Chapter 11

TIMBER

11.1 SCOPE

11.1.1 This Section relates to the use of structural timber in structures or elements of structures connected together by fasteners/fastening techniques.

11.1.2 This shall not be interpreted to prevent the use of material or methods of design or construction not specifically mentioned herein; and the methods of design may be based on analytical and engineering principles, or reliable test data, or both, that demonstrate the safety and serviceability of the resulting structure. Nor is the classification of timber into strength groups to be interpreted as preventing the use of design data desired for a particular timber or grade of timber on the basis of reliable tests.

11.2 TERMINOLOGY

11.2.1 This section provides an alphabetical list of the terms used in this chapter of the Code. In case of any conflict or contradiction between a definition given in this section and that in Part 1, the meaning provided in this section shall govern for interpretation of the provisions of this chapter.

11.2.2 Structural Purpose Definitions

11.2.2.1 **Beam, Built-Up-Laminated**

A beam made by joining layers of timber together with mechanical fastenings, so that the grain of all layers is essentially parallel.

11.2.2.2 **Beam, Glued-Laminated**

A beam made by bonding layers of veneers or timber with an adhesive, so that grain of all laminations is essentially parallel.

11.2.2.3 **Diaphragm, Structural**

A structural element of large extent placed in a building as a wall, or roof, and made use of to resist horizontal forces such as wind or earthquakes-acting parallel to its own plane.

11.2.2.4 **Duration of Load**

Period during which a member or a complete structure is stressed as a consequence of the loads applied.

11.2.2.5 **Edge Distance**

The distance measured perpendicular to grain from the centre of the connector to the edge of the member.

11.2.2.6 **End Distance**

The distance measured parallel to grain of the member from the centre of the connector to the closest end of timber.

11.2.2.7 **Finger Joint**

Joint produced by connecting timber members end-to-end by cutting profiles (tapered projections) in the form of V-shaped grooves to the ends of timber planks or scantlings to be joined, gluing the interfaces and then mating the two ends together under pressure.

11.2.2.8 Fundamental or Ultimate Stress

The stress which is determined on small clear specimen of timber, in accordance with good practice; and does not take into account the effect of naturally occurring characteristics and other factors.

11.2.2.9 Inside Location

Position in buildings in which timber remains continuously dry or protected from weather.

11.2.2.10 Laminated Veneer Lumber

A structural composite made by laminating veneers, 1.5 mm to 4.2 mm thick, with suitable adhesive and with the grain of veneers in successive layers aligned along the longitudinal (length) dimension of the composite.

11.2.2.11 Loaded Edge Distance

The distance measured from the centre to the edge towards which the load induced by the connector acts, and the unloaded edge distance is the one opposite to the loaded edge.

11.2.2.12 Location

A term generally referred to as exact place where a timber is used in building.

11.2.2.13 Outside Location

Position in buildings in which timbers are occasionally subjected to wetting and drying as in the case of open sheds and outdoor exposed structures.

11.2.2.14 Permissible Stress

Stress obtained by applying factor of safety to the ultimate stress.

11.2.2.15 Sandwich, Structural

A layered construction comprising a combination or relatively high-strength facing material intimately bonded to and acting integrally with a low density core material.

11.2.2.16 Spaced Column

Two column sections adequately connected together by glue, bolts, screws or otherwise.

11.2.2.17 Structure, Permanent

Structural units in timber which are constructed for a long duration and wherein adequate protection and design measures have initially been incorporated to render the structure serviceable for the required life.

11.2.2.18 Structure, Temporary

Structures which are erected for a short period, such as hutments at project sites, for rehabilitation, temporary defence constructions, exhibition structures, etc.

11.2.2.19 Structural Element

The component timber members and joints which make up a resulting structural assembly.

11.2.2.20 Structural Grades

Grades defining the maximum size of strength reducing natural characteristics (knots, sloping grain, etc) deemed permissible in any piece of structural timber within designated structural grade classification.

11.2.2.21 Structural Timber

Timber in which strength is related to the anticipated in-service use as a controlling factor in grading and selection and/or stiffness.

11.2.2.22 Termite

An insect of the order Isopteran which may burrow in the wood or wood products of a building for food or shelter.

11.2.2.23 Wet Location

Position in buildings in which timbers are almost continuously damp or wet in contact with the earth or water, such as piles and timber foundations.

11.2.3 Definitions of Defects in Timber

11.2.3.1 Check

A separation of fibres extending along the grain which is confined to one face of a piece of wood.

11.2.3.2 Compression Wood

Abnormal wood which is formed on the lower sides of branches and inclined stems of coniferous trees. It is darker and harder than normal wood but relatively low in strength for its weight. It can be usually identified by wide eccentric growth rings with abnormally high proportion of growth latewood.

11.2.3.3 Dead Knot

A knot in which the layers of annual growth are not completely intergrown with those of the adjacent wood. It is surrounded by pitch or bark. The encasement may be partial or complete.

11.2.3.4 Decay or Rot

Disintegration of wood tissue caused by fungi (wood destroying) or other microorganisms.

11.2.3.5 Decayed Knot

A knot softer than the surrounding wood and containing decay.

11.2.3.6 Diameter of Knot

The maximum distance between the two points farthest apart on the periphery of a round knot, on the face on which it becomes visible. In the case of a spike or a splay knot, the maximum width of the knot visible on the face on which it appears shall be taken as its diameter.

11.2.3.7 Discoloration

A change from the normal colour of the wood which does not impair the strength of the wood.

11.2.3.8 Knot

A branch base or limb embedded in the tree or timber by natural growth.

11.2.3.9 Knot Hole

A hole left as a result of the removal of a knot.

11.2.3.10 Live Knot

A knot free from decay and other defects, in which the fibres are firmly intergrown with those of the surrounding wood. Syn. 'Integrown knot'; *cf*. 'Dead Knot'.

11.2.3.11 Loose Grain (Loosened Grain)

A defect on a 6 flat sawn surface caused by the separation or raising of wood fibres along the growth rings; C$ 'Raised Grain'.

11.2.3.12 Loose Knot

A knot that is not held firmly in place by growth or position, and that cannot be relied upon to remain in place; *cf* 'Tight Knot'.

11.2.3.13 Mould

A soft vegetative growth that forms on wood in damp, stagnant atmosphere. It is the least harmful type of fungus, usually confined to the surface of the wood.

11.2.3.14 **Pitch Pocket**

Accumulation of resin between growth rings of coniferous wood as seen on the cross section.

11.2.3.15 **Sap Stain**

Discoloration of the sapwood mainly due to fungi.

11.2.3.16 **Sapwood**

The outer layer of log, which in the growing tree contain living cells and food material. The sapwood is usually lighter in colour and is readily attacked by insects and fungi.

11.2.3.17 **Shake**

A partial or complete separation between adjoining layers of tissues as seen in end surfaces.

11.2.3.18 **Slope of Grain**

The inclination of the fibres to the longitudinal axis of the member.

11.2.3.19 **Sound Knot**

A tight knot free from decay, which is solid across its face, and at least as hard as the surrounding wood.

11.2.3.20 **Split**

A crack extending from one face of a piece of wood to another and mns along the grain of the piece.

11.2.3.21 **Tight Knot**

A knot so held by growth or position as to remain firm in position in the piece of wood; C$ 'Loose Knot'.

11.2.3.22 **Wane**

The original rounded surface of a tree remaining on a piece of converted timber.

11.2.3.23 **Warp**

A deviation in sawn timber from a true plane surface or distortion due to stresses causing departure from a true plane.

11.2.3.24 **Warm Holes**

Cavities caused by worms.

11.3 SYMBOLS

11.3.1 For the purpose of this Section, the following letter symbols shall have the meaning indicated against each:

a= Projected area of bolt in main member ($t' X d_3$), mm^2

B= Width of the beam, mm

C= Concentrated load, N

D= Depth of beam, mm

D_1 = Depth of beam at the notch, mm

D_2 = Depth of notch, mm

d= Dimension of least side of column, mm

d_1 = Least overall width of box column, mm

d_2 = Least overall dimension of core in box column, mm

d_3 = Diameter of bolt, mm

d_f = Bolt-diameter factor

e= Length of the notch measured along the beam span from the inner edge of the support to the farthest edge of the notch, mm

E= Modulus of elasticity in bending, N/mm^2

F= Load acting on a bolt at an angle to grain, N

f_{ab} = Calculated bending stress in extreme fibre, N/mm^2

f_{ac} = Calculated average axial compressive stress, N/mm^2

f_{at} = Calculated axial tensile stress, N/mm^2

f_b = Permissible bending stress on the extreme fibre, N/mm^2

f_c= Permissible stress in axial compression, N/mm^2

f_{cn} = Permissible stress in compression normal (perpendicular) to grain, N/mm^2

f_{cp} = Permissible stress in compression parallel to grain, N/mm^2

f_c^{θ}=Permissible compre~sive stress in the direction of the line of action of the load, N/mm^2

f_t = Permissible stress in tension parallel to grain, N/mm^2

H= Horizontal shear stress, N/mm^2

I= Moment of inertia of a section, mm^4

K= Coefficient in deflection depending upon type and criticality of loading on beam

K_1 = Modification factor for change in slope of grain

K_2 = Modification factor for change in duration of loadings

$$\left.\begin{matrix} K_{3,} \\ K_{4,} \\ K_{5,} \\ and \\ K_6 \end{matrix}\right\} = \text{Form factors}$$

K_7 = Modification factor for bearing stress

K_8 = Constant equal to $0.584\sqrt{\frac{E}{f_{cp}}}$

K_9 = Constant equal to $\frac{\pi}{2}\sqrt{\frac{UE}{5qf_{cp}}}$

K_{10}= Constant equal to $0.584\sqrt{\frac{2.5E}{f_{cp}}}$

L= Span of a beam or truss, mm

M= Maximum bending moment in beam N/mm^2

N= Total number of bolts in the joint

n= Shank diameter of the nail, mm

P= Load on bolt parallel to grain, N

P_1 = Ratio of the thickness of the compression flange to the depth of the beam

Q = Statical moment of area above or below the neutral axis about neutral axis, mm^3

q = Constant for particular thickness of plank

q_1 = Ratio of the total thickness of web or webs to the overall width of the beam

R= Load on bolt perpendicular (normal) to grain, N

S= Unsupported overall length of column, mm

t = Nominal thickness of planks used in forming box type column, mm

t' = Thickness of main member, mm

U= Constant for a particular thickness of the plank

V= Vertical end reaction or shear at a section, N

W = Total uniform load, N

x = Distance from reaction to load, mm

γ = A factor determining the value of form factor K_4

δ= Deflection at middle of beam, mm

θ= Angle of load to grain direction

Z= Section modulus of beam, mm3

λ_1 = Percentage factor for t'/d_3 ratio, parallel to grain

λ_2 = Percentage factor for t'/d_3 ratio, perpendicular to grain

11.4 MATERIALS

11.4.1 Species of Timber

The species of timber recommended for structural purposes are given in Table 11.4.1.

11.4.1.1 **Grouping**

Species of timber recommended for constructional purposes are classified in three groups on the basis of their strength properties, namely, modulus of elasticity (E) and extreme fibre stress in bending and tension (f_b).

The characteristics of these groups areas given below:

Group A — E above 12.6 x 103 N/mm^2 and f_b above 18.0 N/mm^2.

Group B — E above 9.8 x 103 N/mm^2 and up to 12.6 x 10^3 N/mm^2 and f_b above 12.0 N/mm^2 and up to 18.0 N/mm^2.

Group C — E above 5.6 x 103 N/mm^2 and up to 9.8 x 103 N/mm^2 and f_b above 8.5 N/mm^2 and up to 12.0 N/mm^2.

NOTE — Modulus of elasticity given above is applicable for all locations and extreme fibre stress in bending is for inside location.

11.4.2

The general characteristics like durability and treat ability of the species are also given in Table 11.4.1.

Species of timber other than those recommended in Table 11.4.1 may be used, provided the basic strength properties are determined and found in accordance with 11.5.1.

NOTE — For obtaining basic stress figures of the unlisted species, reference may be made to the Forest Research Institute, Debra Dun.

11.4.3

The permissible lateral strength (in double shear) of mild steel wire shall be as given in Table 11.4.2 and Table 11.4.3 for different species of timber.

11.4.4

Moisture Content in Timber The permissible moisture content of timber for various positions in buildings shall be as given in Table 11.4.4.

Table 11.4.1 Safe Permissible Stresses for the Species of Timber

Species: Botanical Name	Species: Trade Name	Average Density at 12 percent Content Kg/m^3	Modulus of Elasticity x 10^3 N/mm^2	Permissible Stress in N/mm^2 for Grade I: Bending and Tension Along Grains, Extreme Fibre Stress: Inside Location	Bending and Tension Along Grains, Extreme Fibre Stress: outside Location	Bending and Tension Along Grains, Extreme Fibre Stress: wet Location	Shear all Location: Horizontal	Shear all Location: Along Grain	Compression Parallel to Grain: Inside Location	Compression Parallel to Grain: outside Location	Compression Parallel to Grain: wet Location	Compression Perpendicular to Grain: Inside Location	Compression Perpendicular to Grain: outside Location	Compression Perpendicular to Grain: wet Location	Preservative Characters: Durability Class	Preservative Characters: Treatability Grade	Preservative Characters: Refracterines to All Seasoning
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Acacia nilotica	Babla	797	_	_	12.9	10.3	1.4	2.1	8.9	7.9	6.4	5.2	4.0	3.3	I	b	B
Aglaia odulis	Aglaia	815	12.56	18.2	15.2	12.1	1.4	2.0	10.1	8.9	7.3	4.4	3.4	2.8	_	_	A
Ailantahus grandis	Gokul	404	7.94	8.3	6.9	5.5	0.6	0.8	5.3	4.7	3.9	1.1	0.9	0.7	III	_	C
Altingia excelsa	Jutili	795	11.37	17.1	14.3	11.4	1.2	1.8	11.0	9.8	8.0	6.8	5.3	4.4	II	e	A
Amoora rehituka	Pitraj	668	8.98	12.3	10.2	8.2	1.1	1.5	8.0	7.1	5.8	4.0	3.1	2.6	I	_	B
Amoora wallichii	Lali	583	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Amoora spp.	Arnari	625	1.05	13.4	1.1	9.2	0.9	1.3	8.4	7.4	6.0	3.7	2.9	2.4	II	d	B
Anisoplera glabra	Boilam	573	_	_	_	_	_	_	_	_	_	_	_	_	III	b	_
Aphenamixis polystachya	Pitraj	583	_	_	_	_	_	_	_	_	_	_	_	_	III	e	B
Arlocarpus chaplasha	Chapalish	515	9.11	13.2	11.0	8.8	0.9	1.2	8.5	7.5	6.2	3.6	2.8	2.3	III	d	B
Artocarpus integrifolia	Kanthal	537	_	_	_	_	_	_	_	_	_	_	_	_	III	c	B
Azadirachta indica	Neem	836	8.52	14.6	12.1	9.7	1.3	1.8	10.0	8.9	7.3	5.0	3.9	3.2	_	_	_
Betula lnoides	Birch	625	9.23	9.6	8.0	6.4	0.8	1.1	5.7	5.0	4.1	2.2	1.7	1.4	_	_	B
Bischofia javanica	Bhadi	769	8.84	9.6	8.2	6.5	0.8	1.1	5.9	5.3	4.3	3.6	2.8	2.3	III	_	A
Bruguiera conjugata	Kankra	879	_	_	_	_	_	_	_	_	_	_	_	_	_	_	A

Species		Average Density at 12 percent Content Kg/m^3	Modulus of Elasticity x 10^3 N/mm^2	Permissible Stress in N/mm^2 for Grade I											Preservative Characters		
Botanical Name	Trade Name			Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Bucklandia populnea	Plpli	672	9.89	12.8	10.7	8.6	1.1	1.5	7.9	7.0	5.7	3.5	2.7	2.2	III	e	C
Canarium strictum	White dhup	569	10.54	10.1	8.4	6.7	0.7	1.1	6.2	5.5	4.5	2.1	1.6	1.3	III	_	C
Cassia fistula	Sonalu	865	11.80	19.2	16.0	12.8	1.4	2.0	12.3	10.9	8.9	7.2	5.6	4.6	I	_	A
Castanopsis hystrix	Chestanut	624	9.85	10.6	8.8	7.0	0.8	1.2	6.4	5.7	4.6	2.7	2.1	1.7	II	b	B
Carallia lucida	Maniawaga	748	12.60	18.4	15.3	12.3	1.2	1.7	11.4	10.1	8.3	5.9	4.6	3.8	_	_	_
Cassia siamea	Minjiri	695	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Chukrasia tabularis	Chickrassy	666	8.35	11.8	9.8	7.9	1.1	1.5	7.1	6.3	5.2	3.9	3.1	2.5	II	c	B
Dalbergia sissoo	Sissoo	808	_	_	_	_	_	_	_	_	_	_	_	_	_	_	B
Dillemia indica	Dillenia	617	8.61	12.1	10.0	8.0	0.8	1.2	7.3	6.5	5.3	2.7	2.1	1.7	III	a	B
Dillenia pentagyne	Dillenia	622	7.56	11.8	9.9	7.9	0.9	1.3	7.1	6.3	5.2	3.5	2.7	2.2	III	d	B
Dipterocarpus alatus	Garjan	721	_	_	_	_	_	_	_	_	_	_	_	_	III	a	B
Dipterocarpus rnacrocarpus	Hollong	726	13.34	14.5	12.0	9.6	0.8	1.1	8.8	7.9	6.4	3.5	2.7	2.2	III	a	B
Duabanga sonneratioides	Banderhol	485	8.38	9.8	8.2	6.5	0.6	0.9	6.4	5.7	4.7	1.8	1.4	1.1	III	c	C
Garuga piannata	Garuga	571	7.58	11.7	9.7	7.8	1.0	1.5	7.2	6.4	5.3	3.4	2.6	2.1	I	e	B
Geriops roxbarghiana	Goran	869	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
gGmeline arborea	Garnar	501	7.02	9.8	8.2	6.6	0.8	1.4	5.7	5.0	4.1	4.2	3.2	2.7	I	e	B
Grewia veslita	Dhaman	758	12.00	15.4	12.6	10.3	1.4	2.0	9.1	8.1	6.6	4.1	3.2	2.6	III	d	B
Heritiera spp.	Sundri	872	13.37	17.9	14.9	11.9	1.3	1.8	11.0	9.8	8.0	6.5	5.0	4.1	I	_	A

Species		Average Density at 12 percent Content Kg/m^3	Modulus of Elasticity x 10^3 N/mm^2	Permissible Stress in N/mm^2 for Grade I											Preservative Characters		
Botanical Name	Trade Name			Bending and Tension Along Grains, Extreme Fibre Stress			Shear all Location		Compression Parallel to Grain			Compression Perpendicular to Grain			Durability Class	Treatability Grade	Refracterines to All Seasoning
				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hopea odorata	Telsur	711	_	_	_	_	_	_	_	_	_	_	_	_	III	a	B
Kayea floribund	Karal	813	10.88	16.8	14.0	1.1	1.1	1.6	10.1	9.0	7.3	4.4	3.4	2.8	III	_	_
Lagerstrocmia spp.	Jarul	654	_	_	_	_	_	_	_	_	_	_	_	_	III	e	B
Machilus macrantha	Machilus	692	10.00	12.4	10.3	8.3	1.0	1.5	8.2	7.3	6.0	3.5	2.7	2.2	III	e	B/C
Manglietia insignia		449	10.37	10.9	9.1	7.3	0.7	1.4	8.0	7.1	5.8	3.4	2.6	2.1	_	_	_
Manilota polyandra	Ping	903	13.20	19.1	15.9	12.7	1.3	1.8	1.2	10.0	8.5	5.7	4.4	3.6	III	b	A
Mesua assamica	Keyea	842	12.83	17.4	14.5	11.6	1.0	1.4	11.7	10.4	8.5	5.3	4.1	3.3	II	e	_
Mesua ferrea	Mesua	965	16.30	23.3	19.4	15.5	1.2	1.8	15.5	13.8	11.3	5.9	4.6	3.7	I	_	A
Michelia champaca	Champa	644	_	_	_	_	_	_	_	_	_	_	_	_	_	_	B
Michelia montana	Champ	512	8.25	10.9	9.1	7.3	0.7	1.0	6.6	5.9	4.8	2.8	2.2	1.8	I	_	B
Michelia excelsa	Champ	513	10.12	9.8	8.2	6.5	0.7	1.0	6.1	5.5	4.5	1.6	1.3	1.0	II	e	B
Mitragyna pervifolia	Dakroom	651	7.82	12.6	10.5	8.4	1.0	1.5	7.9	7.0	5.7	3.7	2.9	2.4	III	b	B
Palaquium polyanthum	Tali	734	11.24	14.9	12.4	10.0	1.1	1.6	9.9	8.8	7.2	4.7	3.7	3.0	_	_	B
Phoebe hainesiana	Bonsum	566	9.5	13.2	11.0	8.8	0.8	1.2	8.8	7.8	6.4	2.8	2.1	1.8	II	c	B
Phoebe goalperansis	Bonsum	511	7.65	9.7	8.1	6.5	0.7	1.0	6.6	5.9	4.8	2.2	1.7	1.4	II	c	B
Plerygota alata	Narikel	593	10.95	13.4	11.8	8.9	0.8	1.2	8.2	7.3	6.0	2.7	2.1	1.7	III	_	C
Prunus napeulensis	Arupati	548	9.41	4.4	8.7	69.6	0.9	1.2	6.7	6.0	4.9	2.4	1.9	1.6	_	_	_
Pterespermum acerifolium	Hattipaila	607	9.55	13.5	11.3	9.0	0.9	1.2	8.7	7.7	6.3	3.2	2.5	2.0	III	C	B

Species		Average Density at 12 percent Content Kg/m^3	Modulus of Elasticity x 10^3 N/mm^2	Permissible Stress in N/mm^2 for Grade I											Preservative Characters		
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				Inside Location	outside Location	wet Location	Horizontal	Along Grain	Inside Location	outside Location	wet Location	Inside Location	outside Location	wet Location			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Quercus lineate	Oak	874	12.63	15.2	12.7	10.1	1.2	1.7	9.6	8.6	7.0	5.3	4.1	3.4	II	c	A
Quercus lamellosa	Oak	87	12.44	14.5	12.1	9.7	1.2	1.7	8.7	7.8	6.4	3.8	2.9	2.4	II	c	A
Schima wallichii	Chilauni	693	9.57	11.1	9.3	7.4	0.9	1.3	6.6	5.9	4.8	2.3	1.8	1.4	III	d	B
Seritiera fomes	Sundri	1073	_	_	_	_	_	_	_	_	_	_	_	_	III	b	B
Shotea assamica	Makai	548	9.27	11.1	9.2	7.4	0.9	1.3	7.1	6.3	5.2	2.9	2.2	1.8	III	c	B
Shorea robusta	Sal	889	_	_	_	_	_	_	_	_	_	_	_	_	III	e	B
Sonneralia apetale	Keora	617	8.63	12.8	10.7	8.5	0.9	1.3	7.4	6.6	5.4	4.8	3.7	3.0	II	_	B
Swintonia floribunda	Civit	665	_	_	_	_	_	_	_	_	_	_	_	_	III	a	C
Syzygium cumini	Jamun	841	10.55	14.8	12.4	9.9	1.1	1.6	9.0	8.0	6.5	6.9	5.4	4.4	II	e	A
Syzygium spp.	Jam	823	_	_	_	_	_	_	_	_	_	_	_	_	III	e	A
Taxus buccata	Yew	705	7.79	14.3	11.9	9.5	1.2	1.7	8.7	7.8	6.4	4.7	3.7	3.0	_	_	_
Tectona grandis	Teak	660	9.97	15.5	12.9	10.3	1.2	1.6	9.4	8.3	6.8	4.5	3.5	2.8	I	e	B
Toena ciliata	Toon	487	6.40	8.7	7.3	5.8	0.7	1.0	5.4	4.8	3.9	2.4	1.8	1.5	II	c	B
Terminalia citrna		755	11.89	17.1	14.3	11.4	1.1	1.6	10.8	9.6	7.9	5.0	3.9	3.2	_	_	_
Terminalia myriocarpa	Hollock	615	9.62	11.9	9.9	8.0	0.9	1.2	7.6	6.7	5.5	2.9	2.2	1.8	III	a	B
Xylia dolabriformis	Lohakat	1007	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Xylocarpus rolloensis	Passur	757	_	_	_	_	_	_	_	_	_	_	_	_	_	_	B
Zanthoxylum budranga	Mullilam	587	10.65	14.7	12.2	9.8	0.9	1.2	9.5	8.4	6.9	3.4	2.6	2.1	I	e	B

† Classification for preservation based on durability tests, etc.

Class

I – Average life more than 120 months;

II – Average life 60 months or above but less than 120 months; and

III – Average life less than 60 months.

‡ Treatability Grades

a – Heartwood easily treatable;

b – Heartwood treatable, but complete penetration not always obtained; in case where the least dimension is more than 60 mm;

c – Heartwood only partially treatable;

d – Heartwood refractory to treatment; and

e – Heartwood very refractory to treatment, penetration of preservative being practically nil even from the ends.

Data based on strength properties at three years of age of tree.

§ Classifications based on seasoning behavior of timber and refractoriness w.r.t. cracking , splitting and drying rate.

A – Highly refractory (slow and difficulty to season free from surface and end cracking);

B – Moderately refractory (may be seasoned free from surface and end cracking within reasonably short periods, given a little protection against rapid drying conditions); and

C – Non-refractory (may be rapidly seasoned free from surface and end-cracking even in the open air and sun. If not rapidly dried, they develop blue stain and mould on the surface.

Table 11.4.2 Permissible Lateral Strengths (in Double Shear) of Nails 3.55 mm Dia, 80 mm Long

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (for Both Lengthening Joints and Node Joints) Nx10^2
	Botanical Name	Trade name	Lengthening Joints Nx10^2	Node Joints Nx10^2	
1	2	3	4	5	6
	Acacia nilotica	Babla	15	11	34
	Aphenamixis polystachya	Pitraj	19	9	19
	Canarium strictum	White dhup	9	8	10.5
	Castanopsis hystrix	Chestanut	18	10.5	23.5
	Chukrasia tabularis	Chickrassy	24	8	27
	Dillenia pentagyne	Dillenia	16.5	12	16
	Dipterocarpus rnacrocarpus	Hollong	17	7	20
	Grewia veslita	Dhaman	13	5	24
	Hopea odorata	Telsur	31.5	13	28.5
	Lagerstrocmia spp.	Jarul	24.5	21.5	22.5
	Maniltoa polyandra	Ping	26	23.5	32
	Mesua ferrea	Mesua	26	8	41
	Michelia excelsa	Champ	13	9	20
	Phoebe hainesiana	Bonsum	12	6	13
	Shorea robusta	Sal	23	15.5	19.5
	Syzygium spp.	Jam	15	12	25
	Tectona grandis	Teak	14	8	13
	Terminalia myriocarpa	Hollock	13	10	19
	Toona ciliata	Toon	16	9	21

NOTES

1. Nails of 3.55 mm diameter are most commonly used. The above values can also be used for 4 mm diameter 100 mm long nails.
2. The values in N are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.80665 N.

11.4.4.1 **Tolerances**

Permissible tolerances in measurements of cut sizes of structural timber shall be as follows:

a) For width and thickness:

1) Up to and including 100 mm $\begin{matrix}+3\\-0\end{matrix}$ mm

2) Above 100 mm $\begin{matrix}+6\\-3\end{matrix}$ mm

b) For length $\begin{matrix}+10\\-0\end{matrix}$ mm

11.4.5 Grading of Structural Timber

11.4.5.1 Cut sizes of structural timber shall be graded, after seasoning, into three grades based on permissible defects given in Table 11.4.8:

a) Select Grade
b) Grade I
c) Grade II

Table 11.4.3 Permissible Lateral Strengths (in Double Shear) of Nails 5.00 mm Dia,125 mm and 150 mm Long

Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (for Both Lengthening Joints and Node Joints) Nx10^2
Botanical Name	**Trade name**	**Lengthening Joints Nx10^2**	**Node Joints Nx10^2**	
2	**3**	**4**	**5**	**6**
Acacia nilotica	Babla	27	13.5	53
Dalbergia sissoo	Sissoo	17	15	43
Mesua ferrea	Mesua	24	15.5	57.5
Michelia excelsa	Champ	26	12.5	39
Phoebe hainesiana	Bonsum	20	7.5	30
Shorea robusta	Sal	19.5	17	37
Syzygium spp.	Jam	18	14.5	38.5
Tectona grandis	Teak	28	13	30
Terminalia myriocarpa	Hollock	27.5	9	41

Table 11.4.4 Permissible Percentage Moisture Content Values

Sl No.	**Use**	**Zones (see Note)**			
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
i)	Structural elements	12	14	17	20
ii)	Doors and windows				
	50 mm and above in thickness	10	12	14	16
	Thinner than 50 mm	8	10	12	14
iii)	Flooring strips for general purposes	8	10	10	12

NOTE — The country has been broadly divided into the following four zones based on the humidity variations in the country:

Zone I — Average annual relative humidity less than 40 percent.

Zone II — Average annual relative humidity 40 to 50 percent.

Zone III — Average annual relative humidity 50 to 67 percent.

Zone IV — Average annual relative humidity more than 67 percent.

For detailed zonal classification, tolerances, etc reference may be made to good practice [6-3A(4)].

11.4.6 Sawn Timber

11.4.6.1 Sizes

Preferred cut sizes of timber for use in structural components shall be as given in Tables 11.4.5 to 11.4.7.

Table 11.4.5 Preferred Cut Sizes of Structural Timbers for Roof Trusses (Span from 3 m to 20 m)

Thickness mm	Width mm							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
20	40	50	60	80	100	_	_	_
25	40	50	60	80	100	120	160	180
30	40	50	60	80	100	120	160	180
35	_	_	60	80	100	120	160	180
40	_	_	60	80	100	120	160	180
50	_	_	60	80	100	120	160	180
60	_	_	_	80	100	120	160	180
80	_	_	_	_	100	120	160	180

NOTES

1 For truss spans marginally above 20 m, preferred cut sizes of structural timber may be allowed.

2 Preferred lengths of timhec 1, 1.5,2,2.5 and 3 m.

Table 11.4.6 Preferred Cut Sizes of Structural Timber for Roof Purlins, Rafters, Floor Beams, Etc

Thickness mm	Width mm						
1	2	3	4	5	6	7	8
50	80	100	120	140	_	_	_
60	80	100	120	140	160	_	_
80	_	100	120	140	160	_	_
100	_	_	_	140	160	180	200

NOTE —Preferred lengths of timber: 1.5,2,2.5 and 3 m.

Table 11.4.7 Preferred Cut Sizes of Structural Timbers for Partition Framing and Covering, and for Centering

Thickness mm	Width mm								
1	2	3	4	5	6	7	8	9	10
10	40	50	60	80	_	_	_	_	_
15	40	50	60	80	100	_	_	_	_
20	40	50	60	80	100	120	160	200	_
25	40	50	60	80	100	120	160	200	240
30	40	50	60	80	100	120	160	200	240
40	40	_	60	80	100	120	160	200	240
50	_	50	_	80	100	120	160	200	240
60	_	_	60	80	100	120	160	200	240
80	_	_	_	80	100	120	160	200	240

Table 11.4.8 Permissible Defects for Cut Sizes of Timber for Structural Use

Sl No.	Defects	Select Grade	Grade I	Grade II
1	2	3	4	5
i)	Wane	Shall be permissible at its deepest portion up to a limit of 1/8 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/6 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/4 of the width of the surface on which it occurs
ii)	Worm holes	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible
iii)	Slope of grain	Shall not be more than 1 in 20	Shall not be more than 1 in 15	Shall not be more than 1 in 12
iv)	Live knots:			

Width of Wide Faces of Cut Sizes of Timber	Permissible Maximum Size of Live Knot on		Permissible Maximum Size of Live Knot on		Permissible Maximum Size of Live Knot on	
Max	Narrow faces and 1/4 of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces	Narrow faces and 1/4 of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces	Narrow faces and 1A of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces
1	**2**	**3**	**4**	**5**	**6**	**7**
75	10	10	19	19	29	30
100	13	13	25	25	38	39
150	19	19	38	38	57	57
200	22	25	44	50	66	75
250	25	29	50	57	66	87
300	27	38	54	75	81	114
350	29	41	57	81	87	123
400	32	44	63	87	96	132
450	33	47	66	93	99	141
500	35	50	69	100	105	150
550	36	52	72	103	108	156
600	38	53	75	106	114	159

Sl No.	Defects			
v)	Checks and shakes:			

Width of the Face of the Timber Max	Permissible Depth Max	Permissible Depth Max	Permissible Depth Max
1	2	3	4
75	12	25	36
100	18	35	54
150	25	50	75
200	33	65	99
250	40	81	120
300	50	100	150
350	57	115	171
400	66	131	198
450	76	150	225
500	83	165	249
550	90	181	270
600	100	200	300

11.4.6.2 The prohibited defects given in 4.6.2.1 and permissible defects given in 4.6.2.2 shall apply to structural timber.

11.4.6.2.1 **Prohibited defects**

Loose grains, splits, compression wood in coniferous species, heartwood rot, sap rot, crookedness, worm holes made by powder post beetles and pitch pockets shall not be permitted in all the three grades.

11.4.6.2.2 Defects to the extent specified in Table 11.4.8 shall be permissible.

NOTE — Wanes are permitted provided they are not combined with knots and the reduction in strength on account of the wanes is not more than the reduction with maximum allowable knots.

11.4.6.3 **Location of Defects**

The influence of defects in timber is different for different locations in the structural element. Therefore, these should be placed during construction in such a way so that they do not have any adverse effect on the members.

11.4.7 Suitability

11.4.7.1 **Suitability in Respect of Durability and Treatability for Permanent Structures**

There are two choices as given in 11.4.7.1.1 and 11.4.7.1.2.

11.4.7.1.1 **First choice**

The species shall be any one of the following:

a) Untreated heartwood of high durability. Heartwood if containing more than 15 percent sap wood, may need chemical treatment for protection;
b) Treated heartwood of moderate and low durability and class ‘a’ and class ‘b’ treatability;
c) Heartwood of moderate durability and class ‘c’ treatability after pressure impregnation, and
d) Sapwood of all classes of durability after thorough treatment with preservative.

11.4.7.1.2 **Second choice**

The species of timber shall be heartwood of moderate durability and class ‘d’ treatability.

11.4.7.2 Choice of load-beting temporary structures or semi-structural components at construction site

a) Heartwood of low durability and class ‘e’ treatability; or

b) The species whose durability and/or treatability are yet to be established, as listed in Table 11.4.1.

11.4.8 Fastenings

All structural members shall be framed, anchored, tied and braced to develop the strength and rigidity necessary for the purposes for which they are used.

Allowable stresses or loads on joints and fasteners shall be determined in accordance with recognized principles. Common mechanical fastenings are of bar type such as nails and spikes, wood screws and bolts, and timber connectors including metallic rings or wooden disc-dowels. Chemical fastenings include synthetic adhesives for structural applications.

11.5 PERMISSIBLE STRESSES

11.5.1 The permissible stresses for Groups A, B and C for different locations applicable to Grade I structural timber shall be as given in Table 11.5.1 provided that the following conditions are satisfied:

a) The timbers should be of high or moderate durability and be given the suitable treatment where necessary.
b) Timber of low durability shall be used after proper preservative treatment and
c) The loads should be continuous and permanent and not of impact type.

Table 11.5.1 Minimum Permissible Stress Limits (N/mm2) in Three Groups of Structural Timbers (for Grade I Material)

Sl No.	Strength Character	Location of Use	Group A	Group B	Group C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Bending and tension along grain	Inside [1)]	18.0	12.0	8.5
ii)	Shear [2)] Horizontal	All locations	1.05	0.64	0.49
	Along grain	All locations	15	0.91	0.70
iii)	Compression pe4rpendicular to grain	Inside [1)]	11.7	7.8	4.9
iv)	Compression perpendicular to grain	Inside [1)]	4.0	2.5	1.1
v)	Modulus of elasticity (×103 N/mm^2)	All locations and grade	12.6	9.8	5.6

1) For working stresses for other locations of use, that is, outside and wet, generally factors of 5/6 and 2/3 are applied.
2) The values of horizontal shear to be used only for beams. In all other cases shear along grain to be used.

11.5.2 The permissible stresses (excepting E) given in Table 11.5.1 shall be multiplied by the following factors to obtain the permissible stresses for other grades provided that the conditions laid down in 5.2 are satisfied:

a) For Select Grade Timber 1.16
b) For Grade II Timber 0.84

When low durability timbers are to be used [see 5.2(b)] on outside locations, the permissible stresses for all grades of timber, arrived at by 5.2 and 5.3 shall be multiplied by 0.80.

11.5.3 Modification Factors for Permissible Stresses

11.5.3.1 Due to Change in Slope of Grain

When the timber has not been graded and has major defects like slope of grain, knots and checks or shakes but not beyond permissible value, the permissible stress given in Table 11.4.1 shall be multiplied by modification factor K1 for different slopes of grain as given in Table 11.5.2.

Table 11.5.2 Modifications Factor K1 to Allow for Change in Slope of Grain

slope	Modification Factor K_1	
	Strength of Beams, Joists and Ties	Strength of Posts or Columns
1	2	3
1 in 10	0.80	0.74
1 in 12	0.90	0.82
1 in 14	0.98	0.8
1 in 15 and fla~	1.00	1.00

NOTE — For intermediary slopes of grains, values of modification factor may be obtained by interpolation.

11.5.3.2 Due to Duration of Load

For different durations of design load, the permissible stresses given in Table 1 shall be multiplied by the modification factor K_2 given in Table 11.5.3.

Table 11.5.3 Modifications Factor K_2, for Change in Duratiou of Loading

Duration of Loading	Modification Factor K_2
1	2
Continuous (Normal)	1.0
Two months	1.15
Seven days	1.25
Wind and earthquake	1.33
Instantaneous or impact	2.00

NOTE —The strength properties of timber under load are time dependent.

11.5.3.2.1 The factor K2 is applicable to modulus of elasticity when used to design timber columns, otherwise they do not apply thereto.

11.5.3.2.2 If there are several duration of loads (in addition to the continuous) to be considered, the modification factor shall be based on the shortest duration load in the combination, that is, the one yielding the largest increase in the permissible stresses, provided the designed section is found adequate for a combination of other larger duration loads.

[Explanation: In any structural timber design for dead loads, snow loads and wind or earthquake forces, members may be designed on the basis of total of stresses due to dead, snow and wind loads using K_2 = 1.33, factor for the permissible stress (of Table 11.4.1) to accommodate the wind load, that is, the shortest of duration and giving the largest increase in the permissible stresses. The section thus found is checked to meet the requirements based on dead loads alone with modification K_2 = 1.00].

11.5.3.2.3 Modification factor K2 shall also be applied to allowable loads for mechanical fasteners in design of joints, when the wood and not the strength of metal determine the load capacity.

11.6 DESIGN CONSIDERATIONS

11.6.1 All structural members, assemblies or framework in a building, in combination with the floors, walls and other structural parts of the building shall be capable of sustaining, with due stability and stiffness the whole dead and imposed loadings as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects', without exceeding the limits of relevant stresses specified in this Section.

11.6.2 Buildings shall be designed for all dead and imposed loads or forces assumed to come upon them during construction or use, including uplifts or horizontal forces from wind and forces from earthquakes or other loadings. Structural members and their connections shall be proportioned to provide a sound and stable structure with adequate strength and stiffness. Wooden components in construction generally include panels for sheathing and diaphragms, siding, beams, girder, columns, light framings, masonry wall and joist construction, heavy-frames, glued laminated structural members, structural sandwiches, prefabricated panels, lamella arches, portal frames and other auxiliary constructions.

11.6.3 Net Section

11.6.3.1 The net section is obtained by deducting from the gross sectional area of timber the projected area of all material removed by boring, grooving or other means at critical plane. In case of nailing, the area of the prebored hole shall not be taken into account for this purpose.

11.6.3.2 The net section used in calculating load carrying capacity of a member shall be at least net section determined as above by passing a plane or a series of connected planes transversely through the members.

11.6.3.3 Notches shall be in no case remove more than one quarter of the section.

11.6.3.4 In the design of an intermediate or a long column, gross section shall be used in calculating load carrying capacity of the column.

11.6.4 Loads

11.6.4.1 The loads shall conform to those given in Part 6 Structural Design, Chapter 2 Loads on Buildings and Structures.

11.6.4.2 The worst combination and location of loads shall be considered for design. Wind and seismic forces shall not be considered to act simultaneously.

11.6.5 Flexural Members

11.6.5.1 Such structural members shall be investigated for the following:

a) Bending strength,
b) Maximum horizontal shear,
c) Stress at the bearings, and
d) Deflection.

11.6.5.2 **Effective Span**

The effective span of beams and other flexural members shall be taken as the distance from face of supports plus one-half of the required length of bearing at each end except that for continuous beams and joists the span may be measured from centre of bearing at those supports over which the beam is continuous.

11.6.5.3 Usual formula for flexural strength shall apply in design:

$$f_{ab}\frac{M}{Z} \leq f_b$$

11.6.5.4 **Form Factors for Flexural Members**

The following form factors shall be applied to the bending stress:

a) Rectangular Section — For rectangular sections, for different depths of beams, the form factor K_3 shall be taken as:

$$K_3 = 0.81\left(\frac{D^2 + 89400}{D^2 + 55000}\right)$$

NOTE—Form factor (K_3) shall not be applied for beams having depth less than or equal to 300 mm.

b) Box Beams and I-Beams — For box beams and I-beams, the form factor KA obtained by using the formula:

$$K_4 = 0.8 + 0.8y\left(\frac{D^2 + 89400 - 1}{D^2 + 55000}\right)$$

where

$$y = p_1^2 + (6 - 8p_1 + 3p_1^2)(1 - q_1) + q_1$$

c) Solid Circular Cross-Sections — For solid circular cross sections the form factor KS shall be taken as 1.18.

d) Square Cross-Sections — For square cross-sections where the load is in the direction of diagonal, the form factor KG shall be taken as 1.414.

11.6.5.5 **Width**

The minimum width of the beam or any flexural member shall not be less than 50 mm or 1/50 of the span, whichever is greater.

11.6.5.6 **Depth**

The depth of beam or any flexural member shall not be taken more than three times of its width without lateral stiffening.

11.6.5.6.1 Stiffening

All flexural members having a depth exceeding three times its width or a span exceeding 50 times its width or both shall be laterally restrained from twisting or buckling and the distance between such restraints shall not exceed 50 times its width.

11.6.5.7 **Shear**

11.6.5.7.1 The following formulae shall apply:

a) The maximum horizontal shear, when the load on a beam moves from the support towards the centre of the span, and the load is at a distance of three to four times the depth of the beam from the support, shall be calculated from the following general formula:

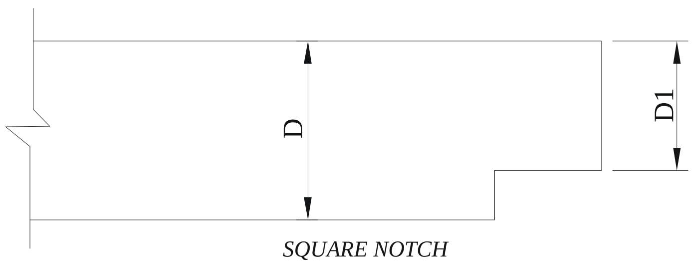
$$H = \frac{VQ}{Ib}$$

b) For rectangular beams:

$$H = \frac{3V}{2bD}$$

c) For notched beams, with tension notch at supports:

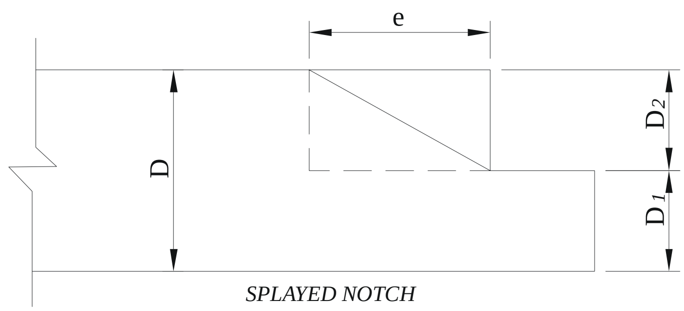
$$H = \frac{3VD}{2bD_1^2}$$



SQUARE NOTCH
(BOTTM SIDE NOTCHED)

d) For notched at upper (compression) face, where e>D:

$$H = \frac{3V}{2bD_1}$$



SPLAYED NOTCH
(UPPER SIDE NOTCHED)

e) For notched at upper (compression) face, where e<D

$$H = \frac{3V}{2b\left[D - \left(\frac{D_2}{D}\right)e\right]}$$

11.6.5.7.2 For concentrated loads:

$$V = \frac{10C(I - x)(x/D)^2}{9I\left[2 + (x/D)^2\right]}$$

and for uniformly distributed loads,

$$V = \frac{W}{2}\left(1 - \frac{2D}{I}\right)$$

After arriving at the value of V, its value will be substituted in the formula:

$$H = \frac{VQ}{Ib}$$

11.6.5.7.3 In determining the vertical reaction following deductions in loads maybe made:

a) Consideration shall be given to the possible distribution of load to adjacent parallel beams, if any;
b) All uniformly distributed loads within a distance equal to the depth of the beam from the edge of the earnest support may be neglected except in case of beam hanging downwards from a particular support, and
c) All concentrated loads in the vicinity of the supports may be reduced by the reduction factor applicable according to Table 11.6.1.

Table 11.6.1 Reduction Factor for Concentrated Loads in the Vicinity of Supports

Distance of Load from the Nearest Support	***LSD* or Less**	**2D**	**2.5D**	**3D or More**
1	**2**	**3**	**4**	**5**
Reduction factor	0.6	0.4	0.2	No Reduction

NOTE — For intermediate distances, factor may be obtained by linear interpolation.

11.6.5.7.4 Unless the local stress is calculated and found to be within the permissible stress, flexural member shall not be cut, notched or bored except as follows:

a) Notches may be cut in the top or bottom neither deeper than one-fifth of the depth of the beam nor farther from the edge of the support than one-sixth of the span;

b) Holes not larger in diameter than one quarter of the depth maybe bored in the middle third of the depth and length; and

c) If holes or notches occur at a distance greater than three times the depth of the member from the edge of the nearest support, the net remaining depth shall be used in determining the bending strength.

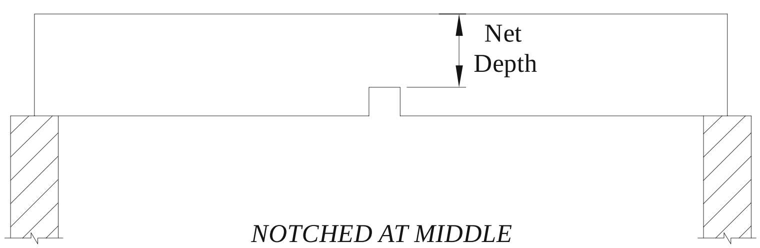


Fig.11.6.1 Notched Beams

11.6.5.8 **Bearing**

11.6.5.8.1 The ends of flexural members shall be supported in recesses which provide adequate ventilation to prevent dry rot and shall not be enclosed. Flexural members except roof timbers which are supported directly on masonry or concrete shall have a length of bearing of not less than 75 mm. Members supported on corbels, offsets and roof timbers on a wall shall bear immediately on and be fixed to wall plate not less than 75 mm x 40 mm.

11.6.5.8.2 Timber joists or floor planks shall not be supported on the top flange of steel beams unless the bearing stress, calculated on the net bearing as shaped to fit the beam, is less than the permissible compressive stress perpendicular to the grain.

11.6.5.8.3 Bearing stress

Length and position of bearing

a) At any bearing on the side grain of timber, the permissible stress in compression perpendicular to the grain, f_{cn}, is dependent on the length and position of the bearing.
b) The permissible stresses given in Table 11.4.1 for compression perpendicular to the grain are also the permissible stresses for any length at the ends of a member and for bearings 150 mm or more in length at any other position.
c) For bearings less than 150 mm in length located 75 mm or more from the end of a member as shown in Fig. 11.6.2, the permissible stress may be multiplied by the modification factor K_7 given in Table 11.6.2.
d) No allowance need be made for the difference in intensity of the bearing stress due to bending of a beam.
e) The bearing area should be calculated as the net area after allowance for the amount of wane.
f) For bearings stress under a washer or a small plate, the same coefficient specified in Table 11.6.2 may be taken for a bearing with a length equal to the diameter of the washer or the width of the small plate.
g) When the direction of stress is at angle to the direction of the grain in any structural member, then the permissible bearing stress in that member shall be calculated by the following formula:

$$f_c\theta = \frac{f_{cp} \times f_{cn}}{f_{cp}\sin^2\theta + f_{cn}\cos^2\theta}$$

Table 11.6.2: Modification factor K_7 for bearing stresses

Length of bearing in mm	15	25	40	50	75	100	150 or more
Modification factor K_7	1.67	1.40	1.25	1.20	1.13	1.10	1.00

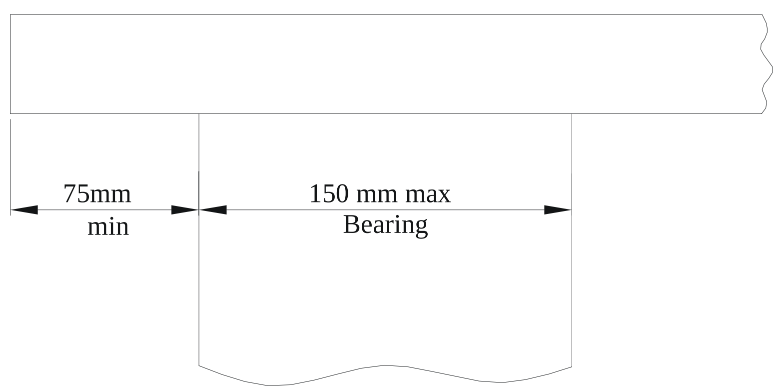


Fig. 11.6.2 Position Of End Bearings

11.6.5.9 **Deflection**

The deflection in the case of all flexural members supporting brittle materials like gypsum ceilings, slates, tiles and asbestos sheets shall not exceed 1/360 of the span. The deflection in the case of other flexural members shall not exceed 1/240 of the span and 1/150 of the freely hanging length in the case of cantilevers.

11.6.5.9.1

Usual formula for deflection shall apply:

$$\delta = \frac{KWL^3}{EI}$$ (ignoring deflection due to shear strain)

K-values = 1/3 for cantilevers with load at free end,
1/8 for cantilevers with uniformly distributed load,
1/48 for beams supported at both ends with point load at centre, and
5/384 for beams supported at both ends with uniformly distributed load.

11.6.5.9.2 In order to allow the effect of long duration loading on E, for checking deflection in case of beams and joists the effective loads shall be twice the dead load if timber is initially dry.

11.6.5.9.3 Self weight of beam shall be considered in design.

11.6.6 Columns

NOTE — The formulae given are for columns with pin end conditions and the length shall be modified suitably with other end conditions.

11.6.6.1 **Solid Columns**

Solid columns shall be classified into short, intermediate and long columns depending upon their slenderness ratio (S/d) as follows:

a) Short columns — where S/d does not exceed 11.
b) Intermediate columns — where S/d is between 11 and K_g, and
c) Long columns — where S/d is greater than K_g.

11.6.6.1.1 For short columns, the permissible compressive stress shall be calculated as follows:

$$f_c = f_{cp}$$

11.6.6.1.2 For intermediate columns, the permissible compressive stress is calculated by using the following formula:

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_g d}\right)^4\right]$$

11.6.6.1.3 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329E}{(S/d)^2}$$

11.6.6.1.4 In case of solid columns of timber, S/d ratio shall not exceed 50.

11.6.6.1.5 The permissible load on a column of circular cross-section shall not exceed that permitted for a square column of an equivalent cross-sectional area.

11.6.6.1.6 For determining S/d ratio of a tapered column, its least dimension shall be taken as the sum of the corresponding least dimensions at the small end of the column and one-third of the difference between this least dimension at the small end and the corresponding least dimension at the large end, but in no case shall the least dimension for the column be taken as more than one and a half times the least dimension at the small end. The induced stress at the small end of the tapered column shall not exceed the permissible compressive stress in the direction of grain.

11.6.6.2 **Built-up Columns**

11.6.6.2.1 Box column

Box columns shall be classified into short, intermediate and long columns as follows:

a) Short columns — where $\frac{S}{\sqrt{d_1^2 + d_2^2}}$ is less than 8;

b) Intermediate columns — where $\frac{S}{\sqrt{d_1^2 + d_2^2}}$ is between 8 and K_9; and

c) Long columns — where $\frac{S}{\sqrt{d_1^2 + d_2^2}}$ is greater than K_9.

11.6.6.2.2 For short columns, the permissible compressive stress shall be calculated as follows:

$$f_c = qf_{cp}$$

11.6.6.2.3 For intermediate columns, the permissible compressive stress shall be obtained using the following formula

$$f_c = qf_{cp}\left[1 - \frac{1}{3}\left(\frac{S}{\sqrt{d_1^2 + d_1^2}}\right)^4\right]$$

11.6.6.2.4 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329UE}{\left(\frac{S}{\sqrt{d_1^2 + d_2^2}}\right)^2}$$

11.6.6.2.5 The following values of U and q, depending upon plank thickness (t) in 11.6.6.2.3 and 11.6.6.2.4, shall be used:

t (mm)	U	q
25	0.80	1.00
30	0.60	1.00

11.6.6.3 **Spaced Columns**

11.6.6.3.1 The formulae for solid columns as specified in 6.6.1 are applicable to spaced columns with a restraint factor of 2.5 or 3, depending upon distances of end connectors in the column.

NOTE — A restrained factor of 2.5 for location of centroid group of fasteners at S/20 from end and 3 for location at S/10 to S/20 from end shall be taken.

11.6.6.3.2 For intermediate spaced column, the permissible compressive stress shall be:

$$f_c = f_{cp}\left[1 - \frac{1}{3}\left(\frac{S}{k_{10}d}\right)^4\right]$$

11.6.6.3.3 For long spaced columns, the formula shall be:

$$f_c = \frac{0.329E \times 2.5}{(S/d)^2}$$

11.6.6.3.4 For individual members of spaced columns, S/d ratio shall not exceed 80.

11.6.6.4 Compression members shall not be notched. When it is necessary to pass services through such a member, this shall be effected by means of a bored hole provided that the local stress is calculated and found to be within the permissible stress specified. The distance from the edge of the hole to the edge of the member shall not be less than one quarter of width of the face.

11.6.7 Structural Members Subject to Bending and Axial Stresses

11.6.7.1 Structural members subjected both to bending and axial compression shall be designed to comply with the following formula:

$$\frac{f_{ac}}{f_c} + \frac{f_{ab}}{f_b}$$

11.6.7.2 Structural members subjected both to bending and axial tension shall be designed to comply with the following formula:

$$\frac{f_{at}}{f_t} + \frac{f_{ab}}{f_b}$$

11.7 DESIGN OF COMMON STEEL WIRE NAIL JOINTS

11.7.1 General

Nail jointed timber construction is suitable for light and medium timber framings (trusses, etc) up to 15 m spans. With the facilities of readily available materials and simpler workmanship in mono-chord and split chord constructions, this type of fabrication has a large scope.

11.7.2 Dimensions of Members

11.7.2.1 The dimension of art individual piece of timber (that is, any single member) shall be within the range given below:

a) The minimum thickness of the main members in mono-chord construction shall be 30 mm.
b) The minimum thickness of an individual piece of members in split-chord construction shall
c) The space between two adjacent pieces of timber shall be restricted to a maximum of 3 times the thickness of the individual piece of timber of the chord member. In case of web members, it may be greater for joining facilities.

11.7.3 No lengthening joint shall preferably be located at a panel point. Generally not more than two, but preferably one, lengthening joint shall be permitted between the two panel points of the members.

11.7.4 Specification and Diameter of Nails

11.7.4.1 The nails used for timber joints shall conform to Part 5 'Building Materials'. The nails shall be diamond pointed.

11.7.4.2 The diameter of nail shall be within the limits of one-eleventh to one-sixth of the least thickness of members being connected.

11.7.4.3 Where the nails are exposed to be saline conditions, common wire nails shall be galvanized.

11.7.5 Arrangement of Nails in the Joints

The end distances, edge distances and spacings of nails in a nailed joint should be such as to avoid undue splitting of the wood and shall not be less than those given in 11.7.5.1 and 11.7.5.2.

11.7.5.1 **Lengthening Joints**

The requirement of spacing of nails in a lengthening joint shall be as follows (see also Fig. 11.7.1):

Sl. No.	Spacing of Nails	Type of Stress in the Joint	Requirement Min
(1)	(2)	(3)	(4)
i)	End distance	Tension	12n
		Compression	10n
ii)	In direction of grain	Tension	10n
		Compression	5n
iii)	Edge distance	-	5n
iv)	Between row of nails perpendicular to the grain	-	5n

Notes:

1. n is shank diameter of nails
2. The 5n distance between the rows of nails perpendicular to the grain may be increased subject to the availability of width of the member keeping edge distance constant.

11.7.5.2 **Node Joints**

The requirement for spacing of nails in node joints shall be as specified in Fig. 11.7.2 where the members are at right angle and as in Fig. 11.7.3 where the members are inclined to one another at angles other than 90° and subjected to either pure compression or pure tension.

11.7.6 Penetration of Nails

11.7.6.1 For a lap joint when the nails are driven from the side of the thinner member, the length of penetration of nails in the thicker member shall be one and a half times the thickness of the thinner member subject to maximum of the thickness of the thicker member.

11.7.6.2 For butt joints the nails shall be driven through the entire thickness of the joint.

11.7.7 Design Considerations

11.7.7.1 Where a number of nails are used in a joint, the allowable load in lateral resistance shall be the sum of the allowable loads for the individual nails, provided that the centroid of the group of these nails lies on the axis of the member and the spacings conform to 7.5. Where a large number of nails are to be provided at a joint, they should be so arranged that there are more of rows rather than more number of nails in a row.

11.7.7.2 Nails shall, as far as practicable, be arranged so that the line of force in a member passes through the centroid of the group of nails. Where this is not practicable, allowance shall be made for any eccentricity in computing the maximum load on the fixing nails as well as the loads and bending moment in the member.

11.7.7.3 Adjacent nails shall preferably be driven from opposite faces, that is, the nails are driven alternatively from either face of joint.

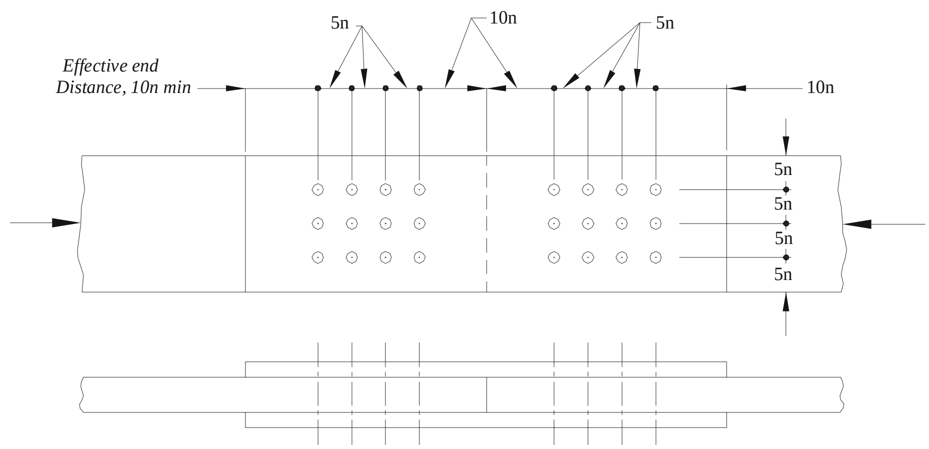
11.7.7.4 For a rigid joint, a minimum of 2 nails for nodal joints and 4 nails for lengthening joint shall be driven.

11.7.7.5 Two nails in a horizontal row are better than using the same number of nails in a vertical row.

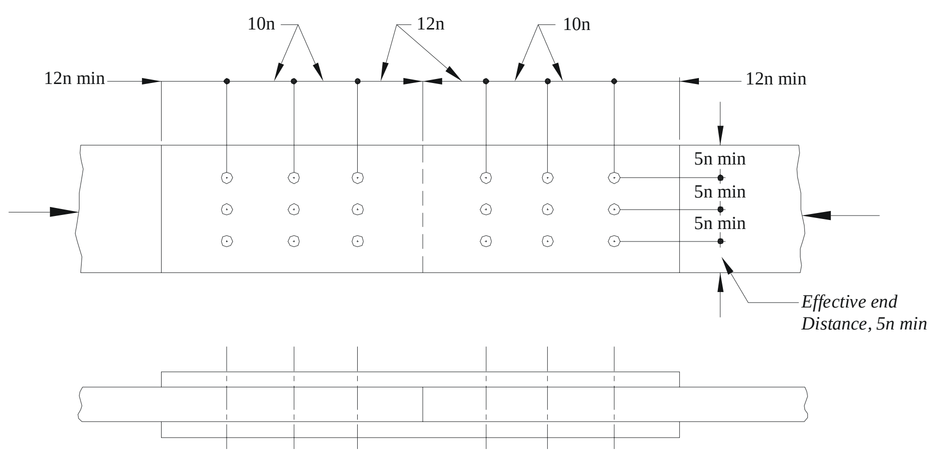
11.7.8 Special Consideration in Nail-Jointed Truss Construction

11.7.8.1 The initial upward camber provided at the centre of the lower chord of nail-jointed timber trusses shall be not less than 1/200 of the effective span for timber structures using seasoned wood and 1/100 for unseasoned or partially seasoned wood.

11.7.8.2 The total combined thickness of the gusset or splice plates on either side of the joint in a mono-chord type construction shall not be less than one and a half times the thickness of the main members subject to a minimum thickness of 25 mm of individual gusset plate.



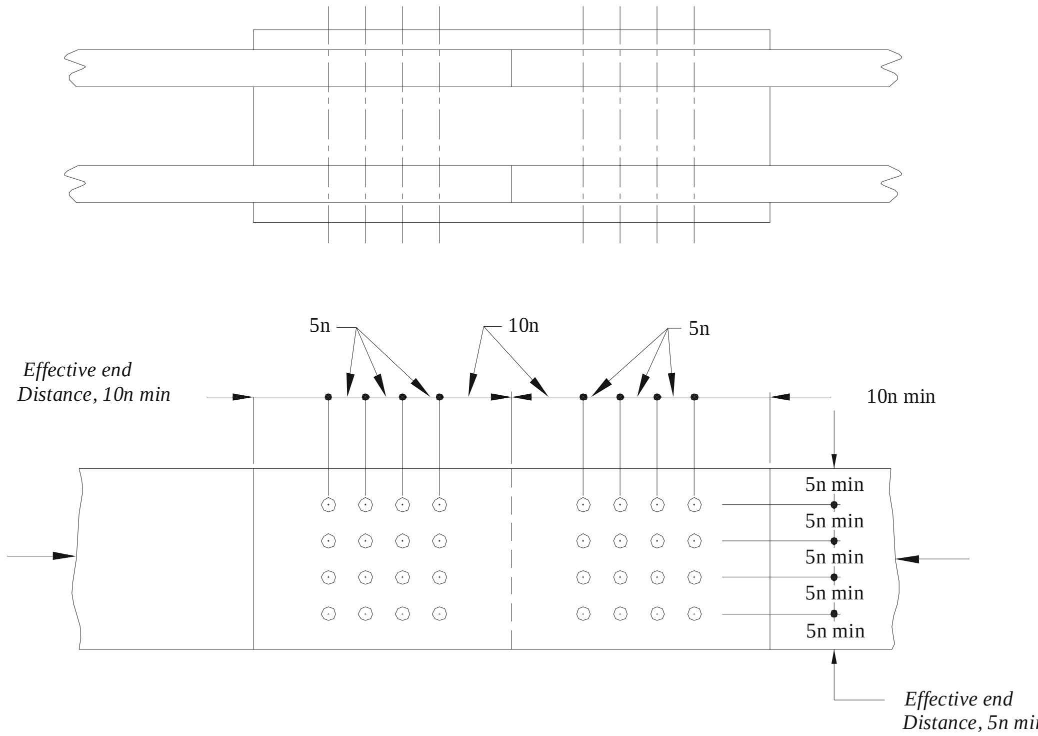
2A MONOCHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION



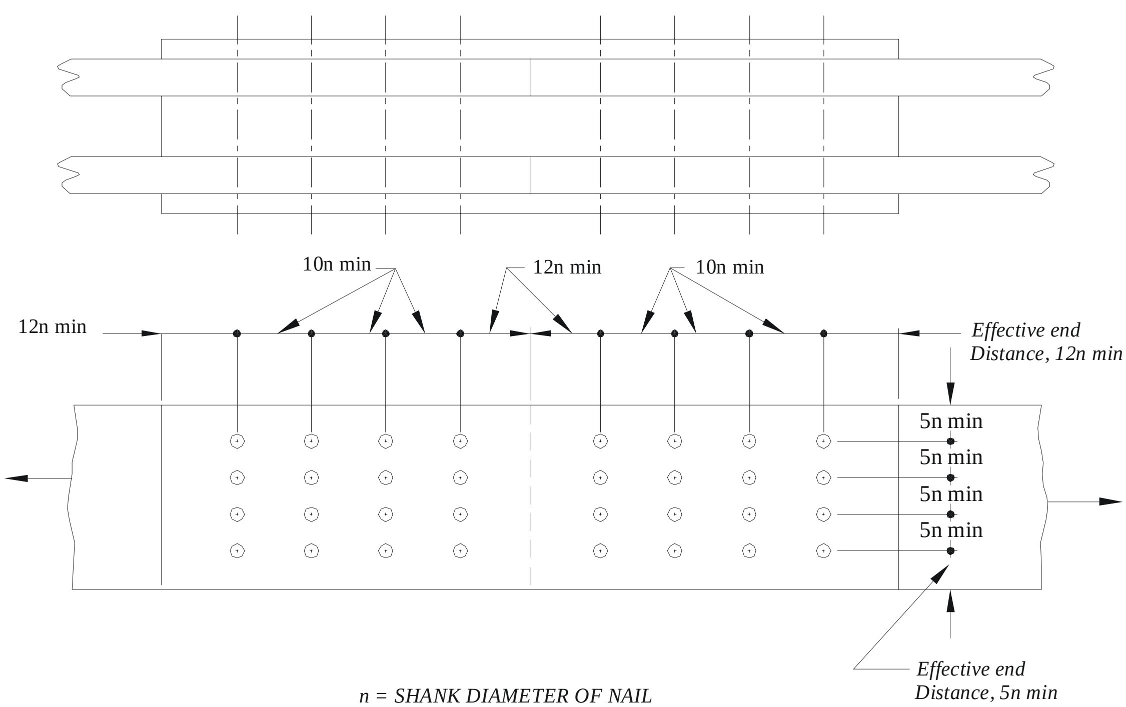
n = SHANK DIAMETER OF NAIL

2B MONOCHORD TYPE BUTT JOINT SUBJECT TO TENSION

Fig. 11.7.1 Spacing of Nails In A Lenghthening Joint - Continued



2C SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION



n = SHANK DIAMETER OF NAIL

2C SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO TENSION

Fig. 11.7.1 Spacing of Nails In A Lenghthening Joint

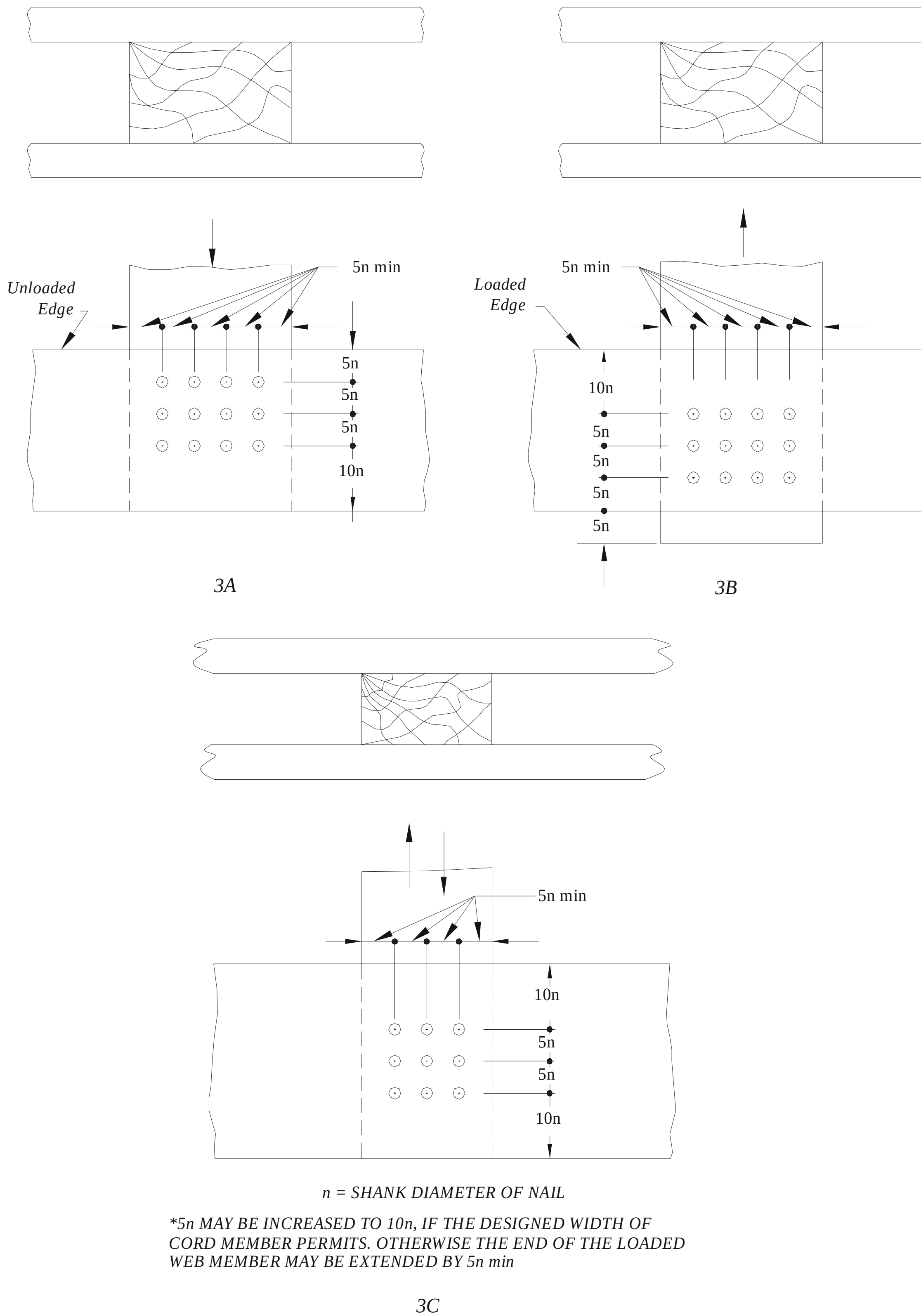
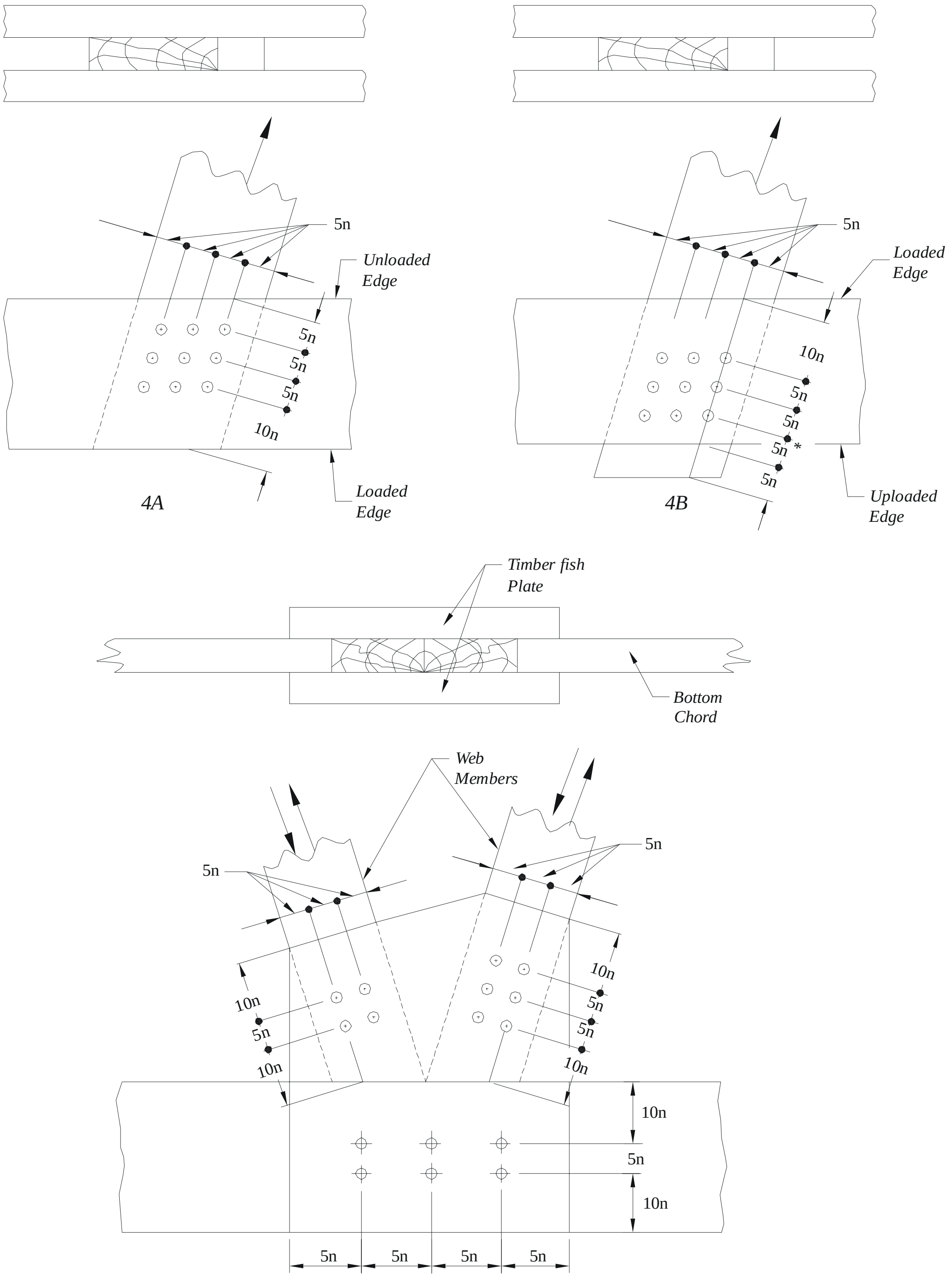


Fig. 11.7.2 Spacing Of Nails Where Members Are At Right Angles To One Another



*5n MAY BE INCREASED TO 10n, IF THE DESIGNED WIDTH OF CHORD MEMBER PERMITS.
OTHERWISE THE END OF THE LOADED WEB MEMBER MAY BE EXTENDED BY 5n min
n = SHANK DIAMETER OF NAIL

Fig. 11.7.3 Spacing Of Nails At Node Where Members Are Inclined To One Another

11.7.8.3 The total combined thickness of all spacer blocks or plates or both including outer splice plates, at any joint in a split-chord type construction shall not be less than one and a half times the total thickness of all the main members at that joint.

11.8 DESIGN OF NAIL LAMINATED TIMBER BEAMS

11.8.1 Method of Arrangement

11.8.1.1 The beam is made up of 20 mm to 30 mm thick planks placed vertically with joints staggered in the adjoining planks with a minimum distance of 300 mm. The planks are laminated with the help of wire nails at regular intervals to take up horizontal shear developed in the beam besides keeping the planks in position (see Fig. 11.8.1).

11.8.1.2 The advantage in laminations lies in dimensional stability, dispersal of defects and better structural performance.

11.8.2 Sizes of Planks and Beams

11.8.2.1 The plank thickness for fabrication of nailed laminated beams recommended are 20,25 and 30 mm.

11.8.2.2 In case of nailed laminated timber beam the maximum depth and length of planks shall be limited to 250 mm and 2000 mm, respectively.

11.8.2.3 In order to obtain the overall width of the beam, the number and thickness of planks to form vertical nailed laminated beams, and also type and size of wire nail shall be as mentioned in Table 10.8.1. The protruding portion of the nail shall be cut off or clenched across the grains.

11.8.3 Design Considerations

11.8.3.1 Nail laminated beams shall be designed in accordance with 11.6.

Table 10.8.1: Number and size of planks and nails for nailed laminated beams

Sl. No.	Overall Width of Beam (mm)	No. of Planks	Thickness of each Plank (mm)	No. and Size of Nail to be used (mm)
(1)	(2)	(3)	(4)	(5)
i)	50	2	25	80 long 3.55 dia
ii)	60	3	20	-do-
iii)	70	3	(2x25) (1x20)	-do-
iv)	80	4	20	100 long 4.0 dia
v)	90	3	30	-do-
vi)	100	4	25	125 long 5.0 dia
vii)	110	4	(3x30) (1x20)	-do-
viii)	120	4	30	-do-
ix)	150	5	30	150 long 5.0 dia

Notes: A number of combinations of different thickness of planks may be adopted as long as the minimum and maximum thickness of the planks are adhered to.

11.8.3.1.1 The deflection in the case of nailed laminated timber beams, joists, purlins, battens and other flexural members supporting brittle materials like gypsum, ceiling slates, tiles and asbestos sheets shall not exceed 1/480 of the span. The deflection in case of other flexural members shall not exceed 1/360 of the span in the case of beams and joists, and 1/225 of the freely hanging length in case of cantilevers.

11.8.3.2 Permissible lateral strength of mild steel wire nails shall be as given in Table 11.4.2 and Table 11.4.3 for Indian Species of timber, which shall apply to nails that have their points cut flush with the faces. For nails clenched across the grains the strength may be increased by 20 percent over the values for nails with points cut flush.

11.8.3.3 **Arrangement of Nails**

11.8.3.3.1 A minimum number of four nails in a vertical row at regular interval not exceeding 75 mm to take up horizontal shear as well as to keep the planks in position shall be used. Near the joints of the planks this distance may, however, be limited to 5 cm instead of 75 mm.

11.8.3.3.2 Shear shall be calculated at various points of the beam and [he number of nails required shall be accommodated within the distance equal to the depth of the beam, with a minimum of 4 nails in a row at a standard spacing as shown in Fig. 11.8.2.

11.8.3.3.3 If the depth of the beam is more, then the vertical intermediate spacing of nails may be increased proportionately.

11.8.3.3.4 If the nails required at a point are more than that can be accommodated in a row, then these shall he provided lengthwise of the beam within the distance equal to the depth of the beam at standard lengthwise spacing.

11.8.3.3.5 For nailed laminated beam minimum depth of 100 mm for 3.55 mm and 4 mm diameter nails, and 125 mm for 5 mm diameter nails shall be provided.

11.9 DESIGN OF BOLTED CONSTRUCTION JOINTS

11.9.1 General

Bolted joints suit the requirements of prefabrication in small and medium span timber structures for speed and economy in construction. Bolt jointed construction units offer better facilities as regards to workshop ease, mass production of components, transport convenience and re-assembly at site of work particularly in defence sector for high altitudes and far off situations.

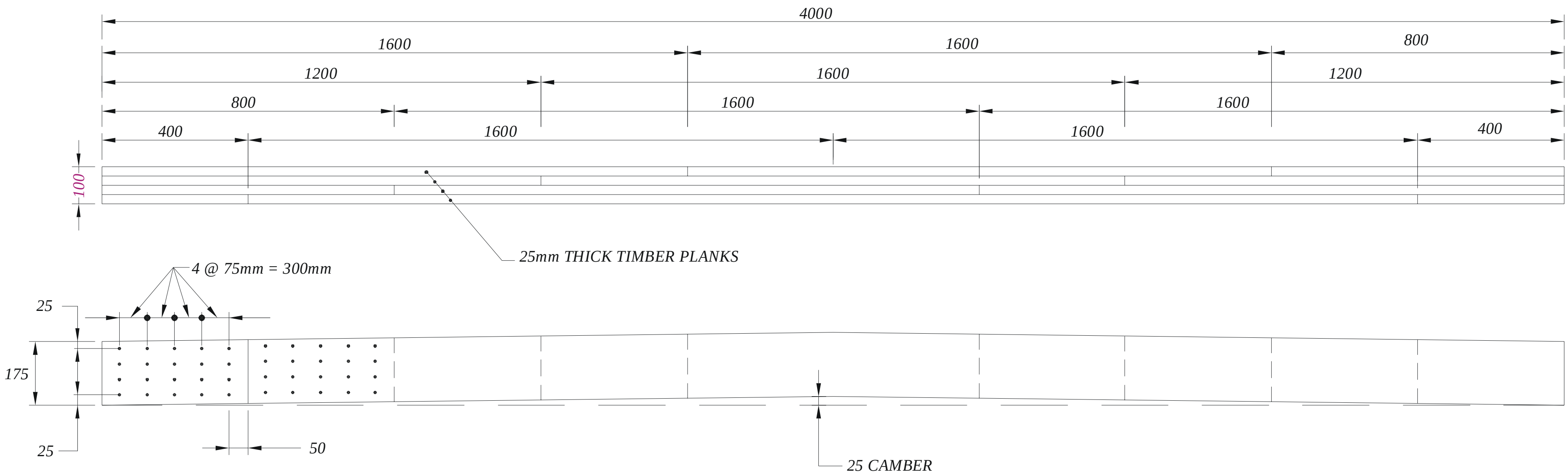
Designing is mainly influenced by the species, size of bolts, moisture conditions and the inclination of loadings to the grains. In principle bolted joints follow the pattern of rivetted joints in steel structures.

11.9.2 Design Considerations

11.9.2.1 Bolted timber construction shall be designed in accordance with 6. The concept of critical section, that is, the net section obtained by deducting the projected area of bolt-holes from the cross-sectional area of member is very important for the successful design and economy in timber.

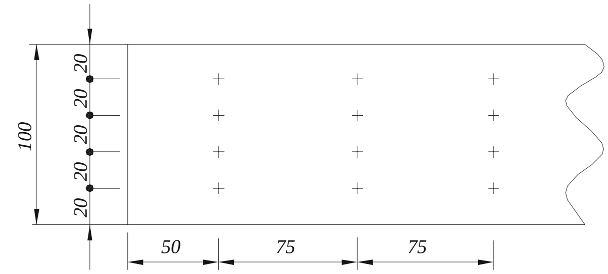
11.9.2.2 **Bolt Bearing Strength of Wood**

The allowable load for a bolt in a joint consisting of two members (single shear) shall be taken as one half the allowable loads calculated for a three member joint (double shear) for the same t'/d3 ratio. The percentage of safe working compressive stress of timber on bolted joints for different t'/d3 ratios shall be as given in Table 11.9.1.

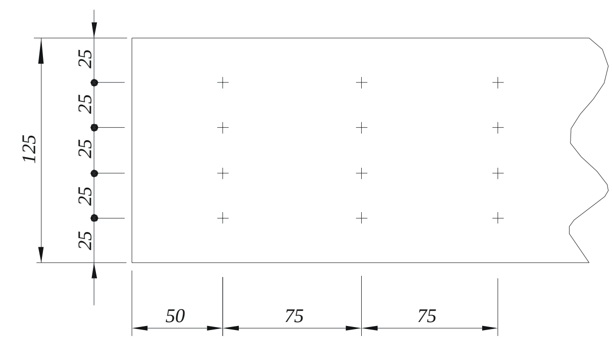


All dimensions in millimetres.

Fig. 11.8.1 Plan And Elevation Of A Typical Nailed Laminated Timber Beam



6A FOR 3.55 mm AND 4 mm DIAMETER NAILS



6B FOR 5 mm DIAMETER NAILS

All dimensions in millimetres.

FIG. 11.8.2 Standard Lengthwise Spacing In Nailed Laminated Beam

11.9.2.2.1

Where a number of bolts are used in a joint, the allowable loads shall be the sum of the allowable loads for the individual bolts.

11.9.2.2.2

he factors for different bolt diameter used in calculating safe bearing stress perpendicular to grain in the joint shall be as given in Table 11.9.2.

11.9.2.3 **Dimensions of Members**

a) The minimum thickness of the main member in mono-chord construction shall be 40 mm.
b) The minimum thickness of side members shall be 20 mm and shall be half the thickness of main members.
c) The minimum individual thickness of spaced member in split-chord construction shall be 20 mm and 25 mm for webs and chord members respectively.

11.9.2.4 **Bolts and Bolting**

a) The diameter of bolt in the main member shall be so chosen to give larger slenderness (t'/d3) ratio of bolt.
b) There shall be more number of small diameter bolts rather than small number of large diameter bolts in a joint.
c) A minimum of two bolts for nodal joints and four bolts for lengthening joints shall be provided.
d) There shall be more number of rows rather than more bolts in a row.
e) The bolt holes shall be of such diameter that the bolt can be driven easily.
f) Washers shall be used between the head of bolt and wood surface as also between the nut and wood.

11.9.3 Arrangement of Bolts

11.9.3.1 The following spacing in bolted joints shall be followed (see Fig. 11.9.1):

a) Spacing of Bolts in a Row — For parallel and perpendicular to grain loading= 4 d3

b) Spacing Between Rows of Bolts

Table 11.9.1: Percentage of safe working compressive stress of timber for bolted joints in double shear

$t^{/}/d_3$ ratio	Stress Percentage	
	Parallel to Grain	Perpendicular to Grain
	λ_1	λ_2
(1)	(2)	(3)
1.0	100	100
1.5	100	96
2.0	100	88
2.5	100	80
3.0	100	72
3.5	100	66
4.0	96	60
4.5	90	56
5.0	80	52
5.5	72	49
6.0	65	46
6.5	58	43
7.0	52	40
7.5	46	39
8.0	40	38
8.5	36	36
9.0	34	34
9.5	32	33
10.0	30	31
10.5	-	31
11.0	-	30
11.5	-	30
12.0	-	28

1) For perpendicular to grain loading — 2.5 d3, to 5 d3 (2.5 d3, for t'/d3, ratio of 2 and 5 d3 for t'/d3 ratio of 6 or more. For ratios between 2 to 6 the spacing shall be obtained by interpolation.

2) For parallel to grain loading — At least (N- 4) d3, with a minimum of 2.5 d3. Also governed by net area at critical section which should be 80 percent of the total area in bearing under all bolts.

c) End Distance — 7d3 for soft woods in tension, 5 d3 for hardwoods in tension and 4 d3 for all species in compression.

d) Edge Distance

1) For parallel to grain loading 1.5 d3 or half the distance between rows of bolts, whichever is greater.
2) For perpendicular to grain loading, (loaded edge distance) shall be at least 4 d3.

11.9.3.2 For inclined members, the spacing given above for perpendicular and parallel to grain of wood may be used as a guide and bolts arranged at the joint with respect to loading direction.

11.9.3.3 The bolts shall be arranged in such a manner so as to pass the centre of resistance of bolts through the inter-section of the gravity axis of the members.

11.9.3.4 Staggering of bolts shall be avoided as far as possible in case of members loaded parallel to grain of wood. For loads acting perpendicular to grain of wood, staggering is preferable to avoid splitting due to weather effects.

Table 11.9.2: Bolt diameter factor

Sl. No. (1)	Diameter of Bolt (mm) (2)	Diameter Factor (d_r) (3)
i)	6	5.70
ii)	10	3.60
iii)	12	3.35
iv)	16	3.15
v)	20	3.05
vi)	22	3.00
vii)	25	2.90

11.9.3.5 **Bolting**

The bolt holes shall be bored or drilled perpendicular to the surface involved. Forcible driving of the bolts shall be avoided which may cause cracking or splitting of members. A bolt hole of 1.0 mm oversize may be used as a guide for preboring.

11.9.3.5.1 Bolts shall be tightened after one year of completion of structure and subsequently at an interval of two to three years.

11.9.4 Outline for Design of Bolted Joints

Allowable load on one bolt (unit bearing stress) in a joint with wooden splice plates shall not be greater than value of P, R, F as determined by one of the following equations:

a) For Loads Parallel to Grain

$$P = f_{cp} a \lambda_1$$

b) For Loads Perpendicular to Grain

$$R = f_{cp} a \lambda_2 d_f$$

c) For Loads at an Angle to Grain

$$F = \frac{PR}{P\sin^2\theta + R\cos^2\theta}$$

11.10 DESIGN OF TIMBER CONNECTOR JOINTS

11.10.1

In large span structures, the members have to transmit very heavy stresses requiring stronger jointing techniques with metallic rings or wooden disc-dowels. Improvised metallic ring connector is a split circular band of steel made from mild steel pipes. This is placed in the grooves cut into the contact faces of the timber members to be joined, the assembly being held together by means of a connecting bolt.

11.10.1.1 Dimensions of Members Variation of thickness of central (main) and side members affect the load carrying capacity of the joint.

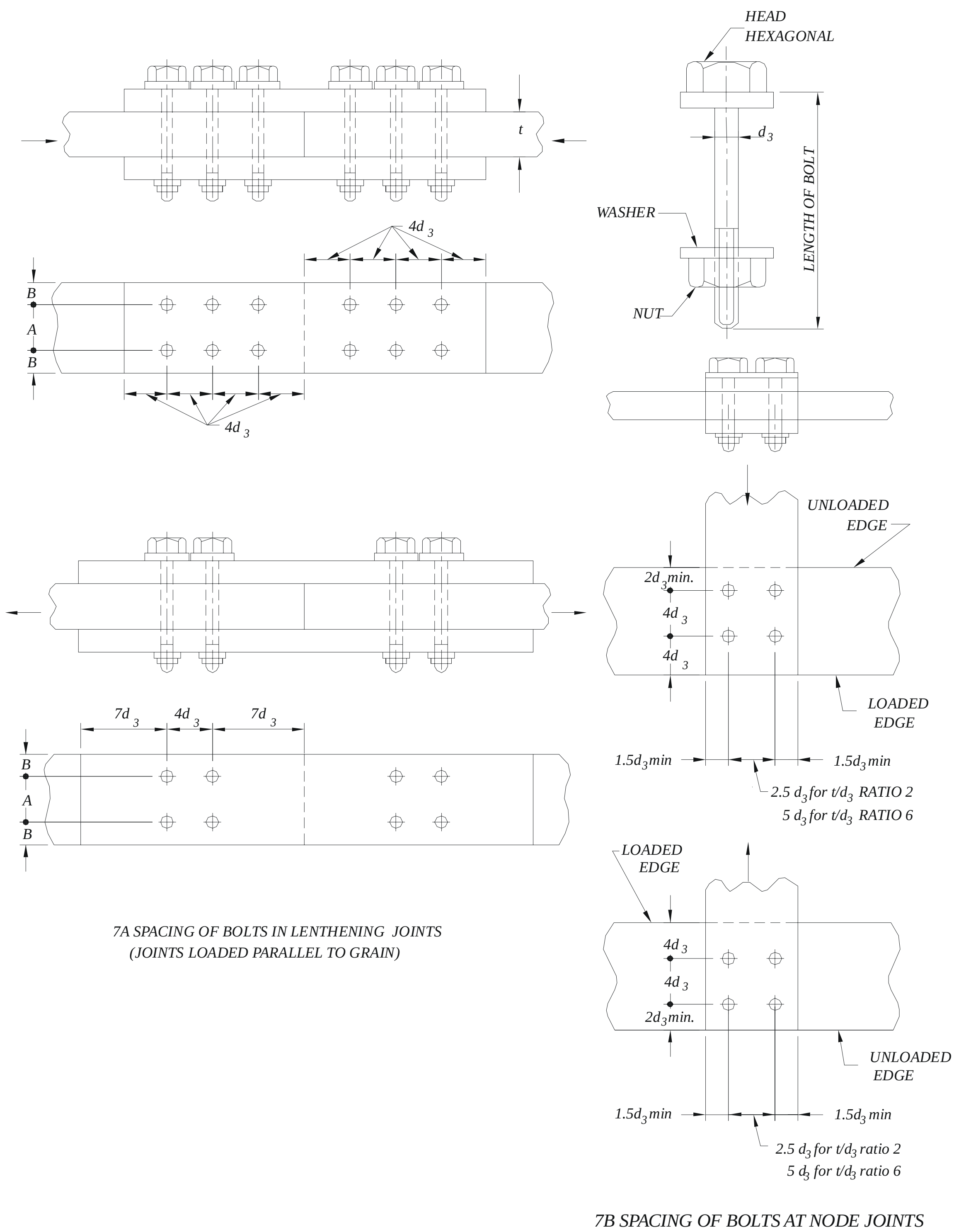


Fig. 11.9.1 Typical Spacing Of Bolts In Structural Joints

The thickness of main member shall be at least 57 mm and that of side member 38 mm with length and width f members governed by placement of connector at joint.

The metallic connector shall be so placed that the loaded edge distance is not less than the diameter of the connector and the end distance not less than 1.75 times the diameter on the loaded side.

11.10.1.2 **Design Considerations**

Figure 11.10.1 illustrates the primary stresses in a split ring connector joint under tension. The shaded areas represent the part of wood in shear, compression and tension. Related formulae for the same are indicated in Fig. 11.10.1.

For fabrication of structural members, a hole of the required size of the bolt is drilled into the member and a groove is made on the contact faces of the joint.

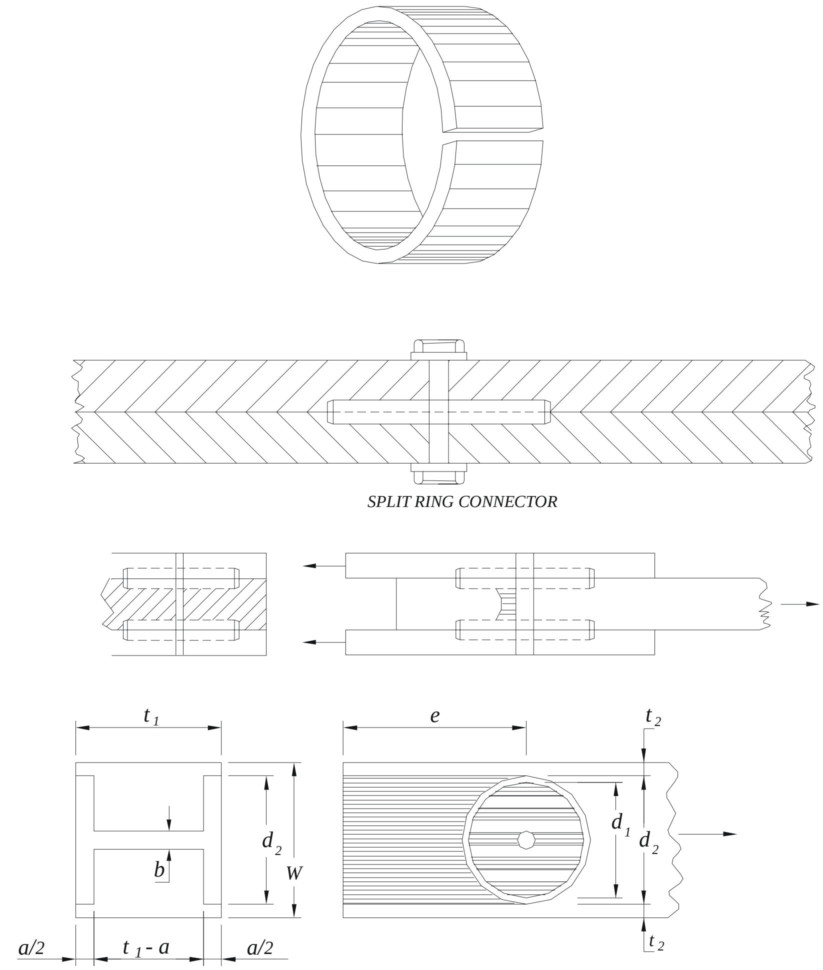


Fig. 11.10.1 Stress Distribution In A Split Ring Connector

11.10.2 Wooden Disc-Dowel

11.10.2.1 It is a circular hardwood disc general] y tapered each way from the middle so as to form a double conical frustum. Such a disc is made to fit into preformed holes (recesses), half in one member and the other half in another, the assembly being held by one mild steel bolt through the centre of the disc to act as a coupling for keeping the jointed wooden members from spreading apart.

11.10.2.2 **Dimensions of Members**

The thickness of dowel may vary from 25 mm to 35 mm anti diameter from 50 mm to 150 mm. The diameter of dowel shall be 3.25 to 3.50 times the thickness.

The edge clearance shall range from 12 mm to 20 mm as per the size of the dowel. The end clearance shall be at least equal to the diameter of dowel for joints subjected to tension and three-fourth the diameter for compression joints. Disc-dowel shall be turned from quarter sawn planks of seasoned material.

11.10.2.3 **Choice of Species**

Wood used for making dowels shall be fairly straight grained, free from excessive liability to shrink and warp, and retain shape well after seasoning species recommended include:

Babul

Sissoo

Pyinkado

Yon

NOTE — Data on the above species as per Table 11.4.1 except for the species Pyinkado, which is not an indigenous species.

11.10.2.4 **Design Considerations**

Figure 11.10.2 illustrates the forces on dowel in a lap joint and butt joint. Dowel is subjected to shearing at the mid-section, and compression along the grain at the bearing surfaces. For equal strength in both the forces, formula equations are given in Fig. 11.10.2 to determine the size of dowel.

The making of wooden discs may present some problems in the field, but they may be made in small workshop to the specifications of the designer. This is also economically important. Once the wood fittings are shop tailored and made, the construction process in the field is greatly simplified.

Theoretical safe loads in design shall be confirmed through sample tests.

11.11 GLUED LAMINATED CONSTRUCTION AND FINGER JOINTS

11.11.1 Developments in the field of synthetic adhesive have brought glueing techniques within the range of engineering practice. Timber members of larger cross-sections and long lengths can be fabricated from small sized planks by the process of gluelam. The term glued laminated timber construction as applied to structural members refers to various laminations glued together, either in straight or curved form, having grain of all laminations essentially parallel to the lengths of the member.

11.11.1.1 **Choice of Glue**

The adhesive used for glued laminated assembly are 'gap filling' type. A 'filler' in powder form is introduced in the adhesive. Structural adhesives are supplied either in powder form to which water is added or in resin form to which a hardener or catalyst is added. However, it is important that only boiling water proof (BWP) grade adhesives shall be used for fabrication of gluelam in tropical, high humid climates like India.

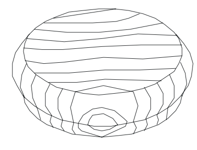
11.11.1.2 **Manufacturing Schedule**

In absence of a systematic flow-line in a factory, provisions of intermediate technology shall be created for manufacturing structural elements. The schedule involves steps:

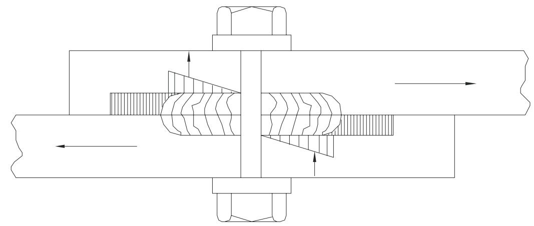
a) Drying of planks;
b) Planning;
c) End-jointing by scarfs or fingers;
d) Machining of laminations;
e) Setting up dry assembly of structural unit;
f) Application of glue;
g) Assembly and pressing the laminations;
h) Curing the glue lines, as specified; and
i) Finishing, protection and storage.

11.11.2

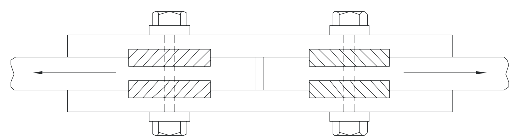
Finger joints are glued joints connecting timber members end-to-end (Fig. 11.11.1). Such joints shall be produced by cutting profiles (tapered projections) in the form of V-shaped grooves to the ends of timber planks or scantling to be joined, glueing the interfaces and then meeting the two ends together under pressure. Finger joints provide long lengths of timber, ideal for upgrading timber by permitting removal of defects, minimizing warping and reducing wastage by avoiding short off-cuts.



DOWEL



LAP JOINT



BUTT JOINT

Lap Joint : Bolt in simple tension due to clockwise turning moment on dowel :

Butt Joint : No tilting moment in dowel due to balancing effect [dowels are in shear (no bending, shearing and tensile stress on bolts)]

Size of dowel for equal strength in both shearing and bearing.

$$\frac{\pi d^2}{4} \times S = d \times \frac{t}{2} \times c$$

Where

d= Mid diameter of the dowel

t= Thickness of dowel

s= Safe working stress in shear along grain, and

c= Safe compressive stress along grain.

NOTE- Symbols are exclusive in this figure.

Fig. 11.10.2 Distribution Of Forces In Doewl Joint

11.11.2.1 In finger joints the glued surfaces are on the side grain rather than on the end grain and the glue line is stressed in shear rather in tension.

11.11.2.1.1 The figures can be cut from edge-to-edge or from face-to-face. The difference is mainly in appearance, although bending strength increases if several fingers share the load. Thus a joist is slightly stronger with edge-to-edge finger joints and a plank is stronger with face-to-face finger joint.

11.11.2.1.2 For structural finger jointed members for interior dry locations, adhesives based on melamine formaldehyde cross linked polyvinyl acetate (PVA) are suited. For high humid and exterior conditions, phenol formaldehyde and resorcinol formaldehyde type adhesives are recommended. Proper adhesives should be selected in consultation with the designer and adhesive manufacturers.

11.11.2.2 **Manufacturing Process**

In the absence of sophisticated machinery, the finger joints shall be manufactured through intermediate technology with the following steps:

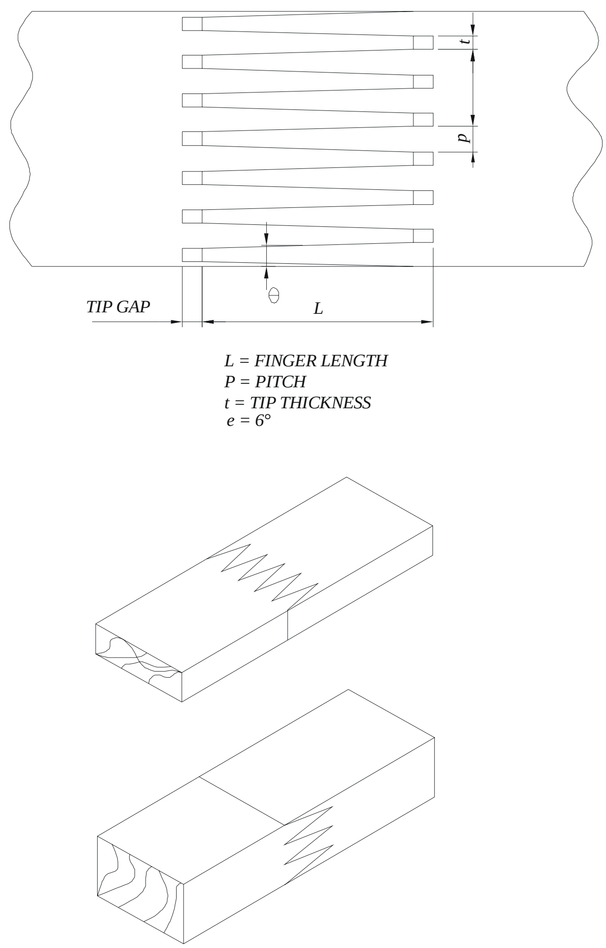
a) Drying of wood,
b) Removal of knots and other defects,
c) Squaring the ends of the laminating planks,
d) Cutting the profile of finger joint in the end grain,
e) Applying adhesives on the finger interfaces,
f) Pressing the joint together at specified pressure,
g) Curing of adhesive line at specified temperature, and
h) Planning of finger-jointed planks for smooth surface.

11.11.2.3 **Strength**

Strength of finger joints depends upon the geometry of the profile for structural purpose; this is generally 50 mm long, 12 mm pitch.

11.11.2.3.1 End joints shall be scattered in adjacent laminations, which shall not be located in very highly stressed outer laminations.

11.11.2.4 Tip thickness will be as small as practically possible.



ORIENTATION OF FINGER JOINTS

Fig. 11.11.1 Typical Finger Joint Geometry

11.12 LAMINATED VENEER LUMBER

11.12.1 Certain reconstituted lignocellulosic products with fibre oriented along a specific direction have been developed and are being adopted for load bearing applications. Laminated veneer lumber is one such product developed as a result of researches in plantation grown species of wood. Density of laminated veneer lumber ranges from 0.6 to 0.75.

11.12.1.1 **Dimensions**

Sizes of laminated veneer lumber composite shall be inclusive of margin for dressing and finishing unless manufactured to order. The margin for dressing and finishing shall not exceed 3mm in the width and thickness and 12mmin the length.

11.12.1.2 **Permissible Defects**

Jointing gaps — Not more than 3 mm wide, provided they are well staggered in their spacing and position between the successive plies.

Slope of grain — Not exceeding 1 in 10 in the face layers.

Tight knot — Three numbers up to 25 mm diameter in one square metre provided they are spaced 300 mm or more apart.

Warp — Not exceeding 1.5 mm per metre length.

11.12.1.3 **Strength Requirements**

The strength requirements for laminated veneer lumber shall be as per Table 11.12.1.

Table 11.12.1: Requirements of laminated veneer lumber

Sl. No. (1)	Properties (2)	Requirement (3)
i)	Modulus of rupture (N/mm^2), Min	50
ii)	Modulus of elasticity (N/mm^2), Min	7500
iii)	Compressive strength:	
	a) Parallel to grain (N/mm^2), Min	35
	b) Perpendicular to grain (N/mm^2), Min	50
iv)	Horizontal shear:	
	a) Parallel to laminac (N/mm^2), Min	6
	b) Perpendicular to laminac (N/mm^2), Min	8
v)	Tensile strength parallel to grain (N/mm^2), Min	55
vi)	Screw holding power:	
	a) Edge (N), Min	2300
	b) Face (N), Min	2700
vii)	Thickness swelling in 2 h water soaking (percent), Max	3

11.13 DESIGN OF GLUED LAMINATED BEAMS

11.13.1 General

Glued laminated structural members shall be fabricated only where there are adequate facilities for accurate sizing and surfacing of planks, uniform application of glue, prompt assembly, and application of adequate pressure and prescribed temperature for setting and curing of the glue. Design and fabrication shall be in accordance with established engineering principles and good practice. A glued laminated beam is a straight member made from a number of laminations assembled both ways either horizontally or vertically. While vertical laminations have limitations in restricting the cross-section of a beam by width of the plank, horizontally laminated section offers wider scope to the designer in creating even the curved members.

Simple straight beams and joists are used for many structures from small domestic rafters or ridges to the light industrial structures.

11.13.2 Design

The design of glue laminated wood elements shall be in accordance with good engineering practice and shall take into consideration the species and grade of timber used, presence of defects, location of end joints in laminations, depth of beams and moisture contents expected while in service. Beams of large spans shall be designed with a suitable camber to assist in achieving the most cost effective section where deflection governs the design. The strength and stiffness of laminated beams is often governed by the quality of outer laminations. Glued laminated beams can be tapered to follow specific roof slopes across a building and/or to commensurate with the varying bending moments.

11.13.3 Material

Laminating boards shall not contain decay, knots or other strength reducing characteristics in excess of those sizes or amounts permitted by specifications. The moisture content shall approach that expected in service and shall in no case exceed 15 percent at the time of glueing. The moisture content of individual laminations in a structural member shall not differ by more than 3 percent at the time of glueing. Glue shall be of type suitable for the intended service of a structural member.

11.13.4 Fabrication/Manufacture

In order to assure a well-bonded and well-finished member of true shape and size, all equipments, end-Jointing, glue spread, assembly, pressing, curing or any other operation in connection with the manufacture of glued structural members shall be in accordance with the available good practices and as per glue manufacturers' instructions as applicable.

11.14 STRUCTURAL USE OF PLYWOOD

Unlike sawn timber, plywood is a layered panel product comprising veneers of wood bonded together with adjacent layers usually at right angles. As wood is strongest when stressed parallel to grain, and weak perpendicular to grain, the lay up or arrangement of veneers in the panel determines its properties. When the face grain of the plywood is parallel to the direction of stress, veneers parallel to the face grain carry almost all the load. Some information/guidelines for structural use of plywood are given in 11.14.1 to 11.14.3.

11.14.1 The plywood has a high strength to weight ratio, and is dimensionally stable material available in sheets of a number of thicknesses and construction. Plywood can be sawn, drilled and nailed with ordinary wood working tools. The glues used to bond these veneers together are derived from synthetic resins which are set and cured by heating. The properties of adhesives can determine the durability of plywood.

11.14.2 In glued plywood construction, structural plywood is glued to timber resulting in highly efficient and light structural components like web beams (I and box sections), (Fig. 11.15.1 and Fig. 11.15.2) stressed skin panels (Fig. 11.15.3) used for flooring and walling and pre-fabricated houses, cabins, etc.

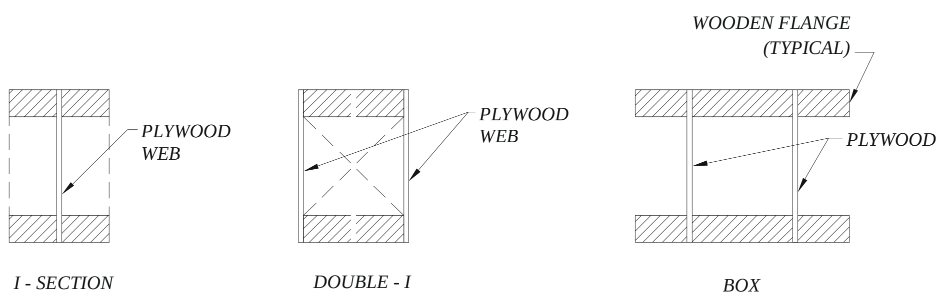


Fig. 11.15.1 Typical Cross - Section Of Web Beams

Glueing can be carried out by nail glueing techniques with special clamps. High shear strength of plywood in combination with high flexural strength and stiffness of wood result in structures characterized by high stiffness for even medium spares. Plywood can act as web transmitting shear stress in web bearing or stressed skin or sandwich construction. The effective moment of inertia of web beam and stressed skin construction depends on modular ratio that is, E of wood to E of plywood.

11.14.3 Structural plywood is also very efficient as cladding material in wood frame construction, such as houses. This type of sheathing is capable of resisting racking due to wind and quack forces. Structural plywood has been widely used as diaphragm (horizontal) as in roofing and flooring in timber frame construction. It has been established that 6 mm thick plywood can be used for sheathing and even for web and stressed skin construction, 9-12 mm thick plywood is suitable for beams, flooring diaphragms, etc. Phenol formaldehyde (PF) and PRF adhesive are suitable for fabrication of glued plywood components. 6 mm-12 mm thick structural plywood can be very well used as nailed or bolded gussets in fixing members of trusses or lattice griders or trussed rafters.

Normally, scarf joints are used for fixing plywood to required length and timber can be joined by using either finger or scarfjoints. Arch panels, folded plates, shelves are other possibilities with this technique.

11.15 TRUSSED RAFTER

11.15.1 General

A roof truss is essentially a plane structure which is very stiff in the plane of the members, that is, the plane in which it is expected to carry loads, but very flexible in every other direction. Thus it can virtually be seen as a deep, narrow girder liable to buckling and twisting under loads. In order, therefore, to reduce this effect, eccentricity of loading and promote prefabrication for economy, low-pitched trussed rafters are designed with bolt ply/nail ply joints. Plywood as gussets, besides being simple have inherent constructional advantage of grain over solid wood for joints, and a better balance is achievable between the joint strength and the member strength.

Trussed rafters are light weight truss units spaced at close centres for limited spans to carry different types of roof loads. They are made from timber members of uniform thickness fastened together in one plane. The plywood gussets may be nailed or glued to the timber to form the joints. Conceptually a trussed rafter is a triangular pin jointed system, traditionally meant to carry the combined roof weight, cladding services and wind loads. There is considerable scope for saving timber by minimizing the sections through proper design without affecting structural and functional requirements.

Trussed rafters require to be supported only at their ends so that there is no need to provide load bearing internal walls, Purlins, etc are dispensed with and in comparison with traditional methods of construction they use less timber and considerably reduces of site labour, Mass production or reliable units can be carried out under workshop controls.

11.15.2 Design

Trussed rafter shall be designed to sustain the dead and imposed loads specified in Part 6 ‘Structural Design: Chapter 2 Loads on Buildings and Structures’ and the combinations expected to occur. Extra stresses/ deflections during handling, transportation and erection shall be taken care of. Structural analysis, use of load-slip and moment, rotation characteristics of the individual joints may be used if feasible. Alternatively the maximum direct force in a member maybe assessed to be given by an idealized pin-jointed framework, fully loaded with maximum dead and imposed load in the combination in which they may reasonably be expected to occur.

11.15.3 Timber

The species of timber including plantation grown species which can be used for trussed rafter construction and permissible stresses thereof shall be in accordance with Table 11.4.1. Moisture contents to be as per zonal requirements in accordance with 11.4.4.

11.15.4 Plywood

Boiling water resistant (BWR) grade preservative treated plywood shall be used. Introduction of a plywood gusset simplifies the jointing and in addition provides rigidity to the joint. Preservation of plywood and other panel products shall be done in accordance with good practice prescribed by Bangladesh Forest Research Institute, Chittagong.

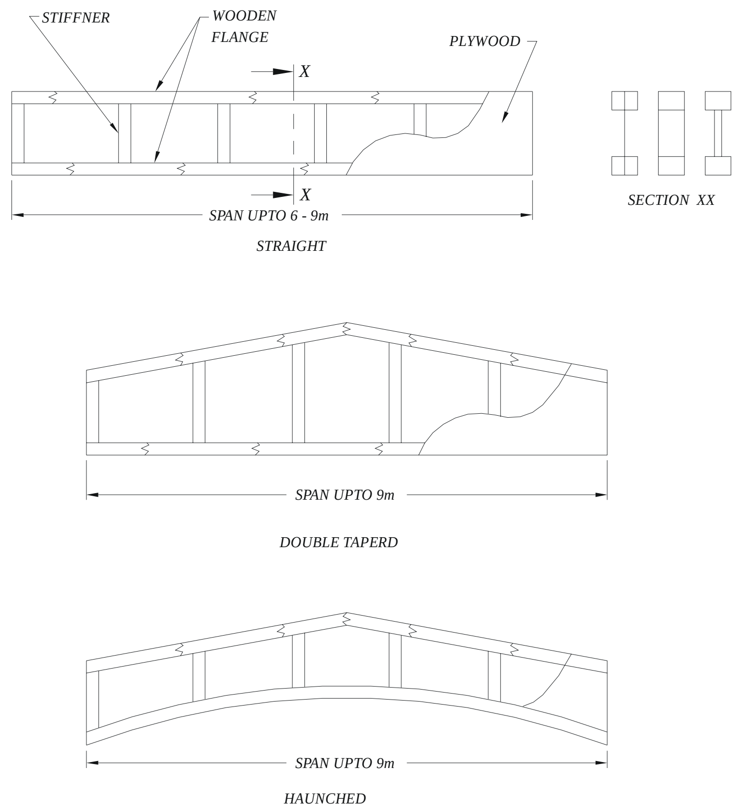


Fig. 11.15.2 Web Beam Configurations

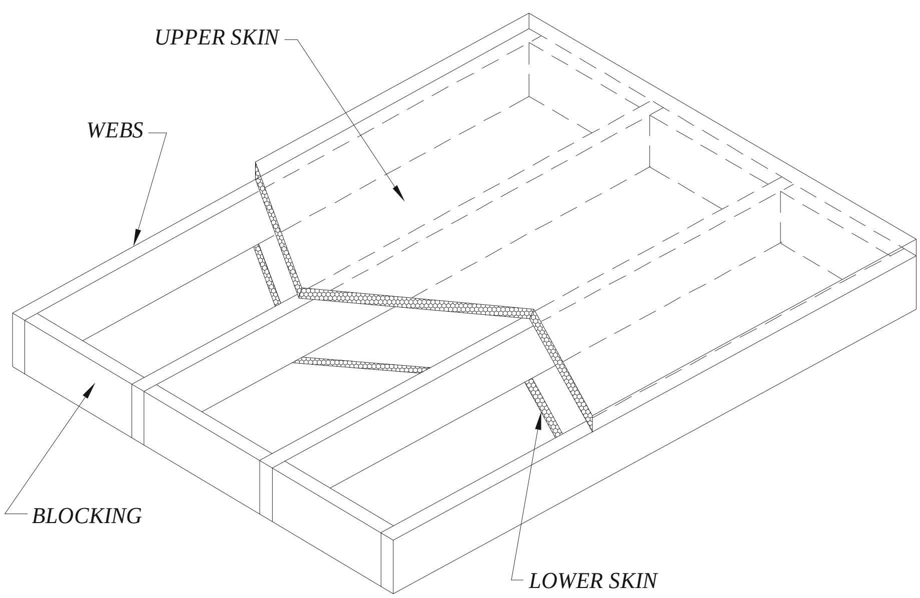


Fig. 11.15.3 Stressed Skin Panel Construction (Single Skin Or Double Skin)

11.16 STRUCTURAL SANDWICHES

11.16.1 General

Sandwich constructions are composites of different materials including wood based materials formed by bonding two thin facings of high strength material to a light weight core which provides a combination of desirable properties that are not attainable with the individual constituent materials (Fig. 11.16.1). The thin facings are usually of strong dense material since that are the principal load carrying members of the construction. The core must be stiff enough to ensure the faces remain at the correct distance apart. The sandwiches used as structural elements in building construction shall be adequately designed for their intended services and shall be fabricated only where there are adequate facilities for glueing or otherwise bonding cores to facings to ensure a strong and durable product. The entire assembly provides a structural element of high strength and stiffness in proportion to its mass.

Non-structural advantages can also be derived by proper selection of facing and core material for example, an impermeable facings can be used to serve as a moisture barrier for walls and roof panels and core may also be selected to provide thermal and/or acoustic insulation, fire resistance, etc, besides the dimensional stability.

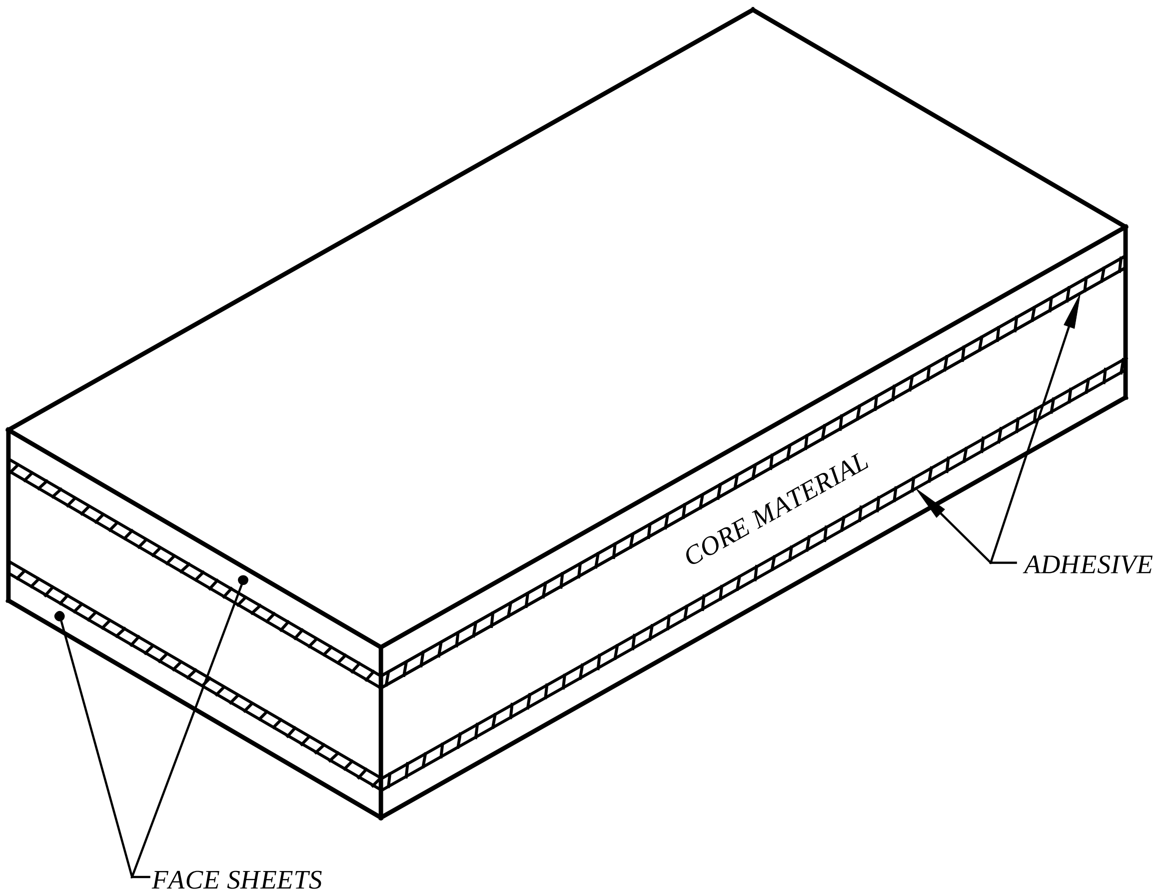


Fig. 11.16.1: Sandwitch construction in structural applications

11.16.2 Cores

Sandwich cores shall be of such characteristics as to give to the required lateral support to the stressed facings to sustain or transmit the assumed loads or stresses. Core generally carries shearing loads and to support the thin facings due to compressive loads. Core shall maintain the strength and durability under the conditions of service for which their use is recommended. A material with low E and small shear modulus may be suitable.

11.16.3 Facings

Facings shall have sufficient strength and rigidity to resist stresses that may come upon them when fabricated into a sandwich construction. They shall be thick enough to carry compressive and tensile stresses and to resist puncture or denting that maybe expected in normal usages.

11.16.4 Designing

Structural designing may be comparable to the design of I-beams, the facings of the sandwich represent the flanges of the I-beam and the sandwich core I-beam web.

11.16.5 Tests

Tests shall include, as applicable, one or more of the following:

a) Flexural strengtldstiffness,
b) Edge-wise compressions,
c) Flat-wise compression,
d) Shear in flat-wise plane,
e) Flat-wise tensions,
f) Flexural creep (creep behaviour of adhesive),
g) Cantilever vibrations (dynamic property), and
h) Weathering for dimensional stability.

11.17 LAMELLA ROOFING

11.17.1 General

The Lamella roofing offers an excellent architectural edifice in timber, amenable to prefabrication, light weight structure with high central clearance. It is essentially an arched structure formed by a system of intersecting skewed arches built-up of relatively short timber planks of uniform length and cross-section. Roof is designed as a two hinged arch with a depth equal to the depth of an individual lamella and width equal to the span of the building. The curved lamellas (planks) are bevelled and bored at the ends and bolted together at an angle, forming a network (grid) pattern of mutually braced and stiffened members (Fig. 11.17.1). The design shall be based on the balanced or unbalanced assumed load distribution used for roof arches. Effect of deformation or slip of joints under load on the induced stresses shall be considered in design. Thrust components in both transverse and longitudinal directions of the building due to skewness of the lamella arch shall be adequately resisted. Thrust at lamella joints shall be resisted by the moment of inertia in the continuous lamella and roof sheathening (decking) of lamella roofing. The interaction of arches in two directions adds to the strength and stability against horizontal forces. For design calculations several assumption tested and observed derivations, long-duration loading factors, seasoning advantages and effects of defects are taken into account.

11.17.2 Lamellas

Planking shall be of a grade of timber that is adequate in strength and stiffness to sustain the assumed loads, forces, thrust and bending moments generated in Lamella roofing. Lamella planks shall be seasoned to a moisture content approximating that they will attain in service. Lamella joints shall be proportioned so that allowable stresses at bearings of the non-continuous lamellas on the continuous Iamellas or bearings under the head or washer of bolts are not exceeded.

11.17.3 Construction

Design and construction of lamella roofs in India assumes the roof surfaces to be cylindrical with every individual lamella an elliptic segment of an elliptical arch of constant curved length but of different curvature. Lamella construction is thus more of an art than science as there is no analytical method available for true generation of schedule of cutting lengths and curvature of curved members forming the lamella grid. Dependence of an engineer on the practical ingenuity of master carpenter is almost final. All the lamella joints shall be accurately cut and fitted to give full bearing without excessive deformation or slip. Bolts at lamella splices shall be adequate to hold the members in their proper position and shall not be over tightened to cause bending of the lamellas or mashing of wood under the bolt heads. Connection of lamellas to the end arches shall be adequate to transmit the thrust or any other force. Sufficient false work or sliding jig shall be provided for the support of lamella roof during actual construction/erection.

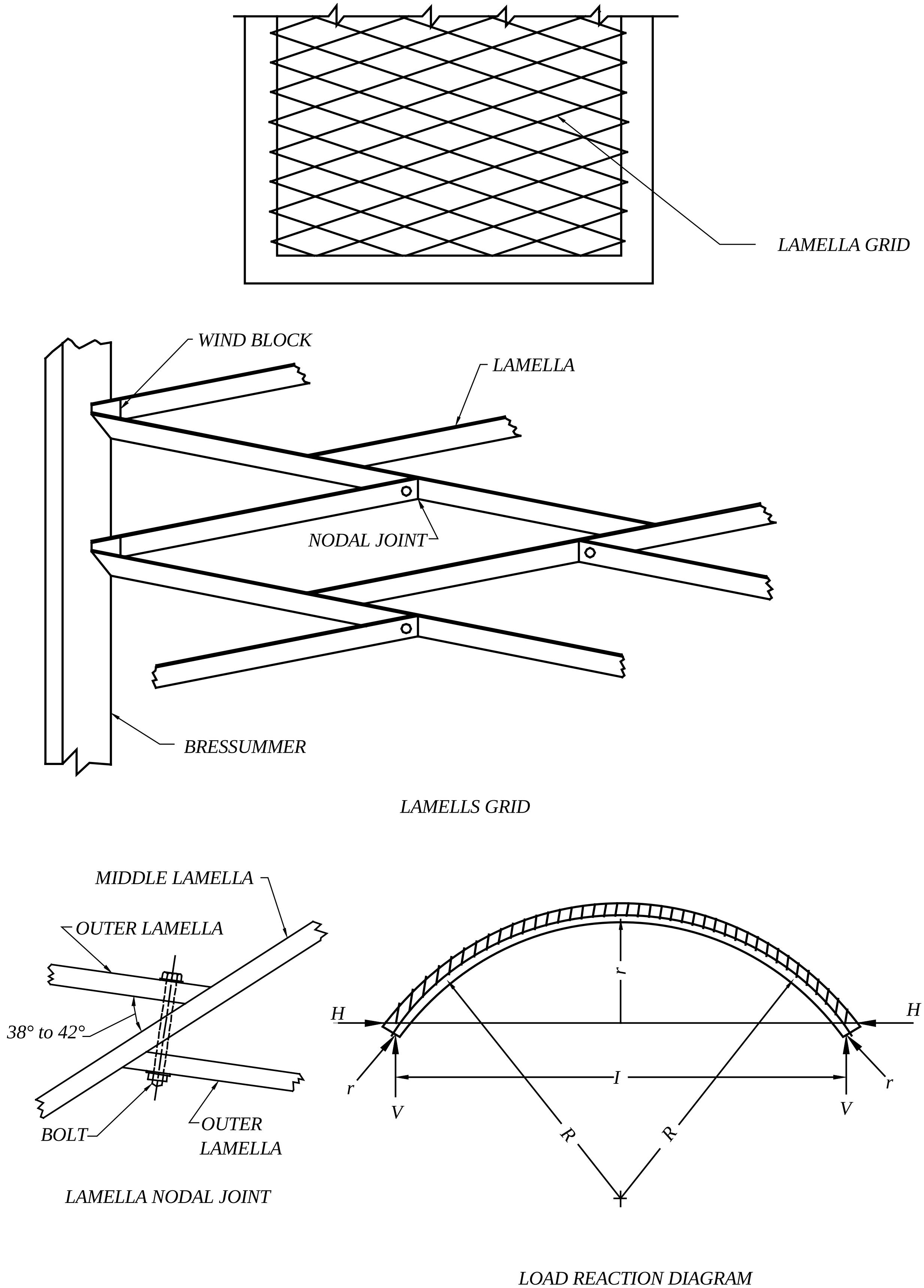


Fig. 11.17.1: Typical arrangement of Lamella roofing

11.18 NAIL AND SCREW HOLDING POWER OF TIMBER

11.18.1 General

One of the most common ways of joining timber pieces to one another is by means of common wire nails and wood screws. Timber is used for structural and nonstructural purposes inform of scantlings, rafters, joists, boarding, crating and packing cases, etc needing suitable methods of joining them. Nevertheless it is the timber which holds the nails or screws and as such pulling of the nails/screws is the chief factor which come into play predominantly. In structural nailed joints, nails are essentially loaded laterally, the design data for which is already available as standard code of practice. Data on holding power of nails/screws in different species is also useful for common commercial purposes. The resistance of mechanical fastenings is a function of the specific gravity of wood, direction of penetration with respect to the grain direction, depth of penetration and the diameter of fastener assuming that the spacing of fasteners should be adequate to preclude splitting of wood.

11.18.2 Nails

Nails are probably the most common and familiar fastener. They are of many types and sizes in accordance with the accepted standards [6-3 A(16)].

In general nails give stronger joints when driven into the side grain of wood than into the end grain. Nails perform best when loaded laterally as compared to axial withdrawal so the nailed joints should be designed for lateral nail bearing in structural design. Information on withdrawal resistance of nails is available and joints may be designed for that kind of loading as and when necessary.

11.18.3 Screw

Next to the hammer driven nails, the wood screw may be the most commonly used fastener. Wood screws are seldom used in structural work because of their primary advantage is in withdrawal resistance, for example, for fixing of ceiling "boards to joists, purlin cleats, besides the door hinges etc. They are of considerable structural importance in fixture design and manufacture. Wood screws are generally finished in a variety of head shapes and manufactured in various lengths for different screw diameters or gauges.

The withdrawal resistance of wood screws is a function of screw diameter, length of engagement of the threaded portion into the member, and the specific gravity of the species of wood. Withdrawal load capacity of wood screws are available for some species and joints may be designed accordingly. End grain load on wood screws are unreliable and wood screws shall not be used for that purpose.

11.19 PROTECTION AGAINST TERMITE ATTACK IN BUILDINGS

11.19.1 Two groups of organisms which affect the mechanical and aesthetic properties of wood in houses are fungi and insects. The most important wood destroying insects belong to termites and beetles. Of about 250 species of wood destroying termites recorded in India, not more than a dozen species attack building causing about 90 percent of the damage to timber and other cellulosic materials. Subterranean termites are the most destructive of the insects that infest wood in houses justifying prevention measures to be incorporated in the design and construction of buildings.

11.19.1.1 Control measures consist in isolating or sealing off the building from termites by chemical and non-chemical construction techniques. It is recognized that 95 percent damage is due to internal travel of the termites from ground upwards rather than external entry through entrance thus calling upon for appropriate control measures in accordance with good practices [6-3A(1 8)].

11.19.2 Chemical Methods

Termites live in soil in large colonies and damage the wooden structure in the buildings by eating up the wood or building nests in the wood. Poisoning the soil under and around the building is a normal recommended practice. Spraying of chemical solution in the trenches of foundations in and around walls, areas under floors before and after filling of earth, etc. In already constructed building the treatment can be given by digging trenches all around the building and then giving a liberal dose of chemicals and then closing the trenches.

11.19.3 Wood Preservatives

Natural resistance against organisms of quite a few wood species provides durability of timber without special protection measure. It is a property of heartwood while sapwood is normally always susceptible to attack by organisms. Preservatives should be well applied with sufficient penetration into timber. For engineers, architects and builders, the following are prime considerations for choice of preservatives:

a) Inflammability of treated timber is not increased and mechanical properties are not decreased;
b) Compatibility with the glue in laminated wood, plywood and board material;
c) Water repellent effect is preferred;
d) Possible suitability for priming coat;
e) Possibility of painting and other finishes;
f) Non-corrosive nature fasteners; and
g) Influence on plastics, in case of metal rubber, tiles and concrete.

11.19.4 Constructional Method

Protection against potential problem of termite attack can simply be carried out by ordinary good construction which prevents a colony from gaining access by:

a) periodic visual observations on termite galleries to be broken off;
b) specially formed and properly installed metal shield at plinth level; and
c) continuous floor slabs, apron floors and termite grooves on periphery of buildings.