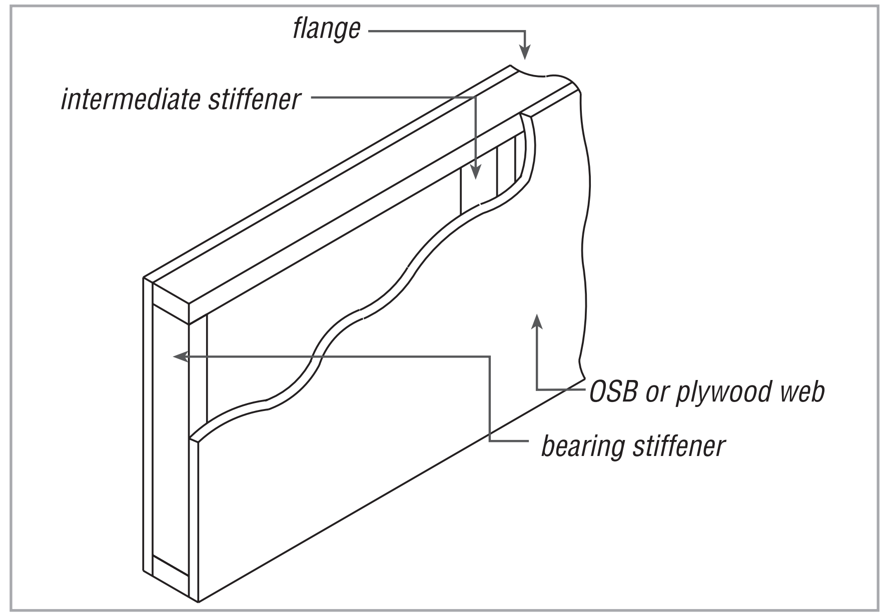


Fig. A 8.4.1 Typical Box Beam

Application
Box beams are manufactured in depths up to 1.2m although the most popular depths are in the order of 600-800mm. Web stiffeners can help control shear buckling of the web and provide convenient locations for web butt joints. Additionally, it is good practice to have stiffeners located at positions of point loads to counter localised web buckling. In box beams, the web joint locations are best alternated from side to side and away from the areas of highest shear.

Applications
- Beams
- Portal frame construction
- Rafters & columns
- Load bearing stud walls
- Formwork supports

The selection of flange material is governed by price, maximum lengths and size availability; parallel stand lumber or LVL flanges can be used to provide longer lengths than solid sawn timber. Finger-joints should be located away from points of high tension and shear.

Typical Dimensions
- Can be fabricated upto 1.2m in depth but 600-800mm are the most common section depths.
- Spans of 30-40m are possible with portal frame construction.

Webs
Structural plywood and OSB are the most common panel products used. Plywood has a high shear resistance which makes it suitable for large spans and high load carrying capacity box beams. The most common size is 2400 x 1200 mm (although the old imperial sizes of 2240 x 1220mm may still be available) with the face grain running in the longer direction (i.e. parallel to the beam span).

Flange to web joints
Webs are usually glued to the flange using phenol resorcinol formaldehyde (PRF) which is the most common glue for structural use of timber. Machine driven nails can aid construction but should not generally be used on their own. All joints should be glued over their full contact area. Stiffeners should be spaced at centres as shown in the design and always at supports and concentrated load points.

Design considerations

Box beams are generally not mass-produced and are designed for one-off situations. Design properties are determined by the material properties of the flange and web materials.

Generally the three most important criteria in size selection are the flange stresses, material costs and the calculated deflection. A summary of the main design considerations are shown below.

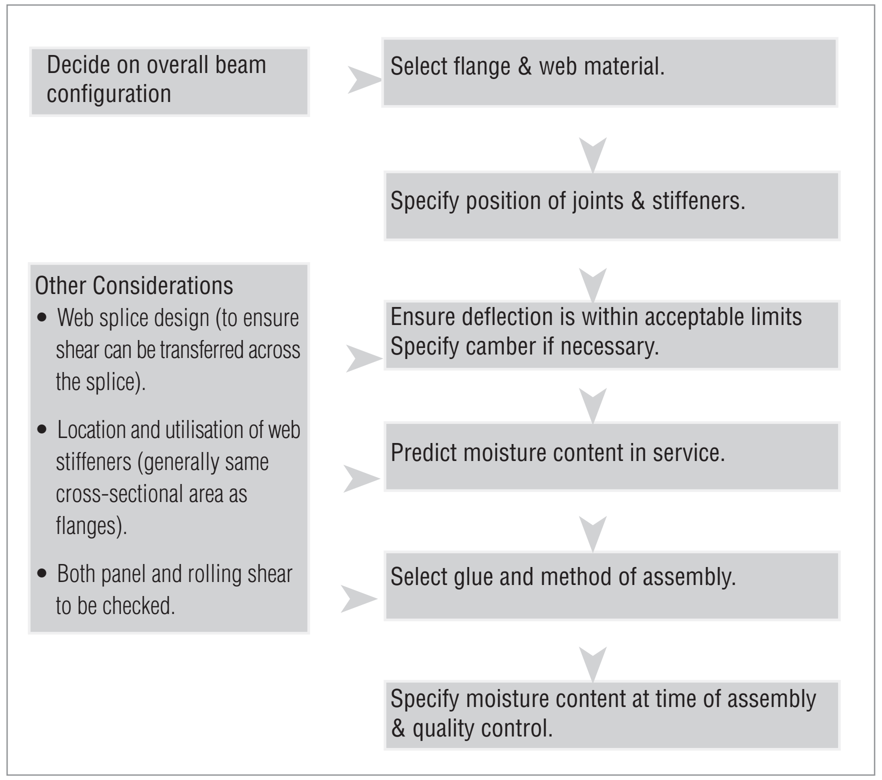


Fig. A 8.4.2 Design considerations

8.5 LAMINATED VENEER LUMBER (LVL)

General

Dried veneers (typically 3mm thick) are laminated together to form panel boards from which structural sections of the desired dimensions are cut. The density of LVL is typically 10% higher than the density of the timber species used in its manufacture. For example, the density of Douglas fir LVL is in the region of 610kg/m^3 as against 530kg/m^3 for solid timber. Various properties for structural design, i.e. design bending stresses, compression stresses, modulus of elasticity, etc. are supplied by the LVL manufacturer.

Applications
1. Beams & columns
2. Flanges of I-joists
3. Scaffold boards
4. Vehicle decking
5. Door & window frames

Common Species
- Norway spruce
- Radiata pine
- Douglas fir
- Yellow poplar
- Lodgepole pine
- Southern yellow pine

Common Sizes

Overall panel size produced:
24m long by 1.2 -1.8m deep and from 19 - 89mm thick. (Panel is then cut to the required product size).

Stock dimensions range from:
38 - 900mm deep by 19 - 89mm thick (lengths over 12m to order). Consult the manufacturer for more details

For beam applications, common sizes are as follows:
44mm thick by 140, 184, 241, 302, 356, 406 and 476mm deep.

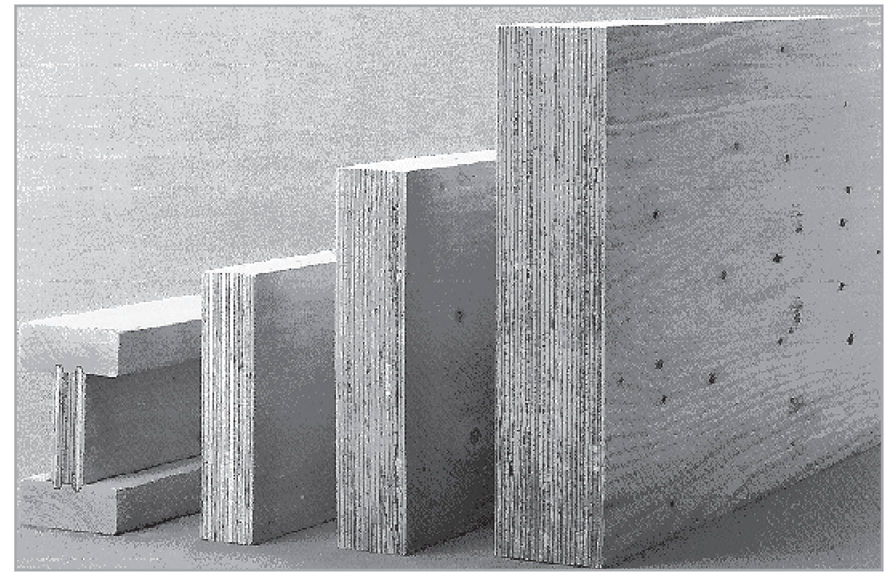


Fig. A 8.5.1 LVL products

Moisture content and storage

LVL is manufactured at a moisture content of approximately 8% and consequently warping or splitting are less likely to occur. Cupping can occur on wide thin sections of LVL when one face gets wet and the other remains dry. LVL will generally take up moisture from the atmosphere at a slower rate than sawn timber.

Installation and fixing

LVL is easily cut and fixed using conventional woodworking tools. Normal joints made with nails, screws, bolts or timber connectors should be structurally designed, the manufacturers' literature should be consulted for details of timber connectors.

An ETA should be checked that it is applicable to the end use. There should be accompanying information showing compliance with the Irish or UK Building Regulations.

Adhesives

Phenolic resins classified in accordance with EN 301 should be used in the manufacture of LVL. In general scarf joints are used on all veneers except for core veneers where butt joints are allowed.

Mechanical Properties
Refer to the manufacturer's Agrément certificate or similar documentation.

Code approval and design

LVL can be used for construction provided the manufacturer has appropriate third party certification. In Ireland manufacturers must have an approved accreditation in accordance with Technical Guidance Document D to the Irish Building Regulations (or the equivalent document in the U.K.). Reference should be made to the manufacturer's technical literature for specific design guidelines and values.

All LVL should comply with EN 14279:2004+A1:2009 'Laminated veneer lumber (LVL). Definitions, classification and specifications'

Note that British Board Agrément certificates are often accepted for use in Ireland (unless an Irish Agrément Board is available), but a European Technical Approval (ETA) would also be acceptable but would need additional documentation to show compliance with the Irish Building Regulations (in the UK this documentation would be to the UK Building Regulations).

Durability and treatment
LVL is satisfactory for use in conditions where moisture content does not exceed 16% for any significant period or 20% at any time. The use of LVL is generally restricted to areas where preservative treatment is not required. Consult the manufacturer's literature if in doubt. Treatments are available that can improve resistance to insect and fungal attack.

Behaviour in fire
LVL behaves similarly to solid wood with charring rates related to the density of timber used in its manufacture. LVL has a Class 3 surface spread of flame classification. Treatments are available that can improve the surface spread of flame to Class 1 or Class 0.

Connections
Dowel type fasteners are commonly used with LVL. Bolt and nail performance is similar to that of sawn timber. It is advisable to seek manufacturers' advice with respect to approved connector types and performance.

8.6 PARALLEL STRAND LUMBER

Applications
1. Beams & columns
2. Truss members
3. Window & door headers
4. Portal frames
5. Post & beam systems

Common species
- Douglas fir
- Southern yellow pine
- Western hemlock

Common sizes
Lengths up to 20m ±3mm
Depths 200 to 406mm ±1mm
Thicknesses 45 to 178mm ±1mm
Columns available:
89 x 89, 89 x 133, 89 x 178, 133 x 133, 133x 178 and 178 x 178mm.
(to the required product size)
Consult the supplier for more details.

General
Parallel Strand Lumber (e.g. Parallam) is an engineered wood composite product consisting of long thin strands of veneer laminated together to form a structural member. The density of Parallel Strand Lumber is typically 15% higher than the timber species from which it is made. Various properties for structural design are supplied by the manufacturer.

Moisture content and storage
Parallel Strand Lumber is manufactured at approximately 10% moisture content and is a very stable product. Parallel Strand Lumber will take up moisture at a slower rate than solid sawn timber but still must be protected from the weather.
Parallel Strand Lumber can be expected to swell approximately 12% perpendicular to the face of the strands and 5% parallel to the strands after prolonged exposure.

Parallel Strand Lumber should be stored above ground on level bearings and should be protected from the weather. Other construction materials should not be stacked on PSL beams or columns.

Installation and fixing
Connections designed for specific applications vary based on design loads and local building codes. Typical connections used in the US are joist hangers, framing anchors, column caps, dowels and tie straps. Manufacturers' literature should be consulted for standard connection details. The same fasteners and strength capacities that are commonly used for solid sawn are used for this material.

Weathering
Discolouration may occur due to long exposure to sunlight or repeated wetting and drying. Parallel Strand Lumber should not delaminate but prolonged exposure to weather must be avoided. Such exposure will cause roughening of the surface.

Adhesives
The adhesive used in the manufacture of Parallel Strand Lumber is usually phenol formaldehyde mixed with wax, which enhances the stability of the finished product. The formaldehyde is almost all consumed chemically in the curing process and emissions are generally not a problem.

Code approval and design
LVL can be used for construction provided the manufacturer has appropriate third party certification. In Ireland manufacturers must have an approved accreditation in accordance with Technical Guidance Document D to the Irish Building Regulations (or the equivalent document in the U.K.). Reference should be made to the manufacturer's technical literature for specific design guidelines and values.

Note that British Board Agrément certificates are often accepted for use in Ireland (unless an Irish Agrément Board is available), but a European Technical Approval (ETA) would also be acceptable with appropriate accompanying information.

Durability and treatment
Untreated Parallel Strand Lumber is satisfactory for use in conditions where moisture content does not exceed 16% for any significant period nor 20% at any time. The use of Parallel Strand Lumber is generally restricted to areas where preservative treatment is not required. Consult the manufacturers' literature if in doubt. Treatments are available that can improve resistance to insect and fungal attack.

Behaviour in fire
Parallel Strand Lumber is a combustible material rated as Class 3 surface spread of flame. It can be upgraded to Class 1 or 0 by specialist treatment.

An ETA should be checked that it is applicable to the end use. There should be accompanying information showing compliance with the Irish or UK Building Regulations.

A9 Wood-based panel products

The following is a range of wood-based products readily available in Ireland and the UK:

- Chipboard
- Hardboard including doorskins
- Laminboard and blockboard
- Medium density fibreboard (MDF)
- Oriented strand board (OSB)
- Plywood
- Softboard

The above list falls into three main groups, namely laminated boards, particle boards and fibreboards. Laminated boards include plywood, blockboard and laminboards. Blockboard although a light-weight material is now rarely used for furniture applications due to show-through of the core blocks on the surface when there are changes of moisture content.

Plywood comes in various types such as interior plywood, exterior grade plywood, and marine plywood. Plywood is made from veneers cut from a wide range of timbers. Veneer thickness and orientation can be varied to achieve particular strength and appearance characteristics. It is important for specifiers to be aware that there are significant quality control variations in plywood manufacture depending on its place of origin. Plywood is the strongest wood-based board available at present.

Particle boards such as chipboard and OSB have many uses. Chipboard of various types is available for veneered furniture. Oriented strand board is a three or five layer wafer board. Rectangular wood flakes in the two surface layers are aligned parallel to the long axis of the board while the core layer flakes are aligned across the board. The result is high bending strength and stiffness in the longitudinal direction. OSB can do many of the tasks required of plywood, such as sheathing for timber-frame buildings.

Low value wood chips and sawdust are processed to manufacture a range of panel board products such as MDF, OSB and chip board. MDF for example is reprocessed to manufacture flooring, skirting boards, furniture, shop fronts and panelling such as the reception area of the European Bank for Restoration and Development

Hardboard, softboard and MDF are fibreboards with a homogeneous construction of wood fibres. Hardboard and softboard do not use additional binders but derive their strength from the "felting" together of the wood fibres allied to the adhesive action of the natural lignin in the wood due to heat and pressure in the manufacturing process. MDF achieves its additional strength through the use of a synthetic resin binder applied to the wood fibres. MDF has mechanical and physical characteristics approaching the levels associated with solid wood. Its density, low moisture content and smooth surface finish make it an ideal base material for various surface finishes including quality veneers. In addition, the range of possible end uses of MDF has been extended through the development of flame retardant grades suitable for use in public buildings with onerous Fire Certificate requirements.

EN 13986 Wood based panels for use in construction – Characteristics, evaluation of conformity and marking.

This standard defines wood-based panels for construction and specifies their relevant characteristics and test methods. A particular board may be intended for a specific use and not all the properties and tests may be appropriate and the manufacturer may therefore only need to state a limited number of performance characteristics. There are 5 general sub-divisions of application in the standard:

- Structural
- Non-structural
- Structural floor decking
- Structural roof decking
- Structural wall sheathing

These are further divided into 3 categories depending in the conditions of use:

- Internal
- Humid
- External

Internal conditions refer to dry conditions typically inside a building such as floor joists (this equates to Eurocode 5 and BS 5268-2 Service Class 1 although floor joists are usually designed for Service Class 2). Humid conditions approximate to Service Class 2 and include members such as roof rafters and members of external timber frame walls. Internal and Humid both describe boards for internal use. External conditions approximate to Service Class 3 and relate to timber used externally and exposed to the weather.

The standard includes 6 main divisions of wood based panels solid wood, plywood (including LVL), OSB, particleboards (chipboards), resin or cement bonded boards and fibreboards (wet and dry process). The main board properties to be determined are listed by application (structural, non-structural etc.) and by conditions of use (Internal, Humid and External).

While the main board properties to be determined are obvious (e.g. bending strength, stiffness and bond quality) there are also some newer properties or probably truer to say properties that have new categories. The most important of these is reaction to fire and involves linings being assigned a Euroclass as defined in EN 13501-1. Boards can be tested to determine their classification or their classification can be taken from Table 8 of EN 13986 provided the boards conform to the requirements of that table.

The requirement for surfaces or linings are given in Technical Guidance Document B (Fire Safety) and in the equivalent UK Approved Document, the old classification system (referred to as National Classes) related to tests to BS 476 Parts 6 and 7. There were 5 classes, 0, 1, 2, 3 and 4 with 0 being the highest classification and was defined in the TGD B/Approved Document, the others being defined in BS 476-7. Timber generally was considered to be Class 3 but could be treated with a flame retardant up to Class 0. The Euroclass system will replace the National Class system and should be used for designs to Eurocode 5.

The Euroclass system has 7 classifications for linings; A1, A2, B, C, D, E and F with A1 being the highest. The additional sub-texts refer to the production of smoke (s1, s2 or s3) and to flaming droplets or particles (d0, d1 or d2). However in relation to specifying the performance of surfaces and linings TGD B/Approved Document refers only to 3 classifications:

Class D-s3,d2 taken as equivalent to National Class 3
Class C-s3,d2 taken as equivalent to National Class 1
Class B-s3,d2 taken as equivalent to National Class 0

The requirement s3 and d2 mean that there is no requirement regarding the production of smoke or flaming droplets and particles.

EN 13986 also gives technical classes for different wood-based panels. For example for plywood the technical classes refer to EN 636 and are EN 636-1 for dry use, EN 636-2 for humid use and EN 636-3 for exterior use. For OSB they are OSB/1, OSB/2, OSB/3 and OSB/4 and the standard referred to is EN 300. For construction EN 636-2 and OSB/3 are the most common references for plywood and OSB.

EN 13986 deals with evaluation of conformity and marking, but there are additional requirements if panels are to be CE marked. Marking refers to the product information (as set out in EN 13986) rather than actual marks on the panels. Additional marking requirements are given in the individual product standards e.g. EN 636 etc. Accompanying documents could contain information not marked on the boards, including performance and strength properties.

9.1 PARTICLEBOARD

General

Chipboard or particleboard is normally formed as a flat panel comprised of wood particles which are dried, coated with resin and bonded together under heat and pressure. Extruded boards, often of flax shives, are widely used for the cores of flush doors.

Particleboard Standards
EN 312
Particleboard Specifications.
EN 633
Cement-bonded Particleboards.
EN 14755
Extruded particleboards. Specifications.

Applications

Chipboard is used in a wide range of interior applications for flooring, interior fittings, furniture and packaging. It is readily available overlaid with natural wood veneer, melamine or foil finishes in a wide range of colours and with a low formaldehyde 'E1' rating.

Sheet sizes

Chipboard is typically available in 2440x1220mm sheets, with other sizes to special order. For flooring, it is available with tongue and groove edges.

Storage

Boards should be stacked flat, off the ground, and on a level surface in a dry storage with all edges flush. Special care should be taken with tongued and grooved and overlaid boards to protect the surface and edges. A sacrificial top board should be used to prevent warping of the upper boards.

Machining

Boards can be cut with normal woodworking saws but tungsten carbide (TCT) blades are recommended.

9.2 HARDBOARD

Hardboard is a fibreboard which is produced by a 'Wet' process whereby wood fibres in a slurry of water are laid down on a wire mesh which allows the water to drain away and the fibres to felt together. The boards are then bound under heat and pressure using the natural lignin in the wood. This produces the characteristic mesh imprint on one side, the top side being smooth. Hardboard is typically produced in thicknesses of 2.5-4mm and in a sheet size of 2440x1220mm. 'Oil-tempered' board with improved moisture resistance is available. Standard hardboard should meet the requirements of Type HB of EN 622 and oil tempered Type HB HLA. Hardboard has no added formaldehyde.

As manufactured hardboard can have a low moisture content and like all wood based sheet materials is hygroscopic. In its use as panelling or for overlaying flooring it should be conditioned before use. This is typically done by laying the boards flat and scrubbing water into the mesh side until it is visibly wetted (the boards have degree of water repellence and mere wetting by spray is insufficient). The boards are then stacked back to back for at least 24 hours before fixing. This procedure ensures that the boards will subsequently shrink and remain flat in service.

Hardwood door skins are made by a slightly different process in moulded patterns to simulate panelling and are supplied pre-primed to specialist door manufacturers.

9.3 PLYWOOD

General

Plywood is a flat panel made up of veneer sheets, bonded under pressure by a bonding agent. In traditional plywood manufacture the veneers are clipped into standard sizes, dried, graded and stacked. Strips of veneer may be jointed into full size sheets by edge gluing, stitching or scarfing. Glue is applied and veneers are laid up at 90° to each other. Veneers are hot pressed, cured, trimmed and sanded. Plywood veneers like other wood-based materials, are hygroscopic, and therefore the moisture content of plywood depends on the climatic conditions of the surrounding air.

Plywood composition

It is a characteristic of plywood that successive veneer layers are at right angles to one another. For most plywood panels, the number of plywood layers is odd (3, 5 etc). For decorative plywood, face veneers tend to be of a higher quality and value than internal veneers. Decorative veneers tend to be cut from hardwoods (oak, birch, beech etc). Utility plywood tends to be made from softwoods (southern yellow pine, Douglas fir, spruce etc)

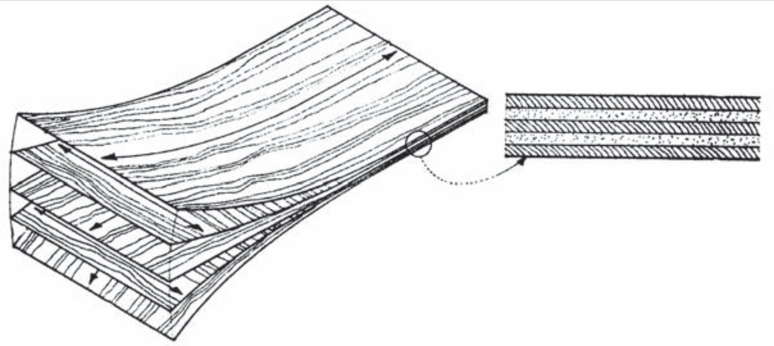


Fig. A 9.1 Plywood is made by bonding veneers together usually with the grain at right angles to each other and symmetrical about the centre ply.

Plywood standards

EN 636 Plywood. Specifications.

Three grades listed:
Type 1 Interior
Type 2 Moisture resistant
Type 3 Exterior

Table A 9.3.1 *Approximate equilibrium moisture contents*

Surrounding air with temperature at 20°C & RH of:	30%	65%	85%
Equilibrium MC of plywood	5%	10%	15%
Equilibrium MC of softwood	6%	12%	17%

Moisture content (MC)

The influence of MC changes is greater in plywood made from denser woods. In general, the movement of plywood depends on the number and thickness of layers, species of wood or woods and MC. Irregular shrinkage or swelling may cause plywood to warp.

Applications

Plywood is utilised in similar applications to OSB. It can be used as the web material for structural I-joists or in stressed skin wall and roof panels as the structural sheathing material. Plywood is also suitable for diaphragms or as gussets in spaced columns and trusses. The advantages of plywood are excellent strength properties, a wide range of available grades, wide acceptance and an attractive grain.

Structural plywood should comply with EN 13986 and EN 636, characteristic design values should be taken from EN 12369-2 or from an ETA, Agrément Board Certificate or similar. For designs to Eurocode 5, EN 12368-2 gives characteristic values based on a F and E classification system, the F referring to the characteristic bending strength and E the mean bending modulus; the F and E values (e.g. F40/E50) should be declared by the manufacturer. EN 636 has characteristic values for the F/E strength class system, these are to enable a plywood to be assigned to a F/E class based on test results; the values in EN 636 must not be used for structural design.

Structural plywood (BS 5268 Part 2) should be subject to the quality control procedures of one of the following:

- American Plywood Association (APA)
- British Standards Institution (BSI)
- Council of Forest Industries (COFI)
- Technical Research Centre of Finland (VTT)
- The National Swedish Testing Institute (Statens Provningsanstalt)
- Timberco Inc. (TECO)
- Or have appropriate certification

Technical data

Recommendations

BS 5268 Part 2 gives recommendations for the use of sanded and unsanded plywood manufactured in accordance with specified standards.

Sheet sizes

Typically available in 2440x1220mm and 2400x1200mm sheets and in standard or tongued and grooved format. Special sizes are available for the timber-frame industry.

Thicknesses range from 3 to 31.5mm in sanded or unsanded finish.

Strength properties

Grade stresses and moduli for structural plywoods are outlined in BS 5268 Part 2. These apply to long-term loading in service class 1 and 2. For other durations of load and/or service class 3 conditions the stresses should be multiplied by the appropriate modification factors outlined in the Standard.

Plywood thickness

Plywood is available from 3-30mm thick. Standard thicknesses are 6, 9, 12, 15, 18mm.

The bending stresses and moduli given in BS 5268 Part 2 apply to the appropriate (transverse or longitudinal) axis of the plane of the board.

Typical sheet sizes: 2440x1220mm
2400x1220mm
2440x590mm
2400x590mm

Durability

Durability of plywood is affected by:

- species used for the veneers
- individual ply thickness
- the adhesive used

Plywood used for permanent structures in damp or wet conditions, unless made from inherently durable species, should be adequately treated against decay with a preservative treatment. If plywood is pretreated with water based products then the plywood glueline should be suitable for humid/wet use as defined in EN 636.

Specifying plywood

When specifying for plywood for structural use, reference should be made to the:

1. Type
2. Grade
3. Nominal thickness
4. Number of plies
5. Finish (sanded/unsanded)

Plywood exposed to the weather and having long term service life expectations should have no open defects (e.g. knots, holes, splits) on the exposed face(s).

The risks of biological attack of plywood given in EN 335-3 is in relation to hazard classes 1, 2 and 3. The use of plywood in hazard class 4 (in contact with ground or fresh water) and in contact with sea water is noted as being appropriate only if the inherent and/or conferred properties of the boards are adequate.

Table A 9.3.2 *Formaldehyde release classes for plywood*

CLASS	CONTENT	RELEASE
E1	≤ 8MG/100g O.D. board	≤ 3.5mg/m²/h
E2	> 8 to 30mg/100mg O.D board	>3.5 to ≤ 8mg.m²/h

Classification

EN 313 Plywood - Classification and terminology Part 1: Classification

Health and safety

Formaldehyde Release refers to the perforator value in EN120 or the Steady state emission value in ENV 717-1. Two formaldehyde release classes are defined, E1& E2, E1 having the lower emission.

Classification

Plywoods can be grouped by:

- general appearance
- construction i.e. veneer plywood and wood core boards – blockboards and laminboards
- their form and shape - flat or moulded
- their principal characteristics
- their durability - for use in exterior, humid or dry conditions
- mechanical properties
- surface appearance
- surface condition - unsanded, sanded, prefinished or overlaid
- user requirements

Surface appearence

EN 635-1 (General rules) divides plywood into 5 classes, based on appearance. EN635-2 Hardwood and EN 635-3 Softwood define the allowable characteristics for any one grade.

Surface appearance

Classification by surface appearance is covered in the four parts of the EN 635 series, Plywood - Classification by surface appearance. These surface appearance classes are not intended to be used for strength classification.

Conditions of use

The conditions are defined according to the parameters laid down for hazard classes in EN 335-1 *Classification of hazard classes:*

Dry conditions: for interior applications with no risk of wetting, defined in Hazard 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 Hazard 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 hazard class 3, where the moisture content will frequently be above 20%.

Structural bending properties
EN 1072: *Plywood - Description of bending properties for structural plywood* defines the bending properties needed for structural plywood.
- characteristic bending moment per unit width
- characteristic bending strength
- characteristic bending stiffness per unit width
- characteristic bending modulus of elasticity

Characteristic values are required for structural design of plywood using the limit state method.

These properties are derived from tests on medium sized pieces tested in accordance with EN 789: Timber structures - Test methods. Determination of mechanical properties of wood-based panels and EN 1058: Wood-based panels - Determination of characteristic values of mechanical properties and density.

Marking
Boards should be marked with the :
- name, logo or code of the manufacturer
- standard number
- type of panel (Trademark)
- nominal thickness
- formaldehyde release class
- quality label and the certification body, if any.

9.4 ORIENTED STRAND BOARD (OSB)

General
OSB to EN 300 is an engineered wood based panel product composed of wood strands (flakes) arranged in layers at right angles to one another and bonded together with a waterproof adhesive. OSB exhibits strength and dimensional properties similar to many plywoods.

OSB like other wood based panels is hygroscopic and its dimensions change in response to changes in humidity. Boards as manufactured (OSB 2) have a low moisture content and may need to be conditioned prior to installation. This enables the moisture content of the board to be brought into equilibrium with its environment. The time required to achieve equilibrium will vary depending on the temperature and relative humidity in the building. OSB 3 grade is a pre-conditioned panel with a moisture content closer to the in-service equilibrium moisture content.

Applications
OSB is used for applications such as wall sheathing, structural flooring, heavy-duty industrial flooring, roof sarking and roof decking when supported at centres of not more than 600mm. Other applications include furniture, packaging, hoarding, signboards, pallet tops, shop fitting and displays. The range typically includes 6mm board for floor wearing surface, 9mm for wall sheathing, 18mm for floor and roof decking and 25mm for industrial applications.

For designs to Eurocode 5, characteristic design values for OSB should be taken from EN 12369-1 (for service class 1) or from the manufacturers published data. Where the manufacturer's published data is less than the value in EN 12369-1 then the lower values should be used in design. Where the board is used for permissible stress design then the design should comply with BS 5268-2. Designs generally should also comply with the recommendations in the manufacturer's Agrément Certificate, European Technical Assessment (ETA) or similar certification.

Classification of Boards
EN 300 classifies boards by their properties, which relate to intended use. Boards are classified into four board types:
OSB/1 General purpose boards, and boards for interior fitments (including furniture) for use in dry conditions.
OSB/2 Load-bearing boards for use in dry conditions.
OSB/3 Load-bearing boards for use in humid conditions.
OSB/4 Heavy duty load-bearing boards for use in humid conditions.

The following table assists the specifier with the selection of the correct type of OSB for typical end uses:

Table A 9.4.1 *Selecting OSB panels*

APPLICATION	CONDITION	OSB TYPE
Pitched roofs		
Sarking		OSB 3
Flat roof decking		
Uninsulated, unheated buildings	Variable humidity	OSB 3
Insulated, heated buildings	Warm deck, low humidity	OSB 3
	Warm deck, high humidity (intermittent)	OSB 3[1]
	Cold deck (ventilated), low humidity	OSB 3
Cladding		OSB 2[1], OSB 3[1]
Soffits		OSB 3[1]
Sheathing	Dry use	OSB 3
	Risk of wetting	OSB 3[1]
Flooring		
Domestic flooring		
OSB3 only should be used for underlayment with hardwood flooring products	Dry use	OSB 2, OSB 3
	Risk of wetting	OSB 3
Non domestic flooring		
Floating	Dry use	OSB 2, OSB 3
	Risk of wetting	OSB 3
Raised	Dry use	OSB 3
	Risk of wetting	OSB 3
Light duty suspended	Dry use	OSB 3
	Risk of wetting	OSB 3
Formwork	One-off usage here	OSB 3 (sanded panels may be needed for above ground formwork)

[1] Implies no protection against decay; if such protection is required, preservation may be necessary.

For formwork, boards are often given a film face to ease release

Conditioning
Wood-based panel products expand on taking up moisture from the air and shrink on losing moisture. It is important that panels are installed at a moisture content close to that which they will attain in service. The likely moisture contents of OSB in various conditions are as follows:

Building with continuous heating 5-7%
Building with intermittent heating 8-10%
Unheated building up to 16%

These values are lower than for solid timber under the same conditions.

Installation and fixing

Floors and roof decking
Boards must be laid with the major axis crossing the joists. The T&G or square edged boards must be fixed to all supports using ring shank nails or screws (minimum penetration to the support of 50mm at maximum 150mm centres on all joists). The cross-joints on the boards must be staggered and the joints between the boards must be glued. Bridging and nogging supports should be used where required. A minimum 10mm expansion gap should be provided around the floor perimeter, larger floors may need a wider gap and intermediate gaps of 2mm per metre to allow for expansion.

Wall sheathing
Where OSB is used in cold frame construction, the vapour check is located on the cold side of the internal leaf of the cavity wall. 0SB 3 boards should be treated as conventional plywood boards with regard to detailing at eaves and soleplate. A 3mm gap between boards is recommended to allow for expansion.

Technical data

Sheet sizes
Smartply manufactures boards in 'laid measure' sizes of 2440x1220mm, 2400x1200mm, 2440x590mm or 2400x590mm. Other cut sizes are available on request. Panels are manufactured in thicknesses of 6, 8, 9, 11, 15, 18 and 25mm. Panels 15mm and 18mm are manufactured either square-edged or tongued and grooved. All T&G panels are fully sanded.

Strength properties
The design properties for Smartply OSB2 and 3 are outlined in the tables below. (Note: these values are for use in limit state design only). It is the responsibility of the specifier to consult the manufacturer's literature to check the design values are still current. Other manufacturers also produce their own tables.

Table A 9.4.2 *Characteristic bending, tension and compression values*

Grade	Thickness	Bending		Tension and Compression			
	t	$f_{m,0}$	$f_{m,90}$	$f_{t,90}$	$f_{c,90}$	$f_{t,90}$	$f_{c,90}$
	mm	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
OSB/2 OSB/3	6 - 10	17.5	13	8	7	10	9
OSB/2 OSB/3	10 < t < 18	18.5	13	10	9	12	11
OSB/2 OSB/3	18 - 25	20	14	10	9	12	10

Table A 9.4.3 *Characteristic modulus of elasticity mean values*

Grade	Thickness	Bending		Tension and Compression	
	t	$E_{m,0}$	$E_{m,90}$	$E_{t,0}$ AND $E_{c,0}$	$E_{t,90}$ AND $E_{c,90}$
	mm	N/mm²	N/mm²	N/mm²	N/mm²
OSB/2 OSB/3	6 - 10	6000	3000	5000	3500
OSB/2 OSB/3	10 < t < 18	6000	3000	5000	3500
OSB/2 OSB/3	18 - 25	6000	3000	5000	3500

Table A 9.4.4 *Characteristic values of density and mean values of modulus of elasticity*

Grade	Thickness	Density	Panel Shear		Planar Shear	
	t	p	Strength	Modulus	Strength	Modulus
	mm	kg/m²	$E_{m,90}$	G_v	f_p	G_p
			N/mm²	N/mm²	N/mm²	N/mm²
OSB/2 and 3	9 - 22	550	7.9	1400	1.3	75

Note: Characteristic values of Modulus of Elasticity are found by multiplication of the mean values of Modulus of Elasticity by a factor of 0.80.

Flooring
Suitable for domestic use as defined in BS 6399 Part 1 *Design loadings for buildings* - which is the Code of Practice for dead and imposed loads for designed joist spacings not exceeding 600mm centres provided the fixings are in accordance with the manufacturer's instructions.

Consult the manufacturer for specific requirements for use as ground floors.

Wall sheathing
The board may be considered as a Category 1 material in accordance with Table 2 of BS 5268 Part 6, Section 6.1. The basic racking resistance for 9mm board when used with the datum conditions for fasteners of Category 1 sheathing is 1.68kN/m and can be used with the modification factors in BS 5268 Part 6, Section 6.1.

Modified half hour fire resistance flooring
T&G Louisiana-Pacific Class 3 OSB panels laid together on min 44mm timber joists and incorporating a 12.5mm plasterboard ceiling fixed with 40mm galvanised nails at 150mm centres with the joints taped and filled and backed by timber.

Roof decking
Suitable for use with an appropriate waterproofing specification, as a roof deck having a minimum finished fall in excess of 1:80 and where access to the roof is restricted for cleaning only.

Roof sarking
A suitable waterproof run-off membrane and batten system should be incorporated.

Behaviour in relation to moisture
The product is unsuitable for use in permanent wet or damp conditions. The product is suitable for installation in buildings where the moisture content does not exceed 16% for any length of time and does not exceed 20% at any time.

Thermal conductivity
The thermal conductivity of OSB is in the region of 0.13 W/(mK).

Edge stacking is not recommended.

Boards are manufactured to dimensional tolerances to allow close fits to be achieved on jointing. Conditioning allows boards to gradually attain the moisture content dictated by the atmosphere within the building.

Durability
When used in the conditions set out in the manufacturer's literature, the product will have adequate resistance to bacterial and fungal attack and physical degradation due to moisture. Under prolonged wet conditions, OSB may be prone to attack by fungi (e.g. wet rot). OSB can be preservative treated to increase resistance to attack by fungi.

Behaviour in relation to fire
In general boards have a European Class D – s3,d2 for their reaction to fire and a Class 3 surface spread of flame in accordance with BS 476: Part 7. It is possible to treat the boards to improve their performance and classification.

Storage
Panels should be stored on level bearers on a flat surface above the ground in a dry stable environment. Where external storage cannot be avoided, panels should be covered with polythene or tarpaulin, and the period of storage should be kept to a minimum.

Edges shall be protected from lashings or other bandings and all boards should be stored to avoid distortion. Details of board type and quantity should accompany each delivery.

A sacrificial protective board should be used as the top board on all stacks to prevent warping of the main top board. Intermediate bearers are recommended every 10 to 15 boards with the bearers placed directly below those above. Bands should be cut as soon as practicable after delivery.

Only when the boards are required for conditioning should any protective wrapping be removed. Boards should be conditioned to the equilibrium moisture content likely to be attained in service prior to fixing. Conditioning in air in an enclosed dry building is suitable for most board types.

Finishing
High quality finishes are achieved when boards are primed and coated with a spirit based coating. Care should be taken when using water based products as they may cause swelling. Varnishes and gloss paints can be used. Certain overlays can be applied to the surfaces of the boards to achieve special finishes.

Reference EN 120 and BS 5669 Part 1
The 'Extraction Method' is used to determine the amount of formaldehyde emission from a board and the results are expressed in mg/100g.

Health and safety
OSB can be machined using normal woodworking machinery but care should be taken to avoid inhalation of the dust particles. The formaldehyde content of the board is controlled by the manufacturer and should be below 8mg/100g (E1 grade).

Marking
All load-bearing board types shall be clearly marked by the manufacturer by indelible direct printing and typically include the following information:
• Manufacturer's name, trade mark or identification mark
• European Norm (e.g. EN)
• Type/grade of board
• Nominal thickness
• Major axis (if not the length of the panel)
• Formaldehyde class
• Batch number or production week and year

9.5 MEDIUM DENSITY FIBREBOARD (MDF)

General
Medium Density Fibreboard (MDF) is an engineered wood based panel product manufactured from wood fibres bonded together with a synthetic resin adhesive. It is usually smooth on both sides, pale sand in colour and with a density in the range 450 - 960 kg/m³. It has excellent machining characteristics and takes a variety of finishes readily due to its homogenous nature. MDF is produced in a range of thicknesses, from 3mm to 60mm. EN 622-5 applies.

Originally only one type of board was produced - standard MDF - there are now several different board types available, to meet varying needs.

Applications
MDF is classified as a dry process board having a density of more than 450 kg/m³ and is further sub-divided into various board types based on the purpose of the board and the environment in which it will be used.

The product range produced is extensive, and includes:*

Medite Ultralite: (Density 500 kg/m³). A low-density board produced for applications where weight is critical.

Standard MDF accepts a wide variety of finishes

Medite Plus: (Density 750 kg/m³). A specially engineered panel with an extra-smooth finish intended for fine machining and further finishing.

Standard MDF (Medite Premier): (Density 620 kg/m³). Suitable for interior joinery including doors and staircases, cabinetry, built-in fitments, furniture, toy-making. Can be machined and profiled.

Flame retardant boards accept a wide range of flame retardant paint and coating systems, veneers, laminates and overlays.

Flame-Retardant Board (Medite FR): (Density 720-750 kg/m³). Flame retardant MDF is available to Class 0 and Class 1 surface spread of flame rating. It is suitable for shop fittings and walls, partitions and ceilings in public buildings to comply with the Building Regulations. Consult the manufacturer for more detail and range of thicknesses available.

High density MDF is suitable for processes that require more exacting machining characteristics.

Provide expansion gaps (5mm per 2440mm) and seal all surfaces and exposed edges with an exterior grade coating system.

Exterior MDF (Medite Exterior): (Density 720-750 kg/m³). An exterior quality board is produced. Care in its external use should be exercised. These boards should be painted and special care taken to achieve the optimum result.

Moisture resistant boards are not suitable for external use.

Moisture Resistant MDF (Medite MR): (Density 720-750 kg/m³). For use in internal joinery applications and in high humidity environments such as bathrooms and kitchens in accordance with MDF.H as defined in EN 622 Part 5.

Flooring quality MDF is suitable as a substrate for a wide variety of overlay materials such as wood veneers, high pressure laminates and melamine impregnated paper overlays.

Flooring Grade MDF (Medite FQ): (Density 850 kg/m³). A substrate produced specifically for laminated flooring applications in domestic and commercial applications.

Zero formaldehyde MDF is now a requirement for many applications.

Zero Formaldehyde MDF (Medite Ecologique): (Density 740 kg/m³). Conventional resin systems, which are formaldehyde based, are not used in production and, as a result, no formaldehyde is added. It is particularly suitable for use in environmentally sensitive areas such as hospitals, laboratories, nurseries and museums.

With the development of continuous pressing technology MDF with thicknesses as low as 3.0mm are now produced.

Technical data

Density
Typically, standard MDF has an average density within the range of 600-800kg/m³. High Density Fibreboard (HDF) weighs up to 960kg/m³. Light MDF has a density of < 600kg/m³ and ultra light MDF has a density of < 550kg/m³. The weight of MDF is not constantly proportional to the thickness due to variation between brands.

Sheet sizes
Available sizes are commonly 1220, 1525 or 1830mm wide by lengths up to 3660mm. Thicknesses are available up to 60mm, although thicknesses between 3.0mm and 30mm are more common.

MDF is available cut to size from any of the four full mat sizes of 1220/1525mmX4880/5490mm. It can be supplied in narrow strips for the door and moulding industries as well as component panels for furniture manufacturers.

**Produced by Coillte MDF*

Table A 9.5.1 *Table of characteristic values for MDF*.*

PRODUCT	Thickness (mm) ±0.15mm	Density (kg/m³) ±4%	MC (%)	Internal bond (N/mm²) (Min.)	Bending strength (N/mm²) (Min.)	MOE (N/mm²) (Min.)	Screw (face) (N) (Min.)	Thickness Swelling (%) (Max.)
Standard MDF	15.0	750	5 - 9	0.70	32.0	3200	1000	10.0
Flame retardant	15.0	750	5 - 9	0.65	30.0	2700	900	10.0
High density	15.8	960	5 - 9	1.50	70.0	5000	1700	5.5
Exterior grade	15.0	740	5 - 9	1.20	37.0	3000	1000	7.0
Flooring grade	8.0	850	5 - 9	1.50	50.0	4500	–	10.0
Moisture resistant	15.0	750	5 - 9	0.90	40.0	3500	1000	6.0
Zero formaldehyde	15.0	740	5 - 9	0.90	35.0	3000	1000	8.0

**Check individual manufacturers*

Movement

MDF is hygroscopic and its dimensions will change in response to change in humidity. Typically, a 1% change in moisture content will increase the length and width by 0.4mm per metre. A 600mm wide door panel made from 15mm thickness MDF will swell by about 1.5mm in width and 0.3mm in thickness in moving from 35 to 85% relative humidity (equivalent to about 5% increase in moisture content). Conditioning before use is recommended. Complete immersion in water must be avoided.

Decay and insect damage resistance

MDF will not normally be attacked by wood-boring insects found in Ireland. It is susceptible to fungal attack if exposed to prolonged wet conditions.

Water vapour resistivity

The vapour resistivity is between 100 and 280MNs/gm when tested in accordance with BS 7374.

Thermal conductivity

The thermal conductivity of MDF is approximately 0.12 W/mK.

Fire properties

Factors such as thickness and method of fixing affect the fire resistance of the board. Seek manufacturer's advice.

Fire properties

Standard grades achieve a Class 3 surface spread of flame rating. There are integrally treated boards on the market which achieve Class 1 or Class 0 rating.

Formaldehyde

MDF that complies with low formaldehyde emission rate Class E1 for total extractable formaldehyde using EN 120 test methods is available.

Cutting and machining

MDF is machine workable using ordinary joinery tools, and may be routed carved, bored and worked in the same way as solid timber. Carbide tipped tools are recommended. Saw blades used for particle-board are normally satisfactory.

Compared to saw blades for solid wood all types of MDF saw blades require higher clearance and increased tooth angles. Having clean edge and face machining characteristics, contour designs are almost unlimited. However, care must be taken in the selection of profiles, as the presence of sharp corners or narrow sections will alter the uniformity of paint coverage and reduce the resistance of profiles to impact damage. A large hook angle is required to ensure clean cutting, with a large clearance angle to prevent the back of the cutter from rubbing against machined edges. Mitre joints are not recommended, especially in external situations.

Installation and fixing

Most adhesives used in the woodworking industry can be used for jointing MDF. The selection of an individual adhesive will depend on the surface characteristics of the material to be bonded, the jointing technique, the strength required, and service conditions.

In general, parallel threaded screws are recommended in pre-drilled pilot holes not less than 25mm (face) or 70mm (edge) from the corners of the board. They should be spaced at 150mm apart to avoid splitting. Nails should only be used if no other jointing technique is applicable. The diameter of dowel holes should be a minimum of 0.2mm greater than the dowel itself to prevent cracking if swelling of the board occurs.

Installation and fixing

Consult manufacturer's literature for specific details. Suitable jointing techniques include:

- Adhesives
- Staples (to fix glue joints)
- Nails
- Dowels
- Screws
- Pins

Finishing

The choice of finish depends on the specific application and the appearance and durability requirements. In general MDF is suitable for painting. Sanding, sealing and priming the surface may be required and it is advisable to follow the manufacturer's advice to ensure satisfactory performance.

Finishing

- Suitable finishes include:
- Nitrocellulose systems
- Water based paint systems
- Acid-catalysed systems
- Polyester systems
- Isocyanate bonds

Health and safety

The dust generated by machining operations carried out on MDF (sawing, moulding, routing, sanding etc.) can be quite fine. Precautions must be taken when working with MDF, as with any wood product, to prevent inhalation of fine dust particles.

MDF Type	Use Classification*
MDF	General purpose - dry
MDF.H	General purpose - humid
MDF.LA	Load bearing - dry
MDF.HLS	Load bearing - humid

**Defined in EN 622: Part 5*

Specification

MDF should be specified in accordance with European standards. The specifications classify boards according to their intended end use.

Specification

The relevant standards include:

EN 622 Fibreboards Specifications: Part 1: General requirements

EN 622 Fibreboards Specifications: Part 5:Requirements for dry process boards

General purpose boards are classified as being suitable for use as furniture. Loadbearing boards are suitable for use where the panels contribute to provide mechanical resistance and stability to a structure.

Fibreboards in the European Standards are separated on the basis of their performance in differing environmental situations. Three environmental situations are defined; these relate to the three Service Class conditions defined in BS 5268 *Structural use of timber Part 2: Permissible stress design, materials and workmanship* and in Eurocode 5: Design of timber structures: common rules and rules for building.

Dry: moisture content in the material corresponding to a temperature of 20°C and relative humidity of surrounding air only exceeding 65% for a few weeks each year. (Service Class 1).

DRY - Boards of this type are only suitable for use in Hazard Class 1 of EN 335-3

HUMID - Boards of this type are suitable for use in Hazard Classes 1 and 2 of EN 335-3 provided an appropriate coating system is used.

EXTERIOR - Boards of this type are suitable for use in Hazard Classes 1, 2 and 3 of EN 335-3 provided an appropriate coating system is used.

Humid: moisture content in the material corresponding to a temperature of 20°C and a relative humidity of surrounding air exceeding 85% for only a few weeks each year. (Service Class 2).

Exterior: moisture content in the material higher than those in humid conditions. This implies exposure to weathering conditions or to water or water vapour in a damp but ventilated location. (Service Class 3).

The general requirements for fibreboards are given in EN 622-1 *Fibreboards - Specifications Part 1 General requirements.*

Marking
Product packs and panels (where possible) should be marked with indelible ink printing or adhesive labelling with the following information:

- manufacturer's name, trade mark or identification mark
- number of the relevant standard and symbol of the board type
- nominal thickness
- batch number or production week and year
- dimensional tolerance
- length
- width and thickness
- squareness
- edge straightness
- moisture content
- mean density within a panel
- formaldehyde class

A 10 Cladding

TImber as a cladding material
Timber is a very attractive and ecological building element as an architectural treatment to the exterior of a building. It has been used for thousands of years and is the most common external finish to Scandinavian, Canadian and American homes. With modern preservative treatment methods and improved detailing, timber cladding is experiencing increasing popularity in Ireland.

The primary function of any external cladding system is the protection of the building structure and fabric from weather, dampness and ultra-violet degradation.

Fire restrictions
The Technical Guidance Documents to the Building Regulations do not permit timber cladding when the wall is less than one metre from the relevant boundary and limits are placed on it depending on its height above ground level. When the boundary distance exceeds one metre, the cladding may be of wood, if it is at least 9mm thick and complies with the 'unprotected area' rule (Technical Guidance Document B to the Building Regulations, Part B4). However, good practice requires a minimum thickness of 18mm (depending on the timber species) for external cladding board for long life durability.

Moisture content
Due to environmental fluctuations, adequate accommodation for moisture movement must be provided to avoid stresses and eventual cracking. Cladding boards should be free to move independently of each other and where overlapping occurs, care should be taken to avoid nailing through underboards. End grain of cladding boards should be sealed to avoid end splitting and ingress of moisture. Specified moisture content should be 18% ± 2%.

Ventilation
All cladding systems should be fixed on battens which allow a continuous vertical cavity. This vertical cavity provides a route for the drainage of any superfluous moisture. It also provides ventilation to the back-face of the cladding, this allows effective and quick drying of both surfaces of timber cladding after heavy rain conditions. Where vertical cladding is used, counter battens will be required unless the profile of the cladding board and staggered horizontal battens are used to allow ventilation and the escape of any penetrating rain water. A breather membrane should always be provided behind the battens.

Ecological considerations
Timber is the classic ecologically friendly material. It is a renewable resource, is very low in embodied energy and it can be recycled.

Most timber today contains both heartwood and sapwood in its sawn state. Preservation is advisable especially for the moderately durable woods, and those of lesser durability (Class 3-5). Preservative treatment is essential if sapwood is present.

Fixings
Both oak and western red cedars are acidic and react with most metals, causing corrosion and dark staining in damp conditions. Austenitic stainless steel or silicon bronze ringshank nails should be used for all external cladding, although the latter are now difficult to obtain. Galvanised or aluminium nails are not suitable as they will stain cladding within a very short time.

Finishes
All wood species will weather naturally to a silvery-grey colour when exposed externally. The rate of weathering will depend on the level of exposure, and areas under overhangs will retain their original colour longer. In urban areas or locations close to traffic discolouration can occur and a surface finish is advisable. Pigmented microporous finishes have been found to perform well in the Irish climate and, if correctly applied, give a long service life. Oils or varnishes when used externally perform poorly and should be avoided.

Key Considerations
- Performance
- Function
- Fire restrictions
- Moisture content
- Detailing

Timber Cladding Systems
- Vertical "Board on Board"
- Horizontal "Shiplap"
- Vertical Tongued, Grooved & V-jointed
- Shingles/Shakes
- Log Effect

Design considerations
- Specific climatic conditions
- Exposure
- Orientation
- Species
- Preservative Treatments
- Finishes
- Jointing
- Maintenance
- Surface spread of flame

Pitfalls
- Moisture entrapment
- Surface cracking
- Peeling of coatings
- Staining
- Discolouring
- Decay
- Movement & Distortion

Reference
EN 942

Table A 10.1 *Suitable species for cladding*

Species	Natural Durability (heartwood)	Durability if preserved	Ease of preservation	Remarks
Douglas fir	3	4/5	3	Small movement, prominent grain, red-brown
Iroko	5	5	1	Small movement, no distinct grain, yellow dark-brown
Larch	3	4/5	3	Small movement, no distinct grain, pale dark-brown
European or American White oak	4/5	5	1	Medium movement, distinct grain, pale yellow yellow-mid brown
Pine, pitch	2/3	4/5	3	Medium movement, distinct grain, yellow-red brown
Pine, Scots	2	4/5	4/5	Medium movement, moderate grain, pale yellow-red brown
Spruce, Norway	2	4	3/4	Small movement, moderate grain, pale-pink brown
Teak	5	5	1	Small movement, no distinct grain, golden dark-brown
Western red cedar	4	5	2/3	Small movement, fine grain, red-brown

1	2	3	4	5
Poor . . . . Average . . . . Good				

Note: The preserved durability of all the timbers listed above can be well in excess of 50 years depending on location, detailing and the treatment schedule chosen.

Close up of cladding - note stainless steel ring-shank nail fixing in v-joint; one fixing per board per batten.

White oak cladding and joinery.

A11 Flooring

Types of timber flooring
- Softwood flooring
- Hardwood flooring (solids and composites)
  - Strip and plank flooring
  - Wood block
  - Parquet
- Wood based panel flooring and structural horizontal diaphragms
  - OSB
  - Chipboard
  - Plywood

Design Considerations
- Aesthetics
- Resistance to wear (impact, abrasion, indenting)
- Resistance to dimensional change (movement/moisture content)
- Slip resistance
- Sound insulation
- Thermal insulation
- Fire resistance
- Resistance to colour change
- Sub floor conditions

Maintenance
- Protecting
- Cleaning
- Re-sanding, finishing, staining and polishing
- Repairs to damage

Pitfalls
- Slippy conditions
- Shrinkage
- Gaps, creaking
- Grooves cut in joists to accomodate services should be avoided
- Inadequate subfloor ventilation
- Poor workmanship

References
- BS 8201
- BS 1187
- BS 4050
- BS 5268
- BS 1297
- BS 7916

Introduction
Timber can provide beautiful and hardwearing floors in narrow or wide boards, wood block, mosaic, parquet and in wood-based products. Hardwoods such as ash, hard maple and white oak will give a long service life if detailed and installed correctly. Special effects can be obtained through the use of borders, medallion inserts, and the use of herringbone patterns.

Types of flooring products
Utility softwood flooring is supplied as tongued and grooved boards. BS 1297 –Tongued and grooved softwood flooring – covers the use of such products. Other timber flooring and its installation is covered by BS 8201 – Code of practice for flooring of timber, timber products, and wood-based panel products. Specific types are covered by a series of European standards.

Decorative flooring is available as:-
1. Solid tongued and grooved strips and parquet boards, either pre-finished or unfinished. Strips are often supplied in random lengths. Widths range from 62 –200mm, but it should be noted that the narrow boards are generally more stable.
2. “Engineered” or “Semi-solid” boards. These are of cross-bonded or plywood construction with a top wear layer, usually 4mm thick, of the chosen species. Movement in the width of these boards is considerably less than with solid boards. The top layer is of sufficient thickness to allow them to be sanded several times. Top wear layers of 6-8 mm thick are available for a longer floor life.
3. Board or panel products, typically with veneer or laminate finishes.

Methods of laying
Traditionally, strip flooring was secret nailed to battens, while block parquet was laid in hot bitumen. Nowadays a number of other methods are more widely used.

1. Secret nailing
Boards are nailed through the tongue on to battens or boards fixed to the sub-floor, usually by machine, and this is the usual method for large areas. Sports floors can incorporate resilient pads and proprietary systems which meet the particular requirements of either BS 7044 or DIN 18032 for such floors are available to achieve the required resillience and rebound for specific sports.

2. Gluing
Boards can be bonded to solid sub-floors with mastic-type adhesives using a toothed trowel. A primer or liquid D.P.M. may be necessary.

3. Clips
Some proprietary systems use metal clips inserted into grooves on the underside of the boards. These clips are sized for various service conditions and the supplier should be consulted for detailed information.

4. Floating
Boards are glued along the tongue and groove joints and laid over a resilient layer, usually plastic foam. This method should only be used when the joints are specifically designed for gluing. As all movement has to take place at the perimeter of the floor it is confined to domestic scale applications. (Less than 4 m wide) and is mainly used for engineered or laminate boards.

As mentioned above, some movement will occur in service due to changes in the humidity of the atmosphere. Allowance for this is made by leaving a gap at the perimeter of areas, and in larger areas by providing intermediate or “washer” gaps (nailed or glued) floors. Perimeter gaps are usually covered by skirting boards. Cover strips, in matching wood, metals or plastic, are widely available to cover expansion gaps at doorways, where timber flooring butts on to tiling, or at radiator pipes. Compressible materials such as cork strip can also be used.

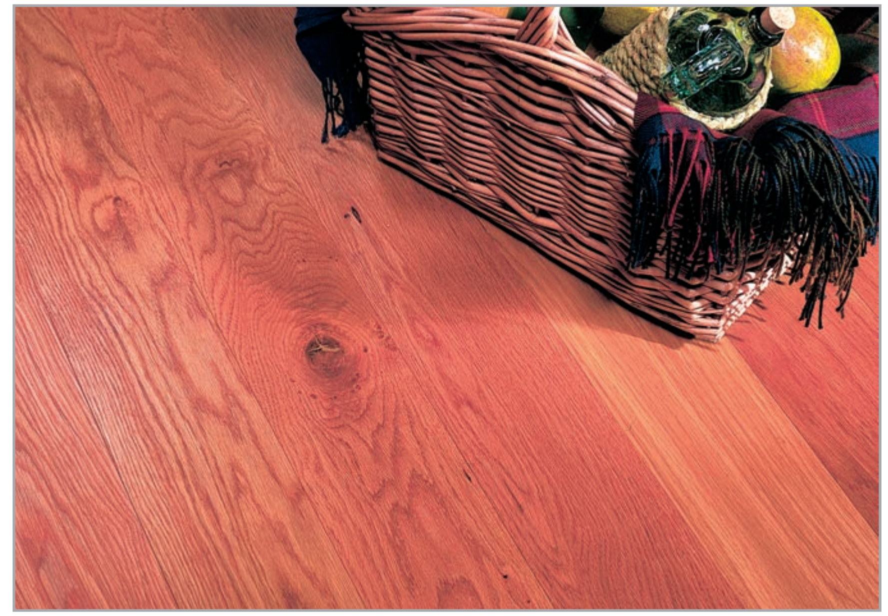


Fig. A 11.1 Wide board solid oak floor laid with a quick clip system.

Finishes
Most flooring is now supplied pre-finished with factory applied lacquer in gloss, semi-gloss or matt. Unfinished boards are sanded and sealed in-situ, usually with two-pack products. Oiled and waxed finishes are popular in Europe but are little used here. Regular light maintenance is required for these latter finishes.

Little maintenance is required for the lacquered products. The need for maintenance and periodic re-finishing is minimised by the provision of mat wells at entrances to trap grit from shoes – the greatest cause of wear. Felt pads should be fitted to the legs of furniture. Floors should be re-finished once wear is apparent and before dirt is ground into the wood so as to minimise re-sanding.

Moisture content and movement
To minimise “movement” or shrinkage and swelling in service, it is essential that timber flooring is laid at the correct moisture content for the service conditions (See table A11.1) and/or provision is made to allow such movement, for example by the provision of expansion gaps at the perimeter of floors. Failure to make such allowance can lead to distortion or the appearance of excessive gaps. For large areas such as sports floors, or where floors are laid with timber at low moisture contents as is the case with some imported products, it is normal practice to provide additional intermediate expansion gaps. When properly calculated for the anticipated service conditions these will close up after laying. Where large changes in moisture content in service are anticipated species with high movement, such as beech, should be avoided.

Moisture movement, classified as % in width for a change from 60-90% RH (approx. 12-20% MC). In-service movement will normally be much less than this.

Large	Medium	Small
Beech	Ash	Teak
Birch	Cherry	Iroko
	Maple	Spruces
	Oak	
	Pines	
	Walnut	

It is also essential that buildings are adequately dry before laying and that heating/air conditioning systems have been commissioned and are in operation. Concrete sub-floors are the most common cause of problems. The usual rule of thumb is to allow 1 day per millimetre of thickness (1 inch/month) for drying but if slab thicknesses exceed 100mm, or are power floated, this period can be extended considerably. The moisture content of such slabs should always be checked before laying. Particular care must be taken in measuring the moisture content of screeds incorporating under-floor heating over concrete slabs as the screed may be dried by the heating coils while residual moisture remains in the underlying slab. The hygrometer method given in BS 8201 is recommended in these cases.

Table A 11.1 *Average moisture content of floor boarding in service (BS 8201)*

Unheated building	15% to 19%
Intermittent heating with a substantial drop in temperature between periods of heating	10% to 14%
Continuous heating with the temperature maintained day and night throughout the year at a reasonably constant level	9% to 11%
Underfloor heating	6% to 8%

Species selection

There is a wide variety of timber species to select for various end uses. Softwoods are generally used in conjunction with a floor covering while hardwoods are used where a more hardwearing or decorative exposed surface is required. Table A11.2 lists the most widely available species, but many other species are available from specialist suppliers. It should be noted that the terms "hardwood" and "softwood" do not refer to the actual hardness of a given species and some hardwood species used for flooring, for example alder and cherry, are softer than pitch pine, a softwood.

Within a given species a wide range of effects can be obtained, with grades ranging from clear, straight-grained sapwood free boards of uniform colour (often referred to as Prime or 1st. grade) to Rustic grades incorporating knots, sapwood and distorted grain. It is best to view a sample of at least a square metre to assess the appearance when laid.

Table A 11.2 *Species selection*

	Species	Hardness & Wearability	Moisture Movement	Texture	Remarks
Softwoods	Douglas fir	3	Small	Medium	Reddish-brown with flame-like growth figure, when flat-sawn.
	Larch	3/4	Small	Fine	Pale to dark brown with distinct grain.
	Pine, pitch	4	Medium	Medium	Yellow to red-brown with noticeable grain.
	Pine, Scots	3	Medium	Fine	Pale yellow to red-brown with moderate grain.
	Spruce, Sitka	2	Small	Fine	Pale to pink-brown. Indents easily.
	Spruce, Norway	2/3	Small	Fine	Pale to yellowish. Indents easily.
Hardwoods	Ash, American/European	4	Medium	Coarse	White to light brown with noticeable grain.
	Beech, American/European	4	Large	Fine	White to pale brown. European more consistent in colour.
	Birch, American/European	4	Large	Fine	White to brown with moderate grain.
	*Cherry, American/European	3	Medium	Fine	Red to reddish brown, darkening on exposure to light.
	Iroko	5	Small	Medium	Yellow to dark brown with no distinct grain.
	Maple, hard	5	Medium	Fine	Cream to light red-brown with generally straight grain.
	Maple, soft	3	Medium	Fine	Grey-white to red-brown. Not as hardwearing as hard maple.
	Oak, red	4	Medium	Medium	Yellow to red-brown, not as hardwearing as white oak.
	Oak, white	4	Medium	Medium	Pale yellow to mid-brown. More figure than red oak.
	Sycamore	3	Medium	Fine	White to yellow-white often with interlocking grain.
	Teak	5	Small	Medium	Golden to dark brown with no distinct grain.
	Walnut, American/European	3	Medium	Coarse	Light to dark chocolate brown. Generally straight grained.

1	2	3	4	5
Poor		Average		Good

Note: Hard maple has excellent abrasion qualities. Great care should be taken with beech with under-floor heating or south facing rooms with large glazed areas as it may move too much. A proprietary system on the market claims to overcome this problem.

** Cherry commonly incorporates some pale sapwood, giving a distinct colour contrast*

A 12 Joinery

Suitable species

Table A 12.1 has been scored on the basis of natural durability, timber density, moisture movement and end use suitability. Most timbers will score in the region of 4 to 5 for exterior use if they are given the recommended preservative treatment in accordance with their likely exposure or hazard class, for example, Hazard/Use Class 3A for external joinery and cladding. Some species such as iroko, mahogany, white oak and teak are extremely resistant to preservative impregnation treatment but their natural durability more than compensates.

Western red cedar would be as naturally durable as white oak but its low density and softness make it unsuitable for areas where strength or abrasion resistance is required, such as glazed doors, opening windows or thresholds. Non-durable species listed at "1" in the table below – Ash; beech; maple and sycamore are unsuitable for exterior use.

Both oak and western red cedar are acidic and will corrode most metals and cause rust staining in damp conditions. Choose stainless steel fixings in these conditions. Silicon bronze or stainless steel ringshank nails should be used for all external cladding. Galvanised or aluminium nails will stain cladding within a short time. Stainless steel pins are best for joinery. Aspects such as colour and texture have not been included in the table and samples should be sought prior to final specification.

Note
Hazard and Use class are synonomous with Hazard class gradually replacing Use class

Moisture movement, classified as % in width for a change from 60-90% RH (approx. 12-20% MC). In-service movement will normally be much less than this.

Large	Medium	Small
Beech Birch	Ash Cherry Maple Oak Pines Walnut	Teak Iroko Spruces

Table A 12.1 *Joinery species suitability*

SPECIES	INTERIOR			EXTERIOR			REMARKS/USES
	Furniture	Doors	Stairs	Windows	Doors	Steps	
Ash[+]	4	4	4	1	1	1	Medium movement; panelling & flooring
Alder[+]	4	4	2	1	1	1	Medium movement; kitchen cabinets, mouldings
American soft maple[+]	4	4	3	1	1	1	Medium movement; kitchen cabinets, joinery
American tulipwood	4	3	2	1	1	1	Medium movement; kitchen cabinets, mouldings
Beech[+]	4	4	4	1	1	1	Large movement; furniture & flooring
Cherry	4	4	4	2	2	2	Medium movement; furniture & cabinetry
Douglas fir*	3	4	3	4	4	4	Small movement; external joinery & cladding
Iroko	5	5	5	5	5	5	Small movement; external joinery & cladding
Larch*	4	4	4	4	4	4	Small movement; external joinery & flooring
Mahogany	5	5	5	4	4	4	Small movement; joinery & furniture
Maple, hard or rock[+]	5	5	5	1	1	1	Medium movement; furniture & flooring
Oak, red	4	4	2	2	2	2	Medium movement; furniture & flooring
Oak, white	5	5	5	4	4	4	Medium movement; furniture & flooring
Pine, lodgepole*	4	4	3	3	3	2	Small movement; panelling & furniture
Pine, pitch*	4	4	4	4	4	3	Medium movement; joinery & flooring
Pine, Scots*	4	4	3	3	3	3	Medium movement; construction & joinery
Pine, southern yellow*	4	4	3	3	3	3	Medium movement; construction & interior use
Spruce, Sitka*	3	3	2	2	2	2	Small movement; construction
Spruce, Norway*	3	3	3	3	3	2	Small movement; construction & joinery
Sycamore[+]	4	4	3	1	1	1	Medium movement; panelling & furniture
Teak	5	5	5	5	5	5	Small movement; joinery & furniture
Western red cedar	2	3	1	2/3	3	2	Small movement; cladding & greenhouses
Walnut	5	5	4	2	2	2	Small/medium movement; panelling, furniture, joinery

1	2	3	4	5
Poor		Average		Good

* Softwoods. These species require preservative treatment for exterior use.

\+ Non durable hardwoods not suitable for exterior use

Fig. A 13.1 Multi-veneered door inspired by Mondrian, Botanic Gardens Centre.

A 13 Veneers

The art of veneering is nearly four thousand years old and was practiced in Egypt under the Pharaohs. The price of veneers can vary greatly. Inexpensive veneers include gaboon, koto and sapele. Moderately costed veneers include ash, aspen, beech (steamed and unsteamed), cherry, Douglas fir, elm, maple, oak, pine, sycamore, teak, American black walnut, wenge and zebrano.

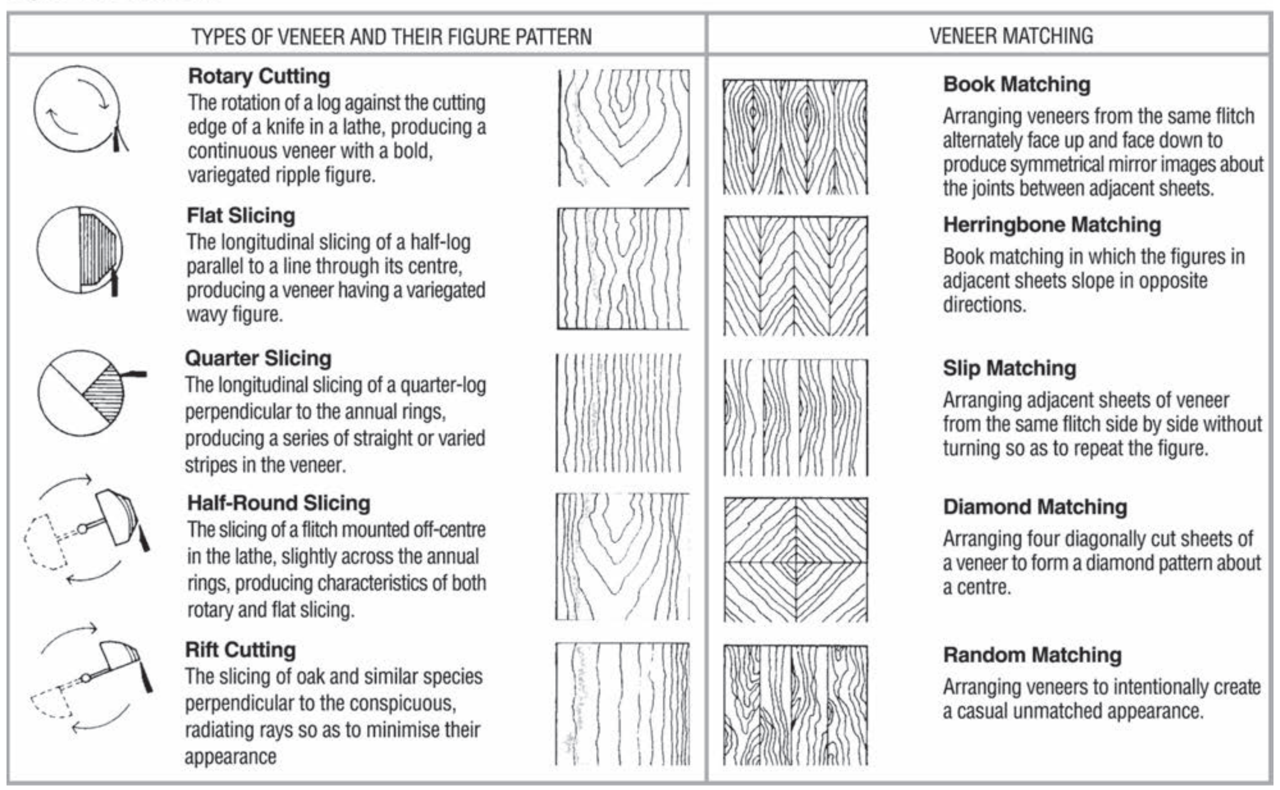
Expensive veneers include white fiddle back anegré, bird's eye maple, pear, rosewood, thuya burr, American/European burr walnut and yew. Representative samples of veneers should be sought before making the selection.

The specifier should be informed when the *whole* of the stock is available for inspection and approval prior to the commencement of the work to ensure uniformity.

Don't just specify 'veneer' as a generic finish. There are five principal veneer cutting methods, each one of which will produce a different visual effect from the same wood species.

- Rotary veneers are exceptionally wide with a multi-patterned grain marking.
- Flat slicing is cut parallel to a line through the centre of the log. As a result it looks similar to a conventionally cut solid board.
- Quarter-sawn veneer produces a series of stripes both straight and varied and highlights the medullary rays of most species.
- Rift-cut veneer gives a comb-like grain effect without any medullary ray.
- Half-round slicing results in a cut slightly across the annual growth rings and usually shows the combined yet modified effects of both rotary and flat sliced veneers.

Fig A 13.1 *Veneers*



TYPES OF VENEER AND THEIR FIGURE PATTERN	VENEER MATCHING
Rotary Cutting The rotation of a log against the cutting edge of a knife in a lathe, producing a continuous veneer with a bold, variegated ripple figure.	**Book Matching** Arranging veneers from the same flitch alternately face up and face down to produce symmetrical mirror images about the joints between adjacent sheets.
Flat Slicing The longitudinal slicing of a half-log parallel to a line through its centre, producing a veneer having a variegated wavy figure.	**Herringbone Matching** Book matching in which the figures in adjacent sheets slope in opposite directions.
Quarter Slicing The longitudinal slicing of a quarter-log perpendicular to the annual rings, producing a series of straight or varied stripes in the veneer.	**Slip Matching** Arranging adjacent sheets of veneer from the same flitch side by side without turning so as to repeat the figure.
Half-Round Slicing The slicing of a flitch mounted off-centre in the lathe, slightly across the annual rings, producing characteristics of both rotary and flat slicing.	**Diamond Matching** Arranging four diagonally cut sheets of a veneer to form a diamond pattern about a centre.
Rift Cutting The slicing of oak and similar species perpendicular to the conspicuous, radiating rays so as to minimise their appearance	**Random Matching** Arranging veneers to intentionally create a casual unmatched appearance.

A 14 Furniture

Timber is easily shaped and moulded and is ideal for furniture. Most specialist workshops can execute one-off furniture designs. Designers should be aware of the European Regulation on General Product Safety which was implemented into Irish legislation in April 1997 under Statutory Instrument No. 197 of 1997. This legislation requires designers and specifiers to provide safe products which will not injure the end user. Chair design requires special attention in this regard.

Fig. A 14.1 Internal view of dining space. The dining tables were designed by the architects

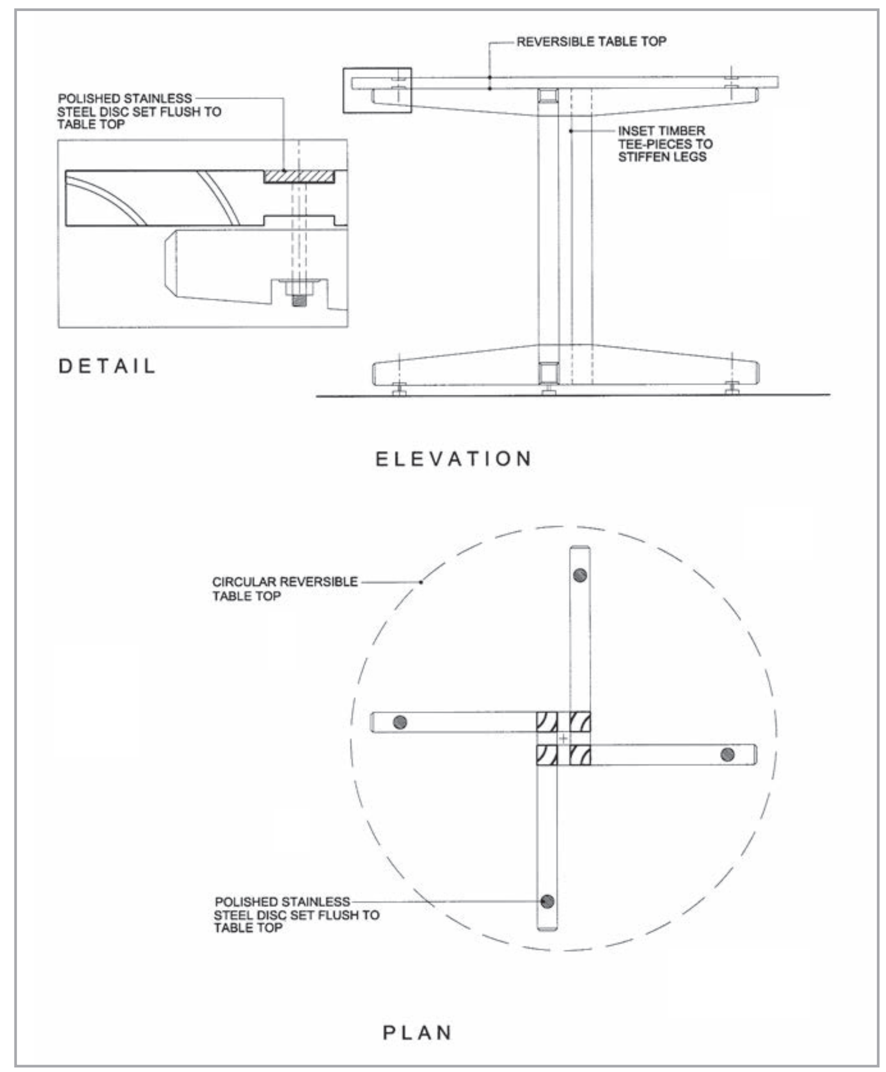


Fig. A 14.2 A detailed drawing of a table.

Conservation principles
- Research prior to planning work
- Minimum intervention - repair rather than replace
- Maintenance of the visual setting
- Where necessary accurate replacement, not conjecture
- Significant new work to be identifiable and recorded
- New interventions to be reversible as far as possible
- Sustainable conservation through proper maintenance and repair

Conservation procedure
- Research and analyse history of timber element/building from primary sources if possible
- Survey using drawings and photographs to identify original material
- Plan and execute work according to conservation principles
- Use experts/specialists where necessary
- Record work in visual and written form
- Put in place regular maintenance procedures

A15 Restoration and conservation

The restoration of a timber building or element involves returning a heritage object to a known earlier state, without the unnecessary introduction of new materials.

Conservation involves the prevention of decay and the prolonging of the life of the particular timber element. This work should be done without damaging the timber element or the building it is a part of. Historical evidence should not be falsified.

Reconstruction generally involves altering a heritage object by the introduction of new or old materials to produce an end result which respects the original.

Restoration and reconstruction often, by necessity, occur in the conservation of old buildings. Pastiche should be avoided but properly executed replicas, in particular cases, are acceptable.

Where completely new works are required in an otherwise conservation setting, the use of architecturally well designed forms and carefully chosen materials of a contemporary nature is far more appropriate and respectful of an historic setting than bland pastiche.

Fig. A 15.1 An historic illustration of the last recorded urban timber-framed historic building in Ireland. Note the angle posts and jettying of the upper floor, the various expressions of bracing, and decorative quatrefoil panelling on the second and third floors similar to extant buildings in Lancashire, Essex, and Shropshire in Britain. This illustration shows a shop and house built by Nicholas Bathe on the corner of Shop St. and Laurence St. in Drogheda, Co. Louth. It was demolished in 1824.

Structural
Structural elements of older buildings have often suffered damage or have become weakened due to decay, insect attack, or alterations or interventions such as notching for plumbing and wiring. Floors may be subject to deflection due to over-stressing. Structural analysis and strengthening may be necessary to meet modern loading and fire requirements. Susceptible areas include parapet gutters and valleys, bearing ends of joists in external walls, or timber at ground level where damp proof courses may not exist.

An assessment of structural timber in older buildings should include:-
Survey of decay, insect attack and other damage/deterioration
Strength grading of components
Identification of species present, so that stresses can be assigned to the timber and structural calculations performed. Note that age alone has a negligible effect on the strength of timber once it remains dry. There are numerous instances of timber in Irish buildings still perfect after 2-3 centuries.

TIMBER WINDOWS
The most common window up to the early 18th century was the side hung casement. The sliding sash window superseded the casement window and dominated window design for over 200 years. It is important not to confuse Georgian and Victorian sliding sash design.

The typical Georgian timber window was not equally split between top and bottom sash. The convention was to have nine panes of glass over six below, with a matching split pattern for the shutter panels of three over two. The Victorians often replaced the Georgian windows with equally split top and bottom sashes. The Victorians also introduced plate glass in lieu of the original Georgian crown or cylinder sheet glass. In addition, the Victorians 'improved' the sash window construction by the addition of window horns (extensions to the bottom of the top sash).

Much information on specialist craftsmen, restorers, and salvage materials is available on the Irish Georgian Society website, www.igs.ie.

Glazing bars varied in their width and thickness with each architectural period. Early 18th century Georgian window glazing bars were wider and usually heavier than mid to late 18th century glazing bars.

Sashes and window weights
If a new sash is required it should be a faithful historical copy. It is important to match the weight of such replacement windows with the original so that the original window sash cords, pulleys and weights can be reused where possible. The rule of thumb is that the weights for the upper sash are a little heavier than the sash itself so as to maintain it at the top of the frame. The opposite is true of the lower sash where the weights are usually a kilo lighter than the sash so as to ensure that it sits firmly on the sill.

Preventing draughts
A common problem with old sliding sash windows is their rattling under wind pressure and subsequent draughts. Proprietary systems are available to draught strip sliding sashes such that they perform as well as any standard replacement window on the market.

Repairing joints
Wear and tear and the inconsistencies of some old animal based glues can lead to the loosening of timber joints over time. If the timber is sound the joints can be reglued and cramped. Where additional strengthening of the joint is required insert a stainless steel or brass screw from the inside (to avoid external rot problems) through the tenon or dovetail joint, ensuring that the structural integrity is not compromised.

Thermal insulation and avoiding condensation
The use of original shutter panels will give added heat insulation and security to sliding sash windows. All buildings need both heat and ventilation in order to avoid mould growth, decay and condensation. If there are no shutter panels, and after draught stripping it is still necessary to improve the thermal performance of sash windows, then secondary glazing is preferable to altering the glazing bars of the original window design. The divisions of the new internal secondary glazing should be aligned with the meeting rail and/or the glazing bars of the original window. To reduce the effect of a double image reflection, the glazing bar members of the secondary window should be painted a dark colour.

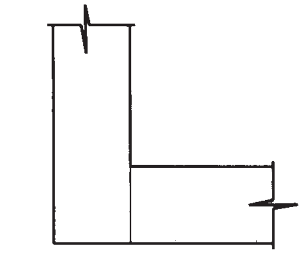
Maintenance
Windows need maintenance inspection and repainting every three to five years. When painting, the elements of the window should be painted in a sequence to avoid the sashes sticking.

A common problem with old windows is the cracking of the linseed oil putty used to glaze the panes of glass. The result is often water ingress at vulnerable corners. There are a number of modern glazing mastics which can be overpainted to match the original putty look and which out-perform putty in terms of lifecycle and protection of the timber glazing bars. Special mastics (to specialist order) can also be got for larger projects with colours to match traditional paint finishes. While some conservation purist might recoil at such a suggestion it is far more preferable to use such compatible special mastics than allow the proven poor track record of putty to undermine historical windows.

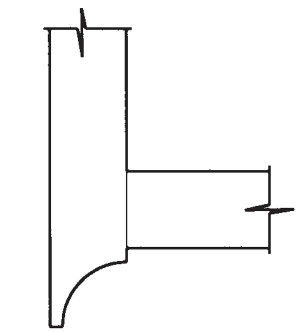
Replacement
If, as a last resort, the original windows cannot be conserved then historically accurate replacement windows should be made. Sliding sash windows are not any more difficult to make than other common window types. Replacement in PVC or aluminium can in no way accurately replace historical timber ones. PVC windows have a life span of 30 to 40 years with repolishing required after 15 - 20 years.

Typical top window sash detail

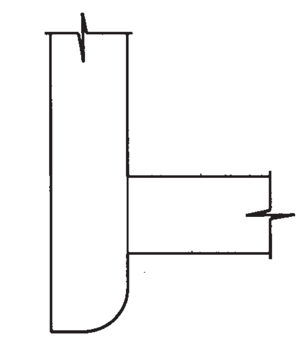
Early Georgian windows did not have horns, or extensions, to the bottom of the sash. Late Georgian windows sometimes had small horns. Scrolled horns belong to the Victorian period.



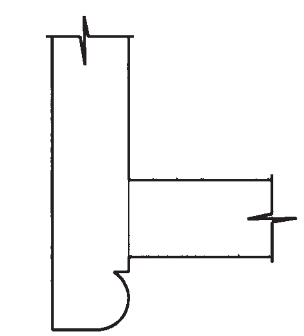
Georgian 18th century, no horn.



Late Georgian, early 19th century, concave horn.



Late Georgian, early 19th century, convex horn.



Victorian scrolled Horn.

Victorian replacement and original Georgian joinery forms part of the history of this 1732 estate house in the National Botanic Gardens.

Wide square edged floorboards with a black painted finish are common in many 18th and 19th century heritage and buildings.

They have thermal expansion and window ironmongery replacement problems. Plastic windows are environmentally unsupportable due to the resources and energy required in their making and their inability to be recycled.

Ireland has many good joinery workshops which can accurately make historically accurate replacement windows under specialist architectural guidance. The choice of correct species and method of preservation would be similar to that of modern windows detailed elsewhere in this specifier's guide.

INTERIOR JOINERY AND FITTINGS

Like timber windows, interior joinery such as staircases, doors, (including ironmongery), architraves, panelling and mouldings are part and parcel of the architectural heritage of an old building. They should not be replaced by either inappropriate modern or pastiche joinery. Where heritage joinery is beyond repair or a significant new addition is required, then a contemporary design of a high standard could be the most appropriate approach. Remember that historical joinery and panelling was always painted except for special feature oak and mahogany handrails, doors and panelling.

STAIRCASES

The medieval spiral stairs developed into more open and feature type staircases in the 18th and 19th century. The urban Georgian houses used the dog leg staircase in a rectangular or elliptical manner with a series of half and quarter landings. Most of these staircases were made of pine and were always painted. In prestige houses the stair handrail would often be made of mahogany or oak and polished in beeswax. Balusters became more slender and refined during the 18th century. Today such balusters are visually elegant but may require careful strengthening in public use buildings to comply with current building regulations. Seek expert advice if such interventions are required.

DOORS AND ARCHITRAVES

The simple ledged door was used in vernacular buildings into the 20th century. The late 17th century saw the widespread introduction of panelled doors in wealthier houses throughout Ireland. Panels were either recessed or raised and fielded with a chamfered edge.

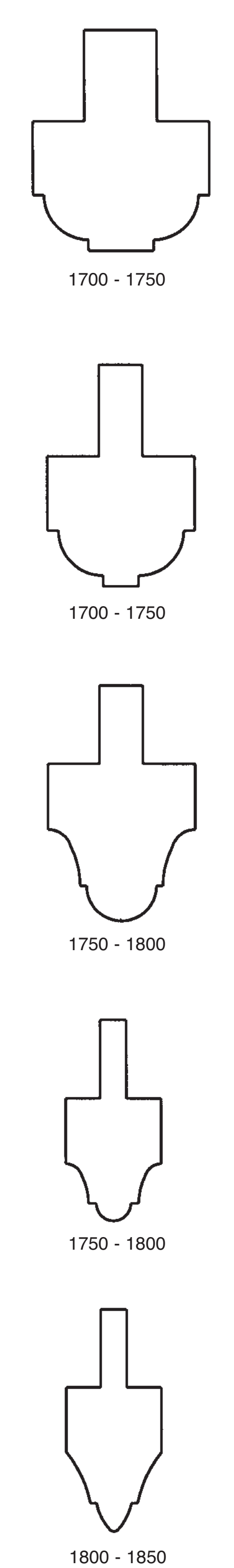
Flat panelling became more common as the 18th century progressed until the application of decorative head moulding became the norm from the middle of the 19th century onwards. Georgian architraves, panelling and mouldings are in general visually lighter than their Victorian counterparts.

Historical ironmongery such as locks, hinges, number plates, door knobs and bell pulls should be preserved. There are a number of specialist brass and metalworkers who can repair and refurbish such ironmongery.

PANELLING

The use of timber wall panelling in public buildings and larger houses became popular at the end of the 17th century. Unlike earlier medieval panelling which was not proportioned in any particular way, 17th century panelling was governed by the rules of classical proportion. The panelling itself was usually of softwood, painted in the popular colours of the time. On occasions oak or mahogany panels finished in beeswax, was used to denote rooms of special importance. On other occasions painted softwood skirtings, panelling and dado rails formed the lower part of the wall with decorative plaster panels above. From 1880 onwards the dado rail became less prominent while the skirting board grew taller and more prominent.

Typical 18th and 19th century glazing bars.
(relative proportions)



TIMBER FITTINGS

Timber mouldings in Georgian and Victorian buildings can be extensive and appear intricate. However, all mouldings are based on two historic and simple forms - the convex quadrant called the ovolo (cavetto when concave), and the right angled, flat faced fillet. Most 18th century mouldings were based on Roman examples while most 19th century mouldings were based on Grecian examples.

Do not use standard hardware shop mouldings in restoration work. Remember that mouldings and panelling were directly proportioned to the proportions of the particular room or space in which they were situated. A good joiner can repair or match damaged mouldings or panels under architectural guidance.

PAINTING

When stripping old timber do not use blowtorches or hot-air guns because of the damage they may cause to the original wood and the risk of fire they pose in historic buildings. The original colour of historical timber work can be determined by chemical and/or spectrometer analysis by a paint specialist. A number of matching historical paints are available from specialist suppliers in Ireland and the U.K.

Note that old paints were lead-based, and the appropriate precautions should be taken.

FLOORS

Most timber floors in heritage buildings would have been made up of square edged floor-boards with a painted finish. Tongue and groove floor-boards are a relatively new floor type. In prestige buildings or particular rooms, oak, mahogany or special inlay floors were laid. Great care is required in repairing an inlay floor. Rare species can be identified by a wood anatomist from a small sample.

TIMBER DECAY

Timber is an organic material. As such it is subject to degrade through wet or dry rot and insect attack unless protected from moisture or preserved by various methods. In historic buildings, the basic building technology used in their construction was not always conducive to the well-being of timber. In particular, bonding timbers were used in masonry wall construction where dampness was present due to the absence of a damp proof course and porous wall construction.

The first priority in any heritage building is to eliminate all sources of water penetration. When the basic fabric of the building is secure from water ingress the conservation work can begin on the other elements of the building including the timber components. Ventilation must be maintained to prevent condensation and build-up of moisture.

WET ROT AND DRY ROT

The fungi that cause Wet and Dry rot are not active below 20% moisture content. If the timber moisture content can be held below 20% there is no need for the saturation use of preservatives particularly in the case of Dry rot. However, if there is a significant damp or insect hazard beyond control then an appropriate Hazard Class treatment should be used as detailed elsewhere in this guide.

Wet rot is a term for decay fungi other than Dry rot. These are usually found where timbers are in ground contact or subject to constant wetting. Affected timbers will need to be removed and the source of damp eliminated.

Dry rot is the most serious of wood rots, but should not be a cause of panic preservative treatment using saturation irrigation systems unless it is very extensive and aggressively active. Dry rot needs moisture to survive. It is still widely believed by many specifiers that Dry rot can obtain moisture from adjacent timber below 20% moisture content and thereby continue to spread throughout a building. This could only occur in unventilated conditions and very rarely happens.

Recent scientific research shows that such a belief is incorrect. Dry rot is normally restricted to areas of timber and masonry which are subject to periodic but severe wetting. However, in areas of restricted ventilation the decay can spread to adjacent areas of drier timber. It is true that dry rot spores can lie dormant for a number of years. However, these spores will only become active above 20% moisture content. If the timber is kept dry the Dry rot will die and spores cannot germinate.

What is most important is the need to discover the location and cause of the dry rot outbreak and its present level of activity. Then eliminate all sources of moisture. Use ventilation or dehumidifiers to reduce the relative humidity and thereby help dry the timber to 16% moisture content or below. Affected timbers should be removed to beyond 300mm past the last signs of decay. Replacement timbers should be pressure preservative treated to the required Hazard Class treatment. Non-decayed timber adjacent to affected wood should have a preservative paste or injected treatment carried out. Similarly, adjacent wall surfaces should be spray treated to kill spores.

For heritage buildings consideration should be given to a remote monitoring system which can detect moisture content levels in hidden areas and thereby indicate if conditions conducive to decay have arisen.

INSECTS

The most common type of wood damaging insect is the furniture beetle or woodworm. It is now less common inside centrally heated houses, preferring wood at a higher moisture content. The young grub (larva) remains in the affected wood for two to five years before it emerges from its flight hole during the period May to August. Severely damaged wood must be replaced with preservative treated timber. The preservative must contain an appropriate insecticide, and not just a fungicide, treated in accordance with its hazard class requirements.Where floor joists or boards are attacked they should be spray treated on all surfaces wherever possible.

Death watch beetle is seldom encountered in Ireland today but it has been found in old oak timber in some heritage buildings. The grub can stay in the wood for up to five years before taking flight in spring time. These insects require the wood to be damp and adequate moisture is necessary for infestation. Attack is frequently initiated in decaying timber, so the drying out of the timber will do much to eradicate death watch beetle attack.

Powderpost beetle is occasionally encountered in the sapwood of recently installed hardwood species with large pores, principally ash and oak. It cannot attack the heartwood of these species, or of softwood species. Attacks normally peter out within a few years even if untreated and any occurrence in older buildings is likely to be extinct.

Ambrosia beetle or “Pinhole borer” attack, characterised by dark-stained holes of varying sizes, occurs only in freshly felled or “green” timber. This attack cannot continue once the timber is dried. It is normally of no structural significance.

FIRE SAFETY REGULATIONS

If the public have access to a heritage property then the owner or ‘person in control’ is responsible for their safety in accordance with Section 18(2) of the Fire Services Acts 1981 and 2003. In addition, the Building Control Regulations may apply and a Fire Safety Certificate be required. There can be a conflict of heritage interests and fire safety requirements. For example, the upgrading of the fire resistance of existing floors could threaten decorative ceilings below the floor. The sub-dividing of halls and staircases to restrict smoke movement can destroy the architectural integrity of these spaces. Similarly, original timber wall panelling or panel doors may not meet surface spread of flame or modern fire rating requirements, respectively. To maintain heritage features and at the same time comply with the Building Regulations fire requirements expert advice is needed. There is an element of flexibility in the Building Regulations’ which allows the Fire Safety Certificate applicant to demonstrate that there are alternative solutions to the standard Regulations. The onus is on the applicant to clearly demonstrate from first principles that any proposed alternative to the Regulations will provide an equivalent level of fire safety.

SAMPLE OF DETERIORATION DUE TO LACK OF MAINTENANCE AND POOR BUILDING PRACTICE

Dry rot damage to roof rafter caused by water and lack of ventilation.

Woodworm infestation of roof rafter at eaves. High moisture content due to restricted ventilation.

A 16 Miscellaneous

16.1 FENCING

General

Timber for post and rail roadside fencing should comply with the requirements of IS 435 Part 1; for farm fencing with IS 436; and for stud fencing IS 437.

At present, NSAI operate a quality control scheme for roadside fencing. It is envisaged that this scheme may be extended to cover farm and stud fencing.

The choice of fence is affected by

- Intended purpose
- Aesthetic considerations
- Maintenance after erection
- Desired service life
- Availability of components

(A) Site Conditions

- Line and length of fence
- Site preparation
- Ground condition
- Location of gates/stiles
- Method of setting posts in ground

(B) Construction

- Species
- Preservative treatment
- Fence height
- Post type/fixing of rail
- Spacing of posts

Typically, the following items will need to be specified:

Selected timbers can be used for the following applications:
1. Roadside (post and rail)
2. Stud (post and rail)
3. Decorative (post and rail)
4. Farm round (post only)

Suitable species

Species suitable for timber post and rail roadside and stud fencing should be chosen from the listed standards. Typical species are outlined in table A 16.1.

Table A 16.1 *Suitable species for roadside and stud fencing**

Common name	Botanical name	Post	Rail
Douglas fir	*Pseudotsuga menziesii*	✓	✓
Larch	*Larix spp.*	✓	✓
Lodgepole pine	*Pinus contorta*	✓	✓
Norway spruce (1)	*Picea abies*	✘	✓
Oak	*Quercus spp.*	✓	✓
Scots pine	*Pinus sylvestris*	✓	✓
Sitka spruce (1)	*Picea sitchensis*	✘	✓

**Reference the NSAI quality scheme document for suitable species for farm posts.*

Work has shown that only home grown spruce will achieve the penetration requirements of IS435. Imported spruce (white deal) is more resistant to treatment.

Limits are generally placed on knots, slope of grain, wane, end splits, fissures, sap stain, decay, insect damage and distortion.

Note

Further information can be obtained from:

1. National Roads Authority Specification for Roadworks: Series 300 Fencing.
2. IS 130 : Chainlink fencing.
3. BS 4102 : Steel wire fences.
4. IS 126 : Galvanised fencing wire.
5. BS 1722 : Fences.
6. IS 435 Timber post and rail roadside fencing:
7. Part 1 Materials;
   Part 2 Erection of fencing by excavation of materials;
   Part 3 Erection of fencing by driving of posts.
8. IS 436 Farm fencing – Timber post and wire.
9. IS 437 Stud fencing: Timber post and rail.
10. BS 144 Wood preservation using coal tar creosotes.
11. BS 5589 Code of practice for preservation of timber.

Advantages

Timber is used extensively for the manufacture of fencing and it is recognised for its:

- aesthetic qualities
- fitness for purpose
- durability
- cost competitiveness
- simple maintainence

Keywords

- Post-Vertical support member set in the ground.
- Rail-Horizontal member joining post to post.
- Chainlink-Wire mesh fixed to field side of rails.
- Pointing-Bottom of posts cut to aid driving.
- Weathering-Angle cut on top of post to allow rainwater run-off.
- Line-Wire running along the bottom of the fence line to hold the chain link in place.

Creosote - health note

Creosote has to be used with great care and is not suitable for use within buildings or where there is a risk of frequent skin contact. Limits are placed on the concentration of certain compounds in creosote. See Clause B.2.2 of IS 435 for full details.

Treatment

After drying and immediately prior to preservative treatment the moisture content of the posts and rails shall not exceed 26% for roadside and stud fencing and shall not exceed 28% for farm posts.

Roadside post and rail fencing - Treatments should comply with the recommendations in BS 8417 Table 9 for Tanalith E/ACQ and BS 8417 Table 5 for creosote. The treatment requirements are detailed in IS 435 for each product.

Farm posts - Treatments allowable are the Copper organic (Copper triazole/ACQ) or Tanalith E/AC500 process and the creosote pressure process. Treatments shall comply with the relevant British Standard.

Unless specified otherwise, all timber shall be cut to final dimensions and all fabrication and machining shall be carried out before treatment. Extended service life is possible through proper maintenance of the fence after erection. Premature failure can be avoided by taking care not to damage the protective treatments during installation. Any cut, drilled or damaged surfaces should be re-treated with an appropriate preservative.

Erection and fixing

Erection and fixing of roadside and stud fencing shall be in accordance with IS 435 and IS 437 respectively.
The posts shall be set in the ground, to the depths shown on the drawings (See fig. A 16.1), in holes of a minimum of 330x300mm on plan or 300mm diameter. All holes shall be 700mm deep. The granular backfill shall be well rammed as the filling proceeds, and finished with topsoil proud of the surrounding ground.

Any proposal to use driven posts must have the approval of the engineer.

Rails shall be fixed to the field side of the posts and shall have their joints staggered so that only alternate joints occur on one post. Rails shall be butt-jointed on the centre line of the posts and each rail shall be fixed to each post with two 100mm long, 4.5mm diameter galvanised round wire nails driven in on the skew.

Chain link and line wire requirements shall be in accordance with IS 435.

To help avoid splitting, the minimum number of nails or staples shall be used. If more than a single line of wire is being erected the staples shall be angled and staggered. Bed-logging shall be used on sharp turns of 90 degrees or less.

Roadside post and rail

Dimensions and tolerances shall be in accordance with the table A 16.2

Table A 16.2 *Dimensions and tolerances for roadside fencing*

Dimension	Post	Rail
Width mm	150 ± 3	100 ± 3
Thickness mm	75 ± 3	44 ± 3
Length mm	2100 ± 3	4200 ± 3

All fence posts shall be cut square at the bottom when placed and backfilled except in the case of driving, when posts shall be pointed. In all cases the top of the posts shall be weathered. Where oak rails are utilised they must be used exclusively. Oak rails, if so specified, may be used untreated but in that event must be free from sapwood.

Stud fencing

Dimensions and tolerances shall be in accordance with the table A 16.3 below.

Table A 16.3 *Dimensions and tolerances for stud fencing*

Dimension	Post	Rail
Width mm	150 ± 3	100 ± 3
Thickness mm	75 ± 3	44 -0,+3 **Paddock 38±3**
Length mm	1800 ± 3	4800 ± 3

All stud posts shall be four way pointed and shall be driven to a depth of 600mm. Where this depth cannot be achieved the minimum shall be 450mm. Obstructions preventing driving shall be excavated and the hole refilled with soil and rammed before proceeding. Where the post has not been driven to the correct depth the top shall be cut and treated.

Farm timber posts

Timber for farm posts shall comply with the requirements and recommendations of NSAI quality scheme for farm round posts. There are 3 types of farm timber posts:

1. Peeled rough
2. Profiled (round or half round)
3. Square sawn

Farm timber posts may be fabricated from lodgepole pine, Douglas fir and larch.

All bales of posts shall carry an identification number on a durable tag. This number shall also be entered on all production records, treatment charge sheets and delivery dockets.

Ensure the use of the correct hand tools when posts are being driven as ordinary sledge hammers can cause damage. If using a hydraulic post driver a post cap shall be used.

Straining posts shall be a minimum diameter of 150mm and correctly bed-logged or strutted where more than one strand of wire is being erected. Straining posts should be used at ends of fences and at marked changes in direction or gradient.

Cutting and notching of posts shall be avoided if possible. Any cut surfaces should be re-treated. To help avoid splitting, the minimum number of nails or staples shall be used. If more than a single line of wire is being erected the staples shall be angled and staggered to avoid splitting posts.

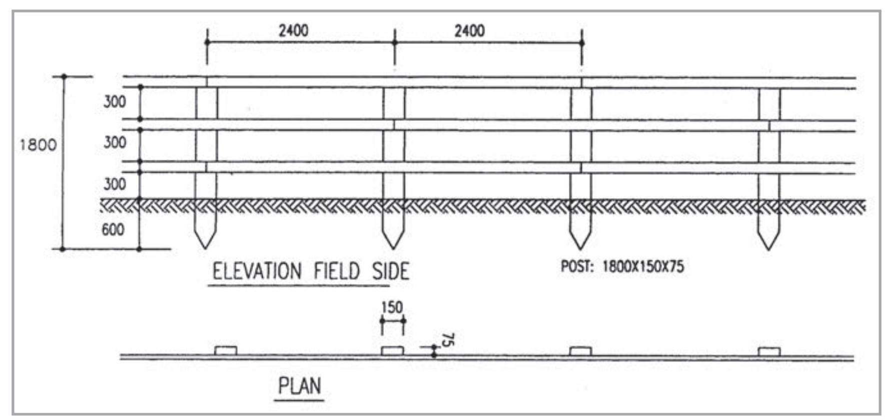


Fig. A 16.1 Post and rail stud fencing (measurements in mm)

Garden fencing

Fencing used in gardens and other areas where people may come into regular contact should follow the basic principles given above, but must be treated with an appropriate preservative such as Tanalith E or ACQ. Creosote is not appropriate and is not permitted in such locations. Horizontal, vertical, and woven patterns are readily available and are often available in modular sections for ease of erection.

16.2 OTHER USES

16.2.1 Temporary works

Raking shores
Optimum angle 60˚ (max. 75˚). A wall piece is fixed to the wall to receive the heads of rakers and spread the load. A timber needle is morticed into the wall piece to resist the thrust of the rakers. The head of the raker should only be placed where there is a floor or a roof at the back of the wall to resist the thrust. The feet of the raker should rest on an inclined sole plate embedded into the ground. Wedging should not be used.

Flying shores
One metre between walls is the maximum allowed for single shores. For spans of 9m-12m a double compound shore should be used with horizontal timber set between walls with the ends resting on the wall pieces, stiffened by inclined struts above and below at each end.

Timber scaffold boards
BS 2482 covers the requirements for timber scaffold boards, both visually and machine graded. Due to safety considerations, it is essential that scaffold boards are properly graded and so marked. Markings are normally placed on the protective end straps. Boards should be carefully handled on site and protected from abuse. Boards in storage should be properly supported and separated by stickers to allow through ventilation. Any boards showing sign of damage or decay should be rejected.

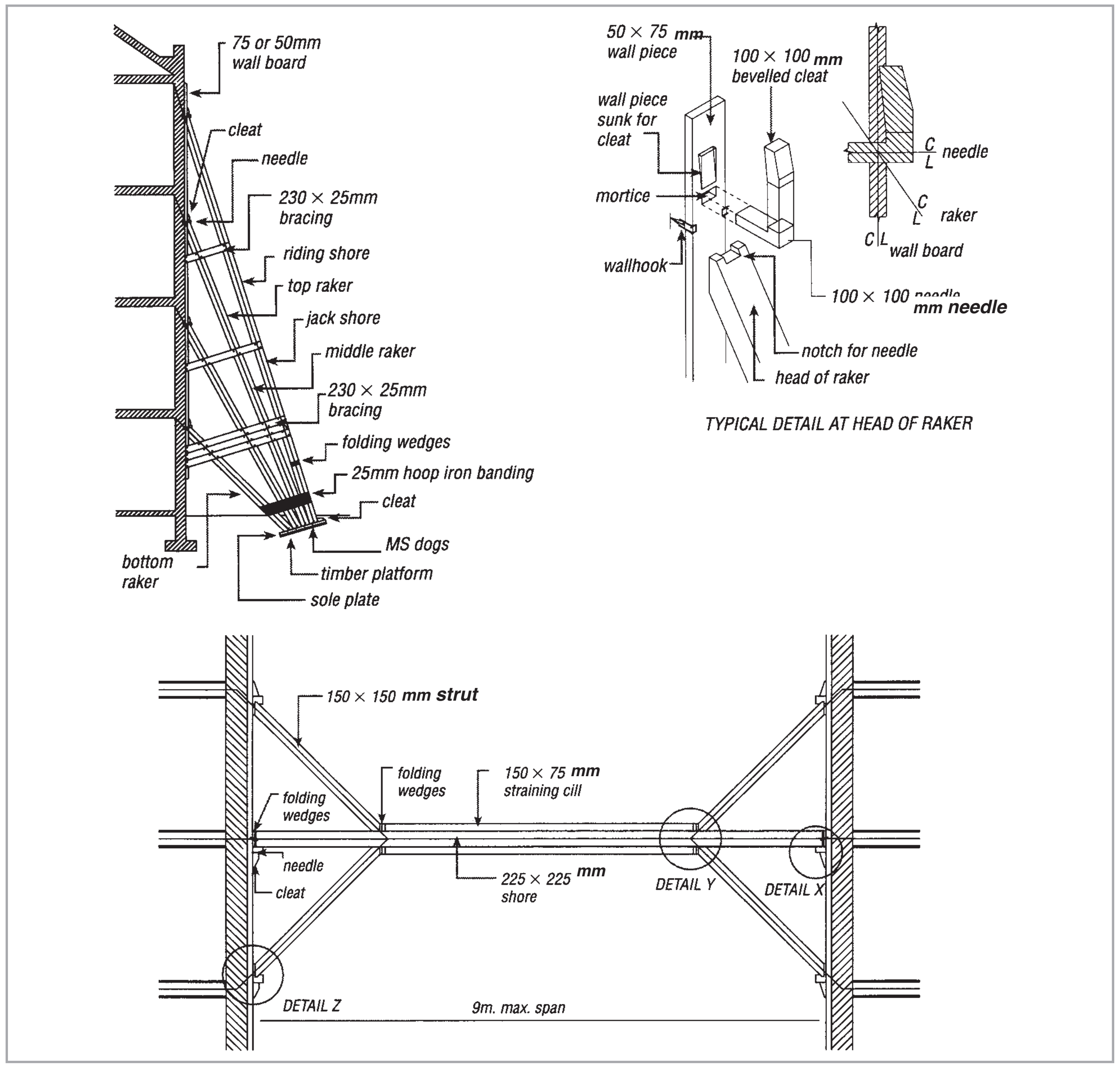


Fig. A 16.2.1 Temporary works - raking and flying shores

16.2.2 Children's play equipment

Children's play equipment has greatly improved in design in play value in the last decade. Gone are the old tarmac and ironmongery playgrounds which have been replaced by more imaginative and timber-based play facilities. A number of specialist suppliers offer an increasing variety of equipment or you can design your own components provided you meet the safety requirements of EN 1176. Timber square or cylindrical posts should be quarter sawn and dressed on all sides, with arrises eased to a diameter of 5mm to avoid cracking and splintering. If possible, steel bases should be specified to keep the timber out of ground contact and allow ease of replacement. All fixings should be concealed for safety reasons. The metal components, such as swing rotation arms, slides and chairs should be sourced from specialist suppliers. All play equipment should be under direct control of the child using it for his/her own safety. If possible give the children under 5 years of age a separate but adjoining space to the older children's play area for reasons of safety and the option of catering for imaginative play and not just diverse physical play. Play equipment needs to be carefully sited, especially swings.

The single most important safety issue is the play area surface. The best surface is a rubber tile laid on a specially prepared space. Other materials such as woodchip pea-gravel or sand require a significant depth of material to meet safety standards and are prone to tracking and animal fouling.

Note: The European Standard allows for heights above ground of 4m which would include any accessible roofs to play structures. However, the British Health and Safety Authority sets an independent height limit of 2.6m. The maximum fall height for the rubber safety tile is presently 3.6m.

Reference: EN 1176
Space for Play ISBN 0 95071130 6

16.2.3 Marine works

Sheet piles, groynes and wave screens
Untreated timber piles require naturally very durable timber such as greenheart or ekki. Other timbers will require inorganic preservative treatment to Hazard Class 5. Specialist design is required.

Fendering
Fendering is used to absorb berthing energy and to protect the berth itself. Influencing issues include the vessel type, variations in the water level and allowable deflection, as well as strength and durability. Similar species and preservation treatment as in piles. Specialist design is required.

Lockgates
Timber lockgates were traditionally made from European oak, with elm boarding but are now generally made of ekki or greenheart because of their superior durability, dry and wet basic stresses, and moduli of elasticity compared to most other tropical hardwoods available from managed resources. Specialist design is required.

Reference: BS6349 and Nederland Standards NEN549 & 6740.

16.2.4 Decking

Decking can be laid on suitably designed joists, beams and column supports, or on a patented support system over a solid structure such as a patio or roof garden. Pre-profiled anti-slip marina decking is available in yellow balau, ekki, and some other hardwoods which are naturally very durable timbers. Other hardwood or softwood decking, for domestic or commercial use, will need to be preservative treated to Hazard Class 4 (ground contact) or 3 (out of ground contact) using a high pressure process with copper based (Tanalith E, ACQ) or copper triazole/ACQ preservative. Ideally all cutting, notching and drilling should be carried out before treatment but if this has to be done afterwards these areas should be liberally treated with an appropriate preservative. For more information please consult the WMF Decking Guide at www.wood.ie

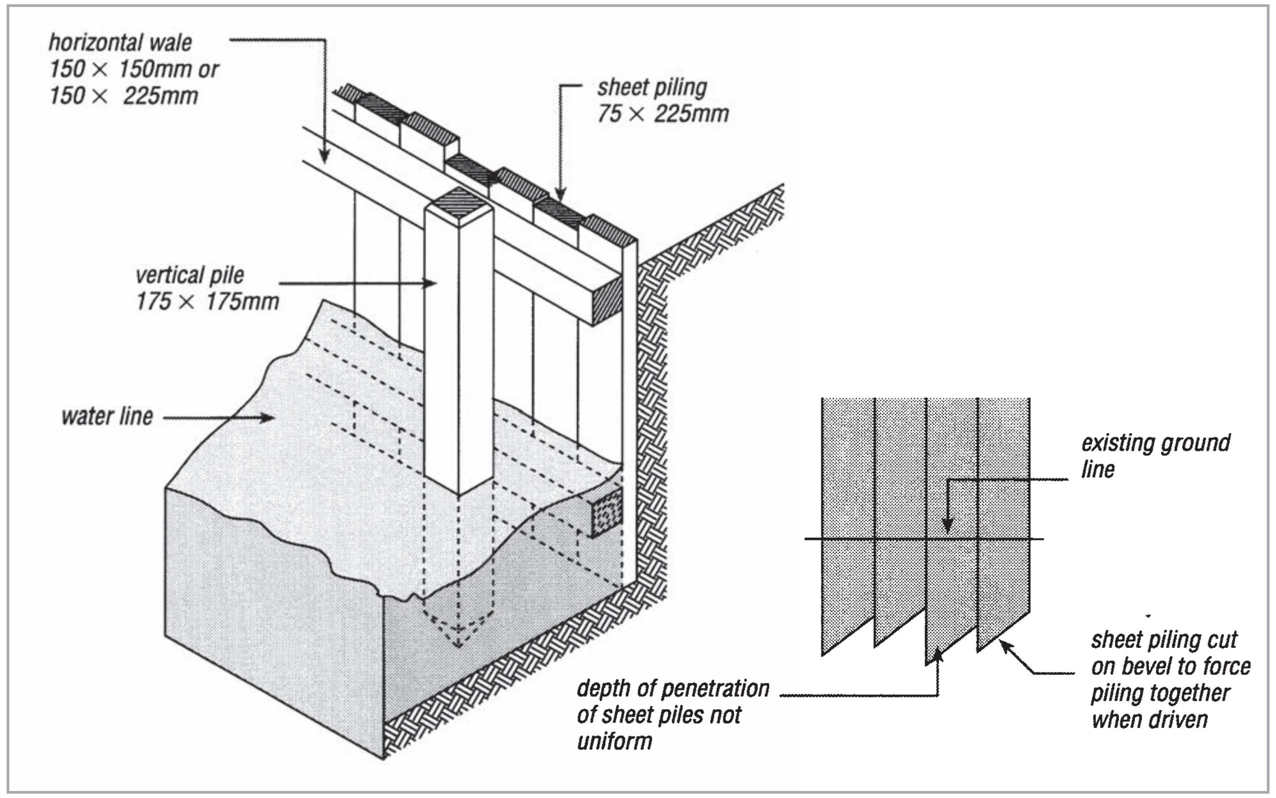


Fig. A 16.2.3 Marine works – sheet piles

Use a minimum gap of 5mm between deck boards. A profiled ribbed surface, laid to a fall to prevent ponding, is the best finish for public areas. To maintain a non-slip surface regularly clean the deck surface with a stiff yard brush and apply a proprietary brand of cleaner a number of times per year to the walking surface. Water repellent or stain finishes can be used to give or maintain a desired colour. Left untreated the wood will weather naturally to a silvery-grey colour.
All fixings should be either stainless steel, hot dip galvanised or coated to the requirements of IS/EN ISO 1461. Ring shank nails, or preferably screws, should be used for fixings to prevent "popping". Deck boards should be pre-bored and countersunk, not closer than 25mm to the edge or end.

Reference: Wood Marketing Federation decking guide. (www.wood.ie)

16.2.5 Timber in the landscape

Crib walls (see Fig. 16.2.5.1)
A number of patent systems are available which are easy to construct and are cost efficient in terms of building a retaining wall. The specially preserved timber, often radiata pine, will last in excess of 50 years in ground contact. A concrete foundation slab is required as is specialist engineering design. Wall infill material should be clean crushed quarried rock or river gravel. Drainage is vital at the rear of the base slab.

Reference: EN 1997-1 Geotechnical design - general rules

Pergola (see Fig. 16.2.5.2)
A pergola can be designed to frame a view, link the landscape to the building or define a space. Columns should be kept out of ground contact using steel bases. Use naturally very durable species or with non-durable species treat in accordance with BS 8417, Similar species options and metal fixings as for external cladding and joinery.

Pavilion (see Fig. 16.2.5.3)
A timber pavilion or shelter set within a parkland can have a mutually enhancing effect on both elements. The versatility of wood allows various expressions from solid structure to tapered dome. Illustrated is an Irish Douglas fir structure and lodgepole pine dome with imported western red cedar shingle roof.

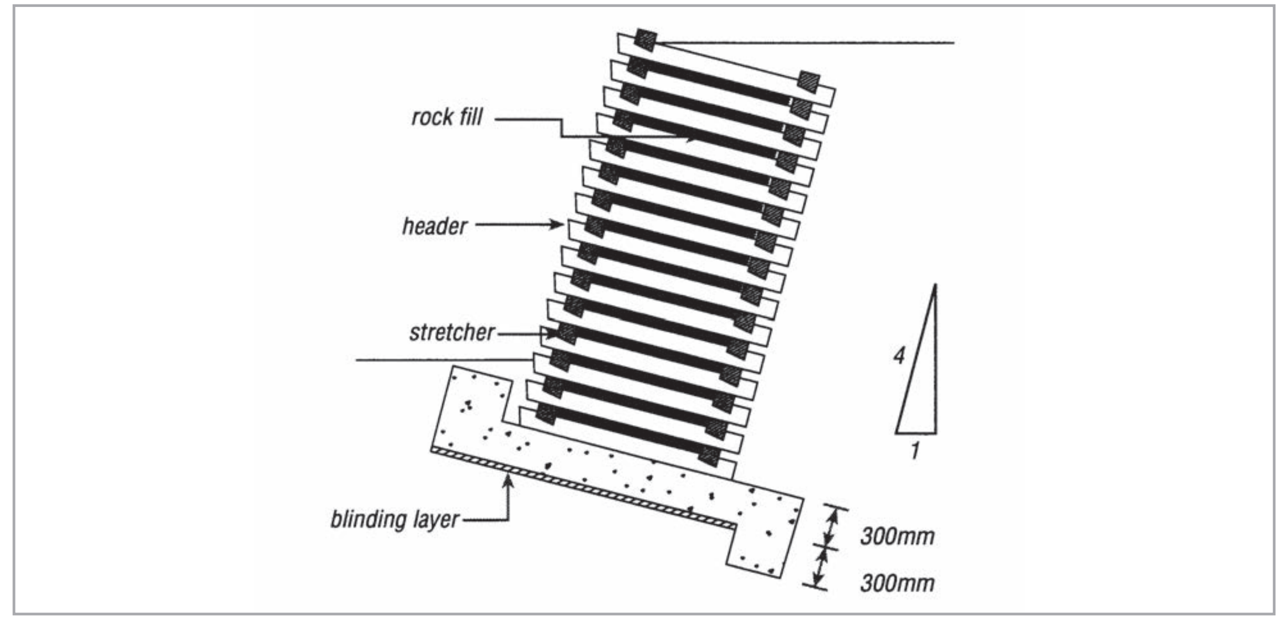


Fig. A 16.2.5.1 Typical crib wall

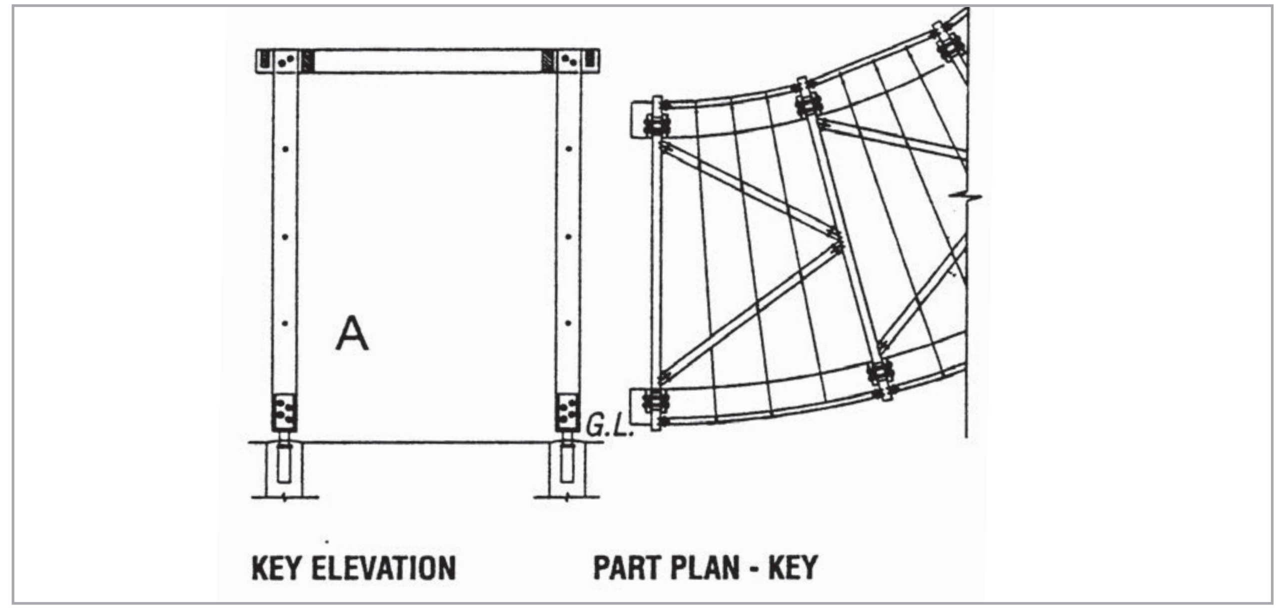


Fig. A 16.2.5.2 Elevation and plan of pergola

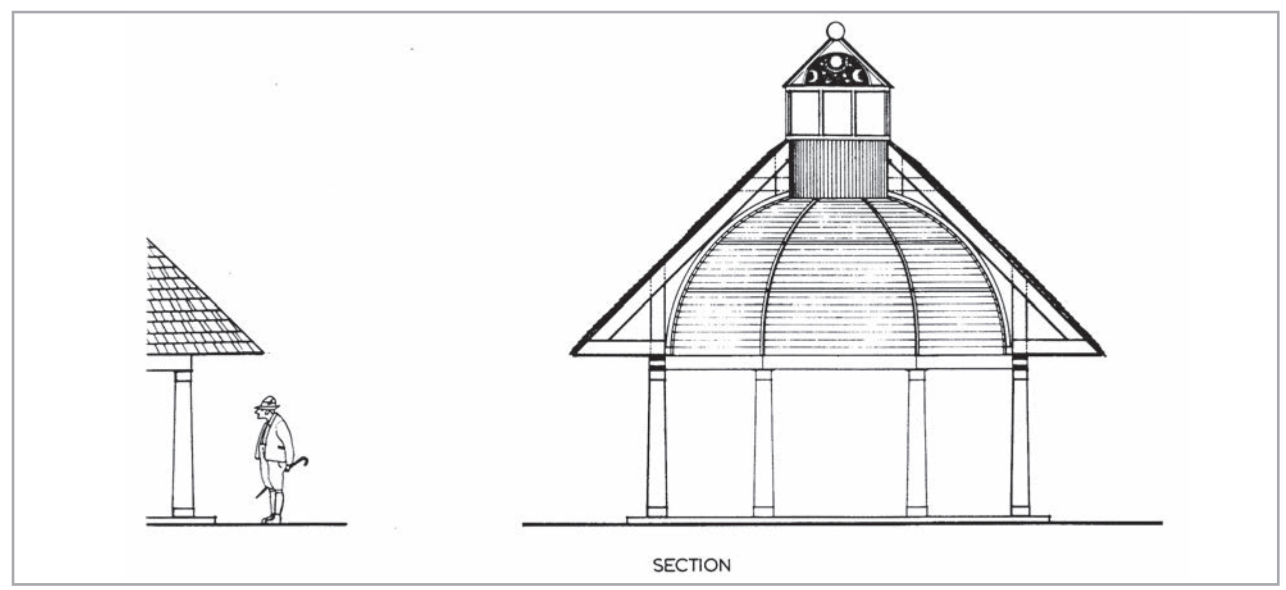


Fig. A 16.2.5.3 Irish timber pavilion in St. Stephens Green, Dublin.

16.2.6. Acoustic barriers

Timber-based barriers have proven to be highly effective at sound reduction, particularly in use on motorways and other roads, as well as at locations such as shopping centres and industrial installations. They are also aesthetically pleasing, and are obtainable in modular units in a range of heights for ease of erection. Preservative treatment, appropriate to the location, should be applied to non-durable species.

Fig. A 16.2.5.4 Oak bridge at Lough Gill, Sligo.

A 17 Modified wood

A wide range of wood-based materials whose properties have been modified by physical or chemical treatment are now available. These include:-

Wood/plastics composites (WPC's)
Wood particles or flour, bound with resin or other plastics, and extruded in various profiles for uses such as cladding, decking and internal trim such as skirting boards. Generally stable in varying humidities and resistant to micro-organisms but less strong and stiff than solid wood or board materials.

Heat-treatment
Wood treated to 160-200˚C in the absence of oxygen, sometimes in hot oil. This reduces the uptake of moisture and renders the wood more stable and resistant to decay. The natural colour of the wood is noticeably darkened. Some reduction in strength properties, particularly shock resistance, occurs.

Chemical modification
Reaction between a chemical and wood can result in modification of wood properties. The most commonly encountered process is acetylation, where the wood is treated with acetic anhydride. Radiata pine so treated is now commercially available under the trade name "Accoya" and supplied for use in joinery and similar applications. The strength, machining and finishing properties of the wood are largely unchanged but durability and stability are considerably enhanced.

Wood can also be impregnated with resin monomers which are then polymerised in-situ by heat or radiation to form a composite product. This process has been widely used for small components such as cutlery handles.

PEG – polyethylene glycol
Wood can be immersed in a solution of polyethylene glycol which diffuses into the wood, taking the place of bound water and thereby minimising shrinkage. This process is widely used for the preservation of even large archaeological remains such as the Swedish warship the "Wasa". It is also widely used in woodturning.