भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
BUREAU OF INDIAN STANDARDS
(Ministry of Consumer Affairs, Food & Public Distribution, Govt. of India)

मानक भवन, 9, बहादुर शाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002
Mob.: 7071963270, Phones: 011-23608594, Extn: 8594
Website: www.bis.org.in , www.bis.gov.in

व्यापक परिचालन मसौदा

हमारा संदर्भ: सीईडी 46 /टी-8 **25 फ़रवरी 2025**

तकनीकी समिति: भारत की राष्ट्रीय भवन निर्माण विषय समिति, सीईडी 46
प्राप्तकर्ता :

1. **सिविल अभियांत्रिकी विभाग परिषद, सीईडीसी के सभी सदस्य**
2. **राष्ट्रीय भवन निर्माण संहिता विषय समिति, सीईडी 46 के सभी सदस्य**
3. **सीईडी 46 की पैनल और अन्य कार्यदल के सभी सदस्य**
4. **रुचि रखने वाले अन्य निकाय।**

महोदय/महोदया,

निम्नलिखित मानक का मसौदा संलग्न हैं:

प्रलेख संख्या	शीर्षक
सीईडी 46 (26944) WC	**भारत की राष्ट्रीय भवन निर्माण संहिता भाग 6 संरचनात्मक डिजाइन अनुभाग 3 इमारती लकड़ी तथा बाँस 3A इमारती लकड़ी** [SP7 (भाग 6,अनुभाग 3, 3ए) का चौथा पुनरीक्षण] (आई सी एस नंबर: 01.120: 91.040.01)

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजे कि यह मसौदा प्रकाशित हो तो इस पर अमल करने में आपको व्यवसाय अथवा कारोबार में क्या कठिनाइयां आ सकती हैं।

सम्मतियाँ भेजने की अंतिम तिथि: 27 मार्च 2025

सम्मति यदि कोई हो तो कृपया अधोहस्ताक्षरी को ई-मेल द्वारा **ced46@bis.gov.in** पर या उपरलिखित पते पर, संलग्न फोर्मेट में भेजें। सम्मतियाँ बीआईएस ई-गवर्नेंस पोर्टल, **www.manakonline.in** के माध्यम से ऑनलाइन भी भेजी जा सकती हैं।

यदि कोई सम्मति प्राप्त नहीं होती है अथवा सम्मति में केवल भाषा संबंधी त्रुटि हुई तो उपरोक्त प्रलेख को यथावत अंतिम रूप दे दिया जाएगा। यदि सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रलेख को अंतिम रूप दे दिया जाएगा।

यह प्रलेख भारतीय मानक ब्यूरो की वैबसाइट **www.bis.gov.in** पर भी उपलब्ध हैं।
धन्यवाद।

भवदीय

ह/-
(द्वैपायन भद्र)
वैज्ञानिक 'ई' एवं प्रमुख (सिविल अभियांत्रिकी विभाग)

सलंग्न: उपरिलिखित

भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
BUREAU OF INDIAN STANDARDS
(Ministry of Consumer Affairs, Food & Public Distribution, Govt. of India)

मानक भवन, 9, बहादुर शाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002
Mob.: 7071963270, Phones: 011-23608594, Extn: 8594
Website: www.bis.org.in , www.bis.gov.in

WIDE CIRCULATION DRAFT

Our Reference: CED 46/T-8 **25 February 2025**

National Building Code of India Sectional Committee, CED 46

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of the National Building Code Sectional Committee, CED 46
3. All Members of Panels and Working Groups under CED 46
4. All others interested

Dear Sir/Madam,

Please find enclosed the following draft:

Doc No.	Title
CED 46 (26944) WC	**National Building Code of India Part 6 Structural Design Section 3 Timber and Bamboo: 3A Timber** [Fourth Revision of SP 7 (Part 6 Section 3,3A)] (ICS No. 01.120: 91.040.01)

Kindly examine the attached draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for comments: 27 March 2025

Comments if any, may please be made in the enclosed format and emailed at **ced46@bis.gov.in** or sent at the above address. Additionally, comments may be sent online through the BIS e-governance portal, **www.manakonline.in**.

In case no comments are received or comments received are of editorial nature, kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website **www.bis.gov.in**.

Thanking you,

Yours faithfully,

Sd/-
(Dwaipayan Bhadra)
Scientist 'E' / Director & Head
(Civil Engineering Department)

Encl: As above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail to ced46@bis.gov.in shall be appreciated**.

Doc. No.: CED 46 (26944) WC **BIS Letter Ref**: CED 46/T-8

Title: National Building Code of India Part 6 Structural Design Section 3 Timber and Bamboo: 3A Timber [Fourth Revision of SP 7 (Part 6 Section 3, 3A)] (ICSNo.01.120:91.040.01)

Last date of comments: **27 March 2025**

Name of the Commentator/ Organization: ________________________________

Clause/ Para/ Table/ Figure No. commented	Comments/Modified Wordings	Justification of Proposed Change

NOTE- Kindly insert more rows as necessary for each clause/table, etc

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY

(Not to be reproduced without the permission of BIS or used as a Standard)

Draft Indian Standard

National Building Code of India

Part 6 Structural Design

Section 3 Timber and Bamboo: 3A Timber

[Fourth Revision of SP 7 (Part 6 Section 3, 3A)]

(ICS No. 01.120: 91.040.01)

Technical Committee	**Last Date for Comments:**
National Building Code, CED 46	**27 March 2025**

C O N T E N T S

National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 3A) deals with the structural design aspect of timber structures. In this Subsection, the various species of Indian timber, classified into three groups depending on the structural properties influencing the design most, are included.

This Section was first published in 1970 which was subsequently revised in 1983, 2005 and 2016. In the 1983 version of the Code, timber was covered under Section 3 of Part 6 under the title 'Wood', which did not cover bamboo. In the version of 2005, the scope of Section 3 was enlarged as Section 3 Timber and Bamboo, which was subdivided into Subsection 3A 'Timber' and Subsection 3B 'Bamboo'. This Subsection pertains to 3A Timber.

In the first revision of 1983, provisions of this Subsection were updated and design of nailed laminated timber beams, were included and information on bolted construction joints was added. In the second revision of 2005, a number of terminologies related to timber for structural purpose were added, strength data of additional species of timber were included, requirements for structural timber and preferred cut sizes thereof were modified, requirements for glued laminated construction and finger joints and also for laminated veneer lumber were introduced. Brief details were included for structural sandwiches, glued laminated beams, lamella roofing, nail and screw holding power of timber, structural use of plywood and trussed rafter. Further, guidelines for protection against termite attack in buildings were also incorporated in the last revision of this Subsection. Also, keeping into consideration the dwindling forest resources, brief details on use of plantation timbers including certain fast growing species and suitable guidelines in terms of their seasoning, sawing, treatment, etc and also use of finger jointing and glued laminated timber was introduced in the last revision so as to effect judicious use of timber.

The third revision of 2016 addressed several significant changes, including modifications to definitions of various terms to align with prevailing engineering practices and the addition of new terminologies related to structural timber. The permissible lateral strength (in double shear) of mild steel common wire was updated to include various new timber species, with modified strength values for certain existing species based on the latest research. Guidance on increased permissible lateral strength for mild steel nails clenched across the grain, as opposed to nails with points cut flush, was incorporated. Design provisions for timber connector joints were further updated, along with data on block shear test results of glued timber joints based on indigenous studies. Additionally, information on the strength properties of glued finger joints from indigenous research was included for design guidance. A new figure illustrating possible orientations of planks in glue-laminated beams (Glulam) was added, as well as a design outline for horizontally laminated beams. Updates were also made to the design provisions for trussed rafters, including data on lateral load-bearing strength of common wire nails in plywood-to-wood joints. Provisions for lamella roofing design were detailed, and the composite nail/screw-holding power of specific Indian timbers was provided for design guidance.

As a result of experience gained in implementation of 2016 version of this Code and feedback received as well as formulation of new standards in the field and revision/ updation of some of the existing standards, a need to revise this Section was felt. This revision has, therefore, been brought out to take care of these aspects.

The significant changes incorporated in this revision include the following:

a) Additional considerations for trussed rafter concerning climatic suitability, use of local timber species and fire and termite resistance.

b) Cross-laminated timber components including material specifications, dimensions, and fire resistance requirements.

c) Testing for bending, compression, and shear strength for CLT and other engineered wood products.

d) Mass timber construction and its components given in **21**.

e) Fire safety enhancements and fire-resistant assembly methods for mass timber, ensuring compliance with structural and fire safety standards.

f) Focus on sustainability with introduction of life cycle assessment (LCA) to evaluate the environmental impact of timber from production to disposal.

g) Guidance for integrating mass timber with steel and concrete to ensure continuous load transfer and seismic performance.

The information contained in this Subsection is largely based on the following Indian Standards:

IS 399 : 1963	Classification of commercial timbers and their zonal distribution (*revised*)
IS 883 : 2016	Code of practice for design of structural timber in building (*fifth revision*)
IS 1150 : 2000	Trade names and abbreviated symbols for timber species (*third revision*)
IS 2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
IS 4891 : 1988	Specification for preferred cut sizes of structural timber (*first revision*)
IS 4983 : 1968	Code of practice for design and construction of nailed laminated timber beams
IS 11096 : 1984	Code of practice for design and construction of bolt-jointed timber construction
IS 14616 : 1999	Specification for laminated veneer lumber

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

Code Users are requested to share their inputs/comments on the draft particularly based on the changes listed above in the foreword; and specially on those text highlighted in blue in this draft.

Important Explanatory Note for Users of the Code

In any Part/Section of this Code, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to '**accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/ Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practices [6-3A(1)] refers to the Indian Standard(s) give at serial number (1) of the list of standards given at the end of this Part/Section, that is, IS 707 : 2011 'Timber technology and utilization of wood, bamboo and cane — Glossary of terms (*third revision*)'.

DRAFT FOR COMMENTS ONLY

(Not to be reproduced without the permission of BIS or used as a Standard)

Draft Indian Standard

National Building Code of India

Part 6 Structural Design
Section 3 Timber and Bamboo: 3A Timber

(ICS No. 01.120: 91.040.01)

Technical Committee	**Last Date for Comments:**
National Building Code, CED 46	**27 March 2025**

1 SCOPE

1.1 This Code (Part 6/Subsection 3A) covers the general principles involved in the design of structural timber in buildings, including elements of structures connected by fasteners/fastening techniques.

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. The classification of timber into strength groups should not be interpreted as preventing the use of design data desired for a particular timber or grade of timber on the basis of reliable tests.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions and those given in the accepted standard [6-3A(1)], shall apply.

2.1 Structural Purpose Definitions

2.1.1 *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.

2.1.2 *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.

2.1.3 *Bressummer* – A beam, across broad opening, sustaining super structure.

2.1.4 *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.

2.1.5 *Duration of Load* – Period during which a member or a complete structure is stressed as a consequence of the loads applied.

NOTE – Timber is stronger under loads of brief duration than under permanently applied loads.

2.1.6 *Edge Distance* – The distance measured perpendicular to grain from the centre of the connector to the edge of the member.

2.1.7 *End Distance* – The distance measured parallel to grain of the member from the centre of the connector to the closest end of timber.

2.1.8 *Finger Joint* – End joint formed by machining a number of similar, tapered, symmetrical fingers in the ends of timber member, which are then bonded together.

2.1.9 *Finger Jointed Timber* – Timber containing adhesively bonded finger joints spaced at manufacturer specified minimum spacing.

2.1.10 *Fundamental or Ultimate Stress* – The stress which is determined on small clear specimen of timber, in accordance with accepted standards [6-3A(2)]; and does not take into account the effect of naturally occurring characteristics and other factors.

2.1.11 *Glue* – A substance capable of holding materials together by surface attachment.

2.1.12 *Glued Laminated (Glulam)* – A wood structural element comprising of sawn wood lamination bonded together with adhesives and in which the grains of all laminations are parallel longitudinally.

2.1.12.1 *Glued laminated, Horizontally* – Glued laminated timber where gluing planes are perpendicular to the largest dimension of the transverse section, that is, in cross-wise direction.

2.1.12.2 *Glued laminated, Vertically* – Glued laminated timber where gluing planes are perpendicular to the smallest dimension of the transverse section.

2.1.13 *Inside Location* – Position in buildings in which timber remains continuously dry or protected from weather.

2.1.14 *Isoptera* – An order of social insects consisting of the termites.

2.1.15 *Lamella Roof* – A roof or frame, made up of relatively short members, called lamellas, forming a network of framing timbers. This network forms a barrel-like structure of mutually braced and stiffened units, arching over the building between supports, and together with the sheathing forms a diaphragm for resistance of vertical and lateral loads.

2.1.16 *Laminations* – Thin elements of wood of appreciable width and length which, when superimposed on each other and fastened together with their grains essentially parallel make up cross section of considerable depth or width.

2.1.17 *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.

2.1.18 *Latewood* – The portion of the wood that is formed in the later part of growth season and consists of thicker walled cells.

2.1.19 *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.

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

2.1.21 *Mechanically Laminated* – A wood structural element comprising of laminations which are not glued but which are held together with mechanical fastenings such as nails or bolts and in which all laminations have the grains approximately parallel longitudinally.

2.1.22 *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.

2.1.23 *Permissible Stress* – Stress obtained by applying factor of safety to the ultimate stress.

2.1.24 *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.

2.1.25 *Spaced Column* – Two column sections adequately connected together by glue, bolts, screws or otherwise.

2.1.26 *Stressed Skin* – A form of construction in which the outer skin, in addition to its normal functioning of providing a surface covering, acts integrally with the framing members contributing to the strength of the unit as a whole.

2.1.27 *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.

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

2.1.29 *Structural Element* – The component timber members and joints which make up a resulting structural assembly.

2.1.30 *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.

2.1.31 *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.

2.1.32 *Stud* – One of a series of slender wood structural members placed vertically as supporting members in a wall partition, or similar structural unit.

2.1.33 *Termite* – An insect of the order *Isoptera* which may burrow in the wood or wood products of a building for food or shelter.

2.1.34 *Wet Loc*ation – 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.

2.2 Definitions of Defects in Timber

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

2.2.2 *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.

2.2.3 *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.

2.2.4 *Decay or Rot* – Disintegration of wood tissue caused by fungi (wood destroying) or other micro-organisms.

2.2.5 *Decayed Knot* – A knot softer than the surrounding wood and containing decay.

2.2.6 *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.

2.2.7 *Discolouration* – A change from the normal colour of the wood which does not impair the strength of the wood.

2.2.8 *Knot* – A branch base or limb embedded in the tree or timber by natural growth.

2.2.9 *Knot Hole* – A hole left as a result of the removal of a knot.

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

2.2.11 *Loose Grain (Loosened Grain)* – A defect on a flat sawn surface caused by the separation or raising of wood fibres along the growth rings; *cf.* 'Raised Grain'.

2.2.12 *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'.

2.2.13 *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.

2.2.14 *Pitch Pocket* – Accumulation of resin between growth rings of coniferous wood as seen on the cross-section.

2.2.15 *Sap Stain* – Discolouration of the sapwood mainly due to fungi.

2.2.16 *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.

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

2.2.18 *Slope of Grain* – The inclination of the fibres to the longitudinal axis of the member.

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

2.2.20 *Split* – A crack extending from one face of a piece of wood to another and runs along the grain of the piece.

2.2.21 *Tight Knot* – A knot so held by growth or position as to remain firm in position in the piece of wood; *cf.* 'Loose Knot'.

2.2.22 *Wane* – The original rounded surface of a tree remaining on a piece of converted timber.

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

2.2.24 *Worm Holes* – Cavities caused by worms.

3 SYMBOLS

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

a = projected area of bolt in main member ($t' \times d_3$), 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
$f_{c\theta}$	=	permissible compressive 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 [extreme fibre stress in bending-tension (f_b) is safe practical estimate of tensile strength due to mode of failure in beams]
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
K_3, K_4, K_5, K_6	=	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 $\frac{\pi}{2}\sqrt{\frac{UE}{5q\ f_{cp}}}$
K_{10}	=	constant equal to $0.584\sqrt{\frac{2.5E}{f_{cp}}}$
ℓ or L	=	span of a beam or truss, mm
M	=	maximum bending moment in beam, N-mm
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	=	static 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
y	=	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, mm^3
λ_1	=	percentage factor for t'/d_3 ratio, parallel to grain
λ_2	=	percentage factor for t'/d_3 ratio, perpendicular to grain

4 MATERIALS

4.1 Species of Timber

The species of timber recommended for structural purposes are given in Table 1 along with their permissible stresses and properties.

Table 1 Safe Permissible Stresses for the Species of Timber

[*Clauses* 4.1, 4.2, 4.7.1.3(b), 5.4.1, 5.4.2 *and* 6.5.8.3.1(b)]

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10^3**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m^3	N/mm^2	N/mm^2													
					Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain					
Botanical Name	Trade Name				Inside Location	Outside Location	Wet Location	Horizontal	Along Grain	Inside Location	Outside Location	Wet Location	Inside Location	Outside Location	Wet Location	[1]Durability Class	[2]Treat-ability Grade	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
GROUP A																		
Acacia catectou	Khair (KHA)	U.P.	1 009	13.44	20.1	16.8	13.4	1.6	2.2	13.8	12.3	10.1	7.7	6.0	4.9	I	-	A
Acacia chundra	Red kutch	M.P.	1 086	16.79	26.5	22.0	17.6	2.2	3.2	17.9	15.9	13.0	10.9	8.4	6.9	-	-	A
Albizia odoratissima	Kala siris (KSI)	Chennai	737	13.54	18.7	15.6	12.5	1.5	2.2	13.3	11.8	9.6	7.3	5.6	4.6	I	e	B
Bruguiera spp.	Bruguiera (BSV) (Mangrove)	Andmans	897	17.68	21.9	18.3	14.6	1.2	1.7	14.3	12.7	10.4	5.5	4.3	3.5	III	-	-
Grewia tiliifolia	Dhaman (DHA)	Chennai	788	14.82	18.3	15.2	12.2	1.3	1.9	12.0	10.7	8.7	6.0	4.7	3.8	III	d	B
Hopea utilis (Balano carpus utilis)	Karung	Chennai	987	16.91	25.1	20.9	16.7	1.5	2.2	16.4	14.6	11.9	9.3	7.3	5.9	-	-	-
Hopea glabra	Hopea (HOP)	Chennai	1 081	14.79	21.3	17.8	14.2	1.5	2.2	14.5	12.9	10.6	9.9	7.7	6.3	I	-	A
Hopea parviflora	Hopea (HOP)	Chennai	923	13.03	18.6	15.5	12.4	1.3	1.8	13.2	11.8	9.6	9.2	7.3	6.0	I	e	A
Manilota polyandra (Syn. Cynometra polyandra)	Ping (PIG)	Assam	903	13.20	19.1	15.9	12.7	1.3	1.8	1.2	10.4	8.5	5.7	4.4	3.6	III	b	A

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10^3**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m^3	N/mm^2	N/mm^2													
					Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain					
Botanical Name	Trade Name				Inside Location	Outside Location	Wet Location	Horizontal	Along Grain	Inside Location	Outside Location	Wet Location	Inside Location	Outside Location	Wet Location	[1]Durability Class	[2]Treat-ability Grade	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Mesua ferrea	Mesua (MES)	Assam	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
Mimusops littoralis	Bullet-wood (BUL)	S.Andaman	1 103	17.39	22.7	18.9	15.1	1.5	2.1	14.2	12.7	10.4	11.3	8.8	7.2	I	-	A
Pesciloneuron indicum	Ballagi (BAL)	Chennai	1 139	16.29	22.4	18.7	15.0	1.5	2.2	14.7	13.1	10.7	8.7	6.8	5.5	I	e	A
Pterocarpus Scantalinus	Red sanders (MA)	Chennai	1 121	12.73	25.0	20.9	16.7	1.7	2.5	18.1	16.1	13.2	11.8	9.2	7.5	-	-	A
Sageraea elliptica	Chooi (COC)	Andmans	869	15.06	21.5	17.9	14.3	1.1	1.5	12.5	11.1	9.1	5.3	4.1	3.4	-	-	A
Stereospermun celonoides	Padri (PAD)	Chennai	731	12.94	19.0	15.8	12.7	1.1	1.6	11.9	10.6	8.7	4.0	3.1	2.6	III	-	B
Vitex altissima	Milla (MIL)	Maharashtra	937	13.01	18.2	15.2	12.1	1.2	1.7	12.6	11.2	9.2	9.5	7.4	6.1	I	e	A
GROUP B																		
Albizzia lebbeck	Kokko (KOK)	Andaman	642	11.17	13.4	11.2	9.0	1.1	1.5	9.0	8.0	6.5	4.4	3.4	2.8	I	e	B
Anogeissus latifolia	Dhaura, Axle wood (AXL) (Bakli)	U.P.	892	10.55	16.1	13.4	10.7	1.1	1.6	9.1	8.1	6.6	4.7	3.7	3.0	I	e	A
Artocarpus hirsulus	Aini (AIH)	Chennai	600	10.45	15.0	12.5	10.0	0.7	1.1	10.4	9.2	7.5	3.3	2.6	2.1	I	-	B
Acacia nilotica	Babul (BAB)	U.P.	797	-	-	12.9	10.3	1.4	2.1	8.9	7.9	6.4	5.2	4.0	3.3	I	b	B
Acacia ferruginea	Safed khair	Maharashtra	993	12.28	23.0	19.2	15.3	1.7	2.4	13.9	12.4	10.1	9.9	7.7	6.3	-	-	-
Acrocarpus fraxinifolius	Mundani (MUN)	Chennai	690	12.59	16.1	13.4	10.8	1.2	1.8	10.5	9.4	7.7	4.6	3.6	2.9	III	c	B

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content	Modulus of Elasticity (All Grades and All Locations) x10[3]	Permissible Stress for Grade I											Preservative Characters		[3)]Refracteriness to Air Seasoning
			Kg/m[3]	N/mm[2]	N/mm[2]													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1)]Durability Class	[2)]Treat-ability Grade	
					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)	(19)
Aglaia odulis	Aglaia (AGL)	Assam	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
Anogeissus acuminota	Yon	Orissa	844	11.67	17.6	14.7	11.7	1.3	1.8	10.8	9.6	7.9	5.1	4.0	3.3	-	-	A
Atalanlia monophylla	Jungli-nimbu (JHI)	Orissa	897	10.31	16.7	13.9	11.1	1.5	2.1	11.3	10.0	8.2	6.3	4.9	4.0	-	-	-
Altingia excelsa	Jutili (JUT)	Assam	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 spp.	Amari (AMA)	Bengal	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
Bucklandia populnea (Syn Exbucklandia populnea)	Pipli (PIP)	W.Bengal	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
Cassia fistula	Amaltas (AMT)	U.P.	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
Carallia lucida	Maniawaga	Assam	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	-	-	-
Canarium strictum	Dhup	Chennai	655	11.86	13.3	11.1	8.9	0.9	1.2	8.1	7.2	5.9	2.8	2.2	1.8	III	-	C
Cassia sienea	Kasod	M.P.	820	10.50	15.4	12.8	10.9	1.0	1.4	10.8	9.6	7.9	5.5	4.3	3.5	-	-	-
Casuerina equisetifolia	Casuarina (CAS)	Orissa	769	11.44	14.6	12.2	9.8	1.3	1.8	8.2	7.3	5.9	4.0	3.1	2.5	III	e	A
Celophyllum temculosum	Poon (POO)	Maharashtra	657	9.77	13.4	11.2	9.0	0.8	1.1	8.6	7.7	6.3	2.8	2.2	1.8	II	-	B
Chloroxylon swielenia	Satin wood (CFI)	M.P.	865	11.69	18.2	15.1	12.1	1.4	2.0	10.9	9.7	8.0	6.3	4.9	4.0	III	-	A
Cullenia resayoana (Syn C. execelsa)	Karani (KAP)	Chennai	625	12.43	14.7	12.3	9.8	0.6	0.9	9.0	8.0	6.6	2.7	2.1	1.7	III	b	C

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10^3**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m^3	N/mm^2	N/mm^2													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Diploknema butyracea (Syn Bassia butyrance)	Hill mahua (HMA)	S.Andaman	780	10.64	15.3	12.8	10.2	1.0	1.5	9.9	8.8	7.2	6.6	5.2	4.2	-	-	-
Dyscxylum malebaricum	White ceda (WCE)	Chennai	745	10.92	13.2	11.0	8.8	1.0	1.4	8.0	7.1	5.8	3.1	2.4	1.9	I	-	B
Dipterocarpus grandiflorus	Gurjan (GUR)	N.Andaman	758	11.71	12.5	10.5	8.4	0.8	1.1	7.9	7.1	5.8	2.7	2.1	1.7	I	-	B
Dipterocarpus macrocarpus	Hollong (HOL)	Assam	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
Dichopsis polyantha (Syn Palaquium polyanthum)	Tali (TAL)	Assam	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
Dichopsis elliptica (Syn Palaquium ellipticum)	Pali (PAL)	Chennai	606	11.86	13.9	11.6	9.3	0.7	1.0	8.5	7.5	6.2	2.9	2.2	1.8	I	e	B
Diospyros micropylla	Ebony (EBO)	Maharashtra	776	12.15	14.2	11.9	9.5	0.9	1.3	8.3	7.3	6.0	3.3	2.6	2.1	-	-	A
Diospyros pyrrhocarpus	Ebony (EBO)	N.Andaman	843	9.93	13.5	11.2	9.0	1.0	1.4	7.9	7.0	5.7	4.0	3.1	2.5	III	-	A
Dipterocarpus bourdilloni	Gurjan (GUR)	Kerala	699	12.71	13.6	11.3	9.0	0.7	1.0	7.8	6.9	5.7	2.5	1.9	1.6	-	-	B
Eucalyptus globulus	Eucalyptus (Blue gum) (BLN)	Chennai	912	14.83	15.9	13.2	10.6	10.3	1.5	9.0	8.0	6.5	3.4	2.6	2.1	I	e	A
Eucalyptus ougenioides	Eucalyptus	Chennai	853	11.47	16.4	13.6	10.9	1.2	1.7	11.3	10.0	8.2	7.6	5.9	4.8	-	-	-
Eugenia gardnery	Jaman (JAM)	Chennai	952	11.94	14.8	12.3	9.8	1.1	1.6	9.2	8.2	6.7	5.8	4.5	3.7	III	d	-

Species: Botanical Name	Species: Trade Name	Locality from where Tested	Average Density at 12 Percent Moisture Content (Kg/m³)	Modulus of Elasticity (All Grades and All Locations) x10³ (N/mm²)	Permissible Stress for Grade I (N/mm²): Bending-Tension Along Grain, Extreme Fibre Stress: Inside Location	Bending-Tension Along Grain, Extreme Fibre Stress: Outside Location	Bending-Tension Along Grain, Extreme Fibre Stress: Wet Location	Shear all Locations: Horizontal	Shear all Locations: 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: [1)]Durability Class	Preservative Characters: [2)]Treat-ability Grade	[3)]Refracteriness to Air Seasoning
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Eugenia jambolana	Jaman (JAM)	U.P.	778	10.94	16.0	13.3	10.6	1.2	1.7	9.7	8.6	7.1	4.7	3.7	3.0			
Gluta travancorice	Gluta (GLU)	Chennai	726	12.73	13.5	11.3	9.0	0.9	1.3	9.0	8.0	6.6	4.0	3.1	2.5	I	-	A
Grewia veslita	Dhaman (DHA)	W.Bengal	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 (SUN)	Assam	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
Kingiodendron pinnatum (Syn Hardwickia pinnata)	Piney (PIN)	Chennai	617	10.62	13.2	11.0	8.8	0.4	1.3	8.2	7.3	6.0	2.9	2.2	1.8	-	-	B
Kayea floribund	Karal	Assam	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	-	-
Lagerstromia lanceolata	Benteak (BEN)	Chennai	617	10.76	12.7	10.6	8.5	0.8	1.2	8.2	7.3	5.9	3.4	2.6	2.2	I	e	B
Lagerstromia parviflora	Lendi (LEN)	U.P.	734	10.97	14.3	11.9	9.5	1.1	1.6	8.7	7.7	6.3	3.7	2.9	2.4	I	e	A
Mimusops elengi	Bakul (BKL)	Chennai	885	12.39	17.3	14.4	11.5	1.3	1.8	11.0	9.8	8.0	5.6	4.3	3.6	I	-	A
Machilus macrantha	Machilus (MAC)	W.Bengal	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
Miliuse tyomentosa (Syn Saccopapetalum tomentosum)	Hoom (HOO)	Maharashtra	745	11.06	14.8	12.3	9.9	0.9	1.3	9.7	8.6	7.0	3.5	2.7	2.2	III	-	B
Pommetia pinnata	-	Andaman	788	12.90	14.3	11.9	9.5	1.1	1.6	9.1	8.0	6.6	4.0	3.1	2.5	-	-	-

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10^3**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refractoriness to Air Seasoning**
			Kg/m^3	N/mm^2	N/mm^2													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Pterocarpus dolbergioides	Padauk (PAD)	N.Andaman	721	11.24	17.1	14.3	11.4	1.0	1.5	12.0	10.7	8.7	5.5	4.3	3.5	I	c	B
Mesua assamica	Kayea	Assam	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	-
Pterocarpus marsupium	Bijasal (BIJ)	Maharashtra	803	10.25	14.9	12.4	9.9	0.9	1.3	9.1	8.1	6.6	4.1	3.2	2.6	I	e	B
Fraxlnus macrantha	Ash (ASH)	U.P.	712	10.69	15.0	12.5	10.0	1.2	1.7	8.5	7.6	6.2	4.3	3.3	2.7	III	-	B
Fraxlnus execlsior	Ash (ASH)	Punjab	719	10.41	14.8	12.3	9.8	1.2	1.7	8.1	7.2	5.8	3.3	2.6	2.1	III	-	B
Planchonia valida (Syn P. andamanica)	Red bombwe (RBO)	Andaman	913	13.10	16.1	13.4	10.7	1.0	1.4	10.8	9.6	7.9	4.9	3.8	3.1	III	-	-
Quercus lamellosa	Oak	W.Bengal	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
Quercus griffithii	Oak	Meghalaya	974	10.06	13.1	10.9	8.8	1.1	1.6	8.0	7.1	5.8	4.6	3.6	2.9	-	-	A
Quercus incane	Oak	Punjab	1008	10.82	15.8	13.1	10.5	1.2	1.8	8.7	7.8	6.3	5.0	3.9	3.2	-	-	A
Quercus lineate	Oak	W.Bengal	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 semecarpifolia	-	Punjab	834	11.58	15.8	13.1	10.5	1.3	1.8	8.3	7.3	6.0	3.8	2.9	2.4	-	-	A
Shorea robusta [4]	Sal (SAL)	M.P.	805	12.67	16.9	14.0	11.2	0.9	1.3	10.6	9.4	7.7	4.6	3.5	2.9	I	e	A
Soymida fabrifuga	Rohini (ROH)	Chennai	1116	12.22	21.5	17.9	14.4	1.6	2.3	15.0	13.3	10.9	12.9	10.0	8.2	I	-	A

Species: Botanical Name	Species: Trade Name	Locality from where Tested	Average Density at 12 Percent Moisture Content Kg/m³	Modulus of Elasticity (All Grades and All Locations) x10³ N/mm²	Permissible Stress for Grade I (N/mm²): Bending-Tension Along Grain, Extreme Fibre Stress: Inside Location	Bending-Tension: Outside Location	Bending-Tension: Wet Location	Shear all Locations: Horizontal	Shear all Locations: 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: [1)]Durability Class	Preservative Characters: [2)]Treat-ability Grade	[3)]Refracteriness to Air Seasoning
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Shorea talura	-	Maharashtra	721	12.20	16.8	14.0	11.2	1.1	1.6	12.6	11.2	9.2	6.8	5.3	4.3	-	-	-
Plerygota alata (Syn. Sterculia alata)	Narikel (NAR)	Assam	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
Syzygium cumini	Jaman (JAM)	Assam	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
Terminalia bellirica	Bahera (BAH)	U.P.	729	10.19	13.6	11.3	9.0	1.0	1.4	8.4	.7.5	6.1	3.7	2.8	2.3	III	b	B
Terminalia chebula	Myrobalan (MYR)	-	918	12.37	17.1	14.2	11.4	1.1	1.6	1.2	10.4	8.5	6.7	5.2	4.3	II	c	A
Terminalia citrina	-	Assam	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 manii	Black-chuglam (BCH)	S.Andaman	822	12.66	16.8	14.0	11.2	1.1	1.6	10.3	9.2	7.5	5.1	4.0	3.2	II	a	B
Tectona grandis	Teak (TEA)	U.P.	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
Terminalia paniculate	Kindal (KIN)	Maharashtra	765	10.57	13.1	10.9	8.7	0.9	1.3	8.6	7.7	6.3	3.6	2.8	2.3	I	c	A
Alreminalia alata	Laurel (LAU), Sain	Chennai	906	10.54	15.1	12.5	10.0	1.1	1.6	9.4	8.4	6.8	6.2	4.8	4.0	I	b	A
Terminalia bilata	White-chuglam (WCH)	S.Andaman	690	12.38	15.5	13.0	10.4	0.9	1.2	9.8	8.7	7.1	3.6	2.8	2.3	III	e	B
Thespesia populnea	Bhendi (BHE)	Maharashtra	766	10.36	18.9	15.8	12.6	1.3	1.9	11.3	10.0	8.2	4.4	3.4	2.8	-	-	B
Xylia xylocarpa	Irul (IRU)	Maharashtra	839	11.63	16.2	13.5	10.8	1.3	1.8	10.9	9.7	7.9	7.8	6.0	4.9	I	e	A

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content** Kg/m^3	**Modulus of Elasticity (All Grades and All Locations) x10^3** N/mm^2	**Permissible Stress for Grade I** N/mm^2											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Zanthoxylum budranga	Mullilam (MUL)	W.Bengal	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
Adina oligocephala	-	Arunachal	715	11.17	15.2	12.7	10.1	1.2	1.7	10.3	9.2	7.5	4.0	3.1	2.4	-	-	-
Castanopsis indica	Chestnut	Meghalaya	688	12.54	14.8	12.3	9.9	1.0	1.4	9.8	8.7	7.1	3.4	2.7	2.2	-	-	B
Eucalyptus citriodara	Eucalyptus	Nilgiri	831	12.12	17.3	14.4	11.5	1.4	2.0	11.0	9.8	8.0	4.2	3.3	2.7	-	-	-
Eucalyptus citriodata	Eucalyptus	Ooty	725	9.35	15.4	12.9	10.3	1.0	1.4	8.6	7.6	6.3	3.0	2.4	2.0	-	-	-
Eucalytus tereticornis	Eucalyptus	Chennai	777	11.05	16.7	13.9	11.1	1.0	1.4	9.7	8.6	7.1	3.4	2.6	2.2	III	e	-
GROUP C																		
Tbizia procera	White siris	U.P.	643	9.02	13.4	11.2	8.9	1.0	1.4	8.5	7.6	6.2	4.3	3.3	2.7	I	c	B
Artocarpus lakocha	Lakooch (LAK)	U.P.	647	6.14	10.0	8.3	6.7	1.0	1.4	5.3	4.7	3.8	2.8	2.2	1.8	I	-	B
Artocarpus hetarophyllus (Syn. A. Integrifolia)	Jack, kathal (KAT)	Chennai	617	9.46	13.9	11.6	9.2	1.0	1.5	9.3	8.3	6.8	4.5	3.5	2.9	I	d	B
Aphanamixis polystachya (Syn. Amoora rehituka)	Pitraj (PIT)	West Bengal	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

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content** Kg/m^3	**Modulus of Elasticity (All Grades and All Locations) x10^3** N/mm^2	**Permissible Stress for Grade I** N/mm^2											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Adina cordifolia [4]	Haldu (HAL)	U.P.	663	8.54	13.3	11.1	8.9	1.0	1.4	8.7	7.7	6.3	4.4	3.4	2.8	III	a	B
Anthocephyalus chinensis (Syn. A. Cadamba)	Kadam (KAD)	-	485	1.88	9.7	8.1	5.4	0.7	1.0	5.9	5.3	4.3	1.9	1.5	1.2	III	a	-
Arlocarpus chaplasha	Chaplash (CHP)	Assam	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
Acacia leucophloea	Hiwar (HIW)	M.P.	737	7.85	13.4	11.2	9.0	1.0	1.5	7.5	6.7	5.4	4.5	3.5	2.8	-	-	A
Acacia melanoxylone	Black wood	Chennai	630	9.45	13.0	10.8	8.7	1.1	1.5	7.6	6.8	5.5	3.2	2.5	2.0	-	-	-
Acacia mearnsii (Syn. A. mollissima)	Black wattle	Chennai	669	6.10	10.4	8.6	6.9	0.8	1.2	6.0	5.4	4.4	2.3	1.8	1.5	-	-	-
Accer spp.	Maple (MAP)	Punjab, U.P.	551	7.35	9.9	8.2	6.5	0.9	1.3	5.5	4.9	4.0	2.1	1.7	1.4	III	-	B
Aegla marmalos (Syn. Intsia bijuga)	Bael (BEL)	U.P.	890	8.81	13.5	11.2	9.0	1.4	2.0	8.8	7.8	6.4	6.8	5.3	4.3	III	-	B
Afzelia bijuga	-	Andaman	705	9.16	13.2	11.0	8.8	1.1	1.5	7.9	7.1	5.8	4.0	3.1	2.6	-	-	-
Ailanthus grandis	Gokul (GOK)	West Bengal	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
Anogeissus pendula	Kardhai (KAH)	U.P.	929	9.75	17.0	14.2	11.4	1.3	1.8	9.8	8.7	7.1	6.5	5.1	4.2	III	-	A
Areca nut	-	Kerala	833	9.48	15.2	12.7	10.2	1.2	1.6	10.8	9.6	7.8	7.3	5.7	4.7	-	-	-

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10^3**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m^3	N/mm^2	N/mm^2													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Albizia lucida	-	Arunachal, A.P.	566	8.51	10.7	8.9	7.1	8.2	1.2	7.3	6.3	5.3	2.3	1.8	1.5	-	-	-
Azadirachta indica	Neem (NEE)	U.P.	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	-	-	-
Boswellia seriata	Salai (SAA)	Bihar	551	7.21	9.4	7.9	6.3	0.7	1.1	5.5	4.9	4.0	2.1	1.6	1.3	I	e	C
Bridelia retusa	Kassi (KAS)	Bihar	584	9.42	11.6	9.7	7.7	0.9	1.3	7.1	6.3	5.1	4.0	3.1	2.6	I	e	B
Betula lnoides	Birch (BIR)	West Bengal	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	Uriam Bishopwood (URI)	Chennai	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
Burserra serrata (Syn. Protium serratum)	Muntenga (MUR)	A.P.	756	1.17	15.5	13.3	10.5	0.9	1.3	10.1	9.0	7.4	5.3	4.1	3.4	II	c	-
Careya arbersa	Kumbi (KUM)	U.P.	889	8.37	13.1	10.9	8.8	1.0	1.5	7.7	6.8	5.6	5.3	4.1	3.4	I	e	A
Cedrus deodara	Deodar (DEO)	H.P.	557	9.48	10.2	8.7	7.2	0.7	1.0	7.8	6.9	5.7	2.7	2.1	1.7	I	c	C
Cupressus torulosa	Cypress (CYP)	U.P.	506	8.41	8.8	7.6	6.2	0.6	0.8	6.9	6.2	5.0	2.4	1.8	1.5	I	e	C
Castanopsis hystrix	Indian chestnut (ICH)	West Bengal	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
Chukrasia vclutina (Syn. C. Tabularis)	Chickrassy (CHI)	West Bengal	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

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content	Modulus of Elasticity (All Grades and All Locations) x10[3]	Permissible Stress for Grade I (N/mm²)											Preservative Characters		[3]Refracteriness to Air Seasoning
			Kg/m³	N/mm²	Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain					
Botanical Name	Trade Name				Inside Location	Outside Location	Wet Location	Horizontal	Along Grain	Inside Location	Outside Location	Wet Location	Inside Location	Outside Location	Wet Location	[1]Durability Class	[2]Treat-ability Grade	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Calophyllum wightianum	Poon (POO)	Maharashtra	689	8.68	13.5	11.2	9.0	1.0	1.4	8.7	7.8	6.4	4.0	3.1	2.5	II	-	B
Canarium strictum	White dhup	Assam	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
Chlorophora excelsa	-	Chennai	471	6.57	10.2	8.5	6.8	0.5	0.7	6.4	5.6	4.6	2.0	1.6	1.3	-	-	-
Cocosnucifera	Coconut (COC)	Kerala	761	7.34	9.2	7.7	6.1	0.7	1.1	9.5	8.4	6.9	3.9	3.0	2.5	-	-	-
Dalbergia latifolia	Rosewood (ROS)	M.P.	884	8.39	12.9	10.8	8.6	1.1	1.6	8.0	7.1	5.8	4.2	3.3	2.7	I	-	B
Dalbergia sissee	Sisso (SIS)	Punjab	799	7.14	12.8	10.7	8.5	1.3	1.8	8.2	7.3	6.0	4.2	3.3	2.7	I	e	B
Dillemia indica	Dillenia (DIL)	West Bengal	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 (DIL)	West Bengal	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
Diospyres melanoxylon	Ebony (EBO)	Maharashtra	818	7.69	10.9	9.1	7.3	0.9	1.2	7.0	6.2	5.1	3.3	2.6	2.1	II	-	A
Duabanga grandiflora (Syn. D. Sonneratioides)	Lampati (LAP)	West Bengal	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
Elesocarpus tuberculatus	Rudrak (RUD)	Chennai	466	8.74	9.7	8.1	6.4	0.7	1.0	6.3	5.6	4.6	2.0	1.5	1.3	-	-	C
Eucalyptus hybrid	Mysore gum (MGU)	Chennai	753	6.00	10.2	8.5	6.8	0.9	1.2	7.3	6.5	5.3	4.0	3.1	2.5	III	e	-

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10³**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m³	N/mm²	N/mm²													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Calitres rhomboidea (Syn. Frenela rhomboidea)	-	Chennai	607	6.48	9.2	7.7	6.1	0.7	1.0	6.9	6.1	5.0	4.0	3.1	2.6	-	-	-
Garuga pinnata	Garuga (GAU)	U.P.	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
gGmeline arborea	Gamari (GAM)	U.P.	501	7.02	9.8	8.2	6.6	0.8	1.2	5.7	5.0	4.1	4.2	3.2	2.7	I	e	B
Gardonia latifolia	Gardenia (GAI)	M.P.	705	7.13	14.1	11.7	9.4	1.2	1.7	8.4	7.4	6.1	4.6	3.6	3.0	-	-	-
Hardwickis binata	Anjan (ANJ)	M.P.	852	6.64	14.1	11.8	9.4	1.3	1.8	9.0	8.0	6.5	7.4	5.6	4.7	I	e	-
Heloptelea integrifolia	Kanju (KAN)	U.P.	592	7.46	12.0	10.0	8.0	0.9	1.3	6.7	6.0	4.9	2.8	2.2	1.8	III	b	B
Heterrophragma rexburghii	Palang (PAL)	M.P.	616	8.69	12.3	10.2	8.2	0.7	1.0	7.9	7.0	5.7	3.4	2.6	2.1	-	-	-
Juglans spp.	Walnut (WAL)	U.P.	565	9.00	9.9	8.3	6.6	0.9	1.2	5.8	5.2	4.2	2.2	1.7	1.4	III	-	B
Lagerstrosmia speciosa (Syn. L. flesregihal)	Jarul (JAAR)	N.Andaman	622	8.53	12.1	10.1	8.1	0.8	1.8	7.7	6.8	5.6	3.4	2.6	2.2	II	e	B
Lannea grandis (Syn. L.coromandelica)	Jhingan (JHI)	U.P.	557	5.63	8.5	7.1	5.7	0.6	0.9	4.9	4.4	3.6	2.2	1.7	1.4	III	e	B
Leucanena leucocephala	Subabul (SUB)	U.P.	673	6.32	11.6	9.7	7.8	1.0	1.5	7.4	6.6	5.4	3.8	3.0	2.4	-	-	
Lophopatalum wightianum	Banati (BAN)	Chennai	460	7.33	8.5	7.5	5.6	0.5	0.8	5.3	4.7	3.8	1.8	1.4	1.1	III	-	C

Species		**Locality from where Tested**	**Average Density at 12 Percent Moisture Content**	**Modulus of Elasticity (All Grades and All Locations) x10³**	**Permissible Stress for Grade I**											**Preservative Characters**		**[3]Refracteriness to Air Seasoning**
			Kg/m³	N/mm²	N/mm²													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Madhuca longifolia varlatifolia (Syn. Bassia latifolia)	Mahua (MAU)	M.P.	936	8.82	13.0	10.8	8.7	1.0	1.4	7.5	6.7	5.5	6.3	4.9	4.0	I	e	A
Mangifera indica	Mango, Aam (MAN)	Orissa	661	9.12	12.2	10.2	8.2	1.0	1.4	7.3	6.5	5.3	3.1	2.4	2.0	III	a	C
Machilus macrantha	Machilus (MAC)	Chennai	521	7.63	10.2	8.5	6.8	0.7	1.0	6.3	5.6	4.6	2.4	1.9	1.5	III	e	B
Mallotus philippinensis	Raini (RAI)	U.P.	662	7.51	10.8	9.0	7.2	1.0	1.4	6.0	5.4	4.4	2.9	2.3	1.8	III	-	B
Manglietia insignia	-	Assam	449	10.37	10.9	9.1	7.3	0.7	1.0	8.0	7.1	5.8	3.4	2.6	2.1	-	-	-
Michelia montana	Champ (CHM)	West Bengal	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
Mitragyna pervifolia (Syn. Stephagyne pervifolia)	Kaim (KAI)	U.P.	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
Michelia excelsa	Champ (CHM)	West Bengal	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
Miliusa velutnia	Domsal (DOM)	U.P.	747	7.92	11.7	9.7	7.8	1.1	1.6	7.0	6.3	5.1	3.7	2.9	2.4	III	-	-
Morus alba	Mulberry (MUL)	U.P.	743	8.20	11.8	9.8	7.9	1.0	1.4	6.6	5.8	4.8	3.8	2.9	2.4	II	-	B
Morus serrata	Mulberry (MUL)	H.P.	657	7.03	10.2	8.5	6.8	0.9	1.3	5.6	5.0	4.1	2.6	2.0	1.6	III	-	B
Morus laevigata	Bola (BOL)	Andaman	588	8.61	12.3	10.2	8.2	1.0	1.5	7.2	6.4	5.3	3.3	2.5	2.1	-	-	B

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content	Modulus of Elasticity (All Grades and All Locations) x10³	Permissible Stress for Grade I											Preservative Characters		[3]Refracteriness to Air Seasoning
			Kg/m³	N/mm²	N/mm²													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Ougeinia eejeinensis (Syn. O. delbergioides)	Sandan (SAD)	M.P.	784	8.54	13.3	11.1	8.9	1.2	1.7	8.5	7.5	6.2	5.1	3.9	3.2	I	-	B
Phoebe hainesiana	Bonsum (BOH)	Assam	566	9.50	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
Pinus roxburghii (Syn. P. longifolia)	Chir (CHR)	U.P.	525	9.82	8.5	7.3	6.0	0.6	0.9	6.0	5.3	4.4	2.0	1.5	1.3	III	b	C
Pinus wallichiana	Kail (KAL)	-	515	6.80	6.6	5.6	5.0	0.6	0.8	5.2	4.6	3.8	1.7	1.3	1.0	II	c	C
Phoebe goalperansis	Bonsum (BOH)	Assam	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
Parretiopsis jacquementiena	Rohu Parrotia	H.P.	761	5.77	12.5	10.4	8.3	1.2	1.7	6.8	6.1	5.0	4.0	3.1	2.5	III	-	B
Pinus kesia (Syn. Pinus insularis)	Khasi pine (KPI)	North East	513	7.38	8.9	7.4	5.9	0.6	0.7	5.8	5.2	4.3	1.5	1.2	1.0	III	a	B
Pistacia integerrima	Kikar singhi	J&K	881	7.32	13.1	10.9	8.7	1.2	1.7	8.0	7.1	5.8	4.3	3.4	2.8	-	-	-
Podocarpus nerrifolius	Thitmin (THT)	S.Andaman	533	9.41	12.5	10.4	8.3	6.1	0.9	8.0	7.1	5.8	2.6	2.0	1.6	II	-	-
Polyalthia fragrances	Debdaru (DEB) (Nedunar)	Maharashtra	752	9.15	11.9	9.9	7.9	0.8	1.2	6.7	6.0	4.9	3.0	2.3	1.9	III	-	B
Polyalthia coreoides		M.P.	700	9.29	13.2	11.0	8.8	1.0	1.4	7.1	6.3	5.2	3.2	2.5	2.0	-	-	-
Prunus napeulensis	Arupati	West Bengal	548	9.41	104.4	8.7	69.6	0.9	1.2	6.7	6.0	4.9	2.4	1.9	1.6	-	-	-

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content	Modulus of Elasticity (All Grades and All Locations) x10³	Permissible Stress for Grade I											Preservative Characters		[3]Refracteriness to Air Seasoning
			Kg/m³	N/mm²	N/mm²													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Pterespermum acerifolium	Hattipaila (HAT)	West Bengal	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
Qucrcus spp.	Oak	North East	657	11.65	11.4	9.5	7.6	0.8	1.2	6.7	5.9	4.8	2.0	1.6	1.3	II	c	B
Raderomachera xylocarpe (Syn. Sterosperam xylocarpum)	Vedankonnai	Chennai	696	8.52	13.2	11.0	8.8	1.1	1.5	9.0	8.0	6.6	4.3	3.3	2.7	II	a	-
Schleichera oleosa (Syn. S. trijuga)	Kusum (KUS)	Bihar	1032	12.12	15.5	13.0	10.4	1.5	2.1	10.9	9.7	7.9	6.1	4.2	3.9	II	a	A
Schima wallichii	Chilauni (CHL)	West Bengal	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
Shotea assamica	Makai (MAK)	Assam	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
Sonneralia apetale	Keora (KEO)	West Bengal	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
Stereospermum suaveolans	Padri (PAD)	U.P.	721	8.86	13.3	11.1	8.9	0.9	1.3	7.3	7.0	5.7	3.5	2.7	2.2	III	-	B
Tactona grandis	Teak (TEA)	M.P.	617	8.49	12.8	10.7	8.5	0.8	1.3	7.9	7.0	5.7	4.0	3.1	2.6	I	e	B
Terminalia arjuna	Arjun (ARJ)	Bihar	794	7.71	12.2	10.2	8.2	1.1	1.6	7.4	6.6	5.4	5.2	4.1	3.3	II	b	B
Terminalia myriocarpa	Hollock (HOC)	Assam	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

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content	Modulus of Elasticity (All Grades and All Locations) x10^3	Permissible Stress for Grade I											Preservative Characters		[3]Refracteriness to Air Seasoning
			Kg/m^3	N/mm^2	N/mm^2													
Botanical Name	Trade Name				Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1]Durability Class	[2]Treat-ability Grade	
					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)	(19)
Terminalia procera	White bombwae (WBO)	N.Andaman	626	8.99	11.8	9.8	7.9	0.9	1.3	7.2	6.4	5.3	3.0	2.3	1.9	III	b	B
Taxus buccata	Yew (YEW)	West Bengal	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	-	-	-
Tamarindus indica	Imli (IML)	Chennai	913	5.63	11.4	9.5	7.6	1.2	1.7	7.0	6.2	5.1	5.3	4.1	3.4	-	-	B
Toena ciliata	Toon (TOO)	U.P.	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
Vateria indica	Vellapine (VEL)	Chennai	535	10.95	11.5	9.6	7.6	0.7	1.1	7.5	6.7	5.5	2.3	1.8	1.4	III	e	C
Aeculas indica	Horse chestnut (HCH)	U.P.	484	7.55	8.5	7.1	5.7	0.8	1.1	4.8	4.2	3.5	1.8	1.4	1.1	-	-	B
Borassus flabelsfer	Tad (Palmyra) (TAD)	A.P.	838	8.79	10.5	8.8	7.0	0.7	1.0	10.0	8.8	7.2	4.7	3.6	2.7	-	-	-
Eucalyptus cemaldulensis	Eucalyptus	Karnataka	804	9.53	12.8	10.6	8.5	0.8	1.1	7.2	6.4	5.2	3.5	2.7	2.2	-	-	A
Eucalyptus camaldulenis	Eucalyptus	U.P.	781	7.03	12.4	10.4	8.3	1.1	1.6	7.9	7.0	5.7	3.5	2.8	2.3	-	-	A
Eucalyptus pilularia	Eucalyptus	T.N.	713	9.22	14.8	12.3	11.1	1.0	1.4	8.5	7.6	6.2	2.8	2.2	1.8	-	-	A
Eucalyptus propingus	Eucalyptus	T.N.	584	7.93	12.8	10.7	8.5	0.8	1.2	8.0	5.4	4.4	2.5	1.9	1.6	-	-	A
Eucalyptus saligna	Eucalyptus	U.P.	819	8.24	11.5	9.6	7.6	1.5	2.1	8.2	7.3	6.0	6.2	4.8	4.0	-	-	A

[1] Classification for preservation based on durability tests, etc.

Class:

I - Average life more than 120 months;

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

III - Average life less than 60 months.

[2] 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.

[3] Classifications based on seasoning behaviour of timber and refractoriness with respect to 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.

[4] Species thus marked and tested from other localities show higher strength to enable their categorization in higher group.

For Example:

i) Sal tested from West Bengal, Bihar, U.P. and Assam can be classified as Group `A' species;

ii) Haldu tested from Bihar can be classified as Group `B' species;

iii) Morus laevigate (Bole) of Assam can be classified in Group `B' species.

NOTE – Any other species (including foreign) of timber may be classified into Group A, B, or C based on their Safe Permissible Stresses and other relevant properties, corresponding to the classification table provided for given Indian timber species. The assignment of a timber species to a specific group may be determined through standardized testing and evaluation of mechanical properties, including strength, durability, and density, in accordance with the applicable test methods and criteria specified in accordance with accepted standards [6-3A(2)].

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-tension (f_b).

The characteristics of these groups are as given below:

a) *Group A* – E above 12.6 kN/mm^2 and f_b above 18.0 N/mm^2.

b) *Group B* – E above 9.8 kN/mm^2 and up to 12.6 kN/mm^2 and f_b above 12.0 N/mm^2 and up to 18.0 N/mm^2.

c) *Group C* – E above 5.6 kN/mm^2 and up to 9.8 kN/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.

4.1.2 Timber species may be identified in accordance with good practice [6-3A(3)].

4.2 The general characteristics like durability, treatability and seasoning of the species are also given in Table 1. Species of timber other than those recommended in Table 1 may be used, provided the basic strength properties are determined and found in accordance with **4.1.1**.

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

4.3 The permissible lateral strength (in double shear) of mild steel common wire nail shall be as given in Table 2 and Table 3 for different species of timber.

4.4 Moisture Content in Timber

The permissible moisture content of timber for various positions in buildings shall be as given in Table 4.

Table 2 Permissible Lateral Strengths (in Double Shear) of Nails 3.55 mm Dia (9 SWG), 80 mm Long
(*Clause* 4.3)

Sl No.	**Species of Wood**		**For Permanent Construction Strength per Nail**		**For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)**
	Botanical Name	Trade Name	Lengthening Joints $N \times 10^2$	Node Joints $N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Albies pirdrow*	Fir	8	2	12
ii)	*Acacia catecha*	Khair	20	17.5	37.0
iii)	*Acacia nilotica*	Babul	15	11	32.5
iv)	*Acrocarpus fraxinifolius*	Mundani	18	9.5	19.5
v)	*Adina cordifolia*	Haldu	23.5	10	22
vi)	*Albizia lebbeck*	Kokko	20	7	24
vii)	*Albizia odoratissima*	Kala siris	14	5	22
viii)	*Anogeissus latifolia*	Axlewood	20	10	29
ix)	*Aphanamixis polystachya*	Pithraj	19	9	19
x)	*Azadiratchta indica*	Neem	22	11.5	19
xi)	*Balanocarpus utilis*	Karung	17.5	21	32
xii)	*Bischofia javnica*	Uriam	13	6.5	18
xiii)	*Betula alnoides*	Birch	13	12	22.5
xiv)	*Boswellia serrata*	Salai	12	5	14.5
xv)	*Calophyllum spp.*	Poon	16	9	21
xvi)	*Canarium euphyllum*	White dhup	9	8	10.5
xvii)	*Castanopsis hystrix*	Indian chestnut	18	10.5	23.5
xviii)	*Cedrus deodara*	Deodar	9	4	15
xix)	*Chukrasia tabularis*	Chikrassy	24	8	27
xx)	*Cinnamomum spp.*	Cinnomon	12	9	13
xxi)	*Cullenia rosaana (Syn. Cullenia excalsa)*	Karani	11.5	5	19
xxii)	*Cupressus torulosa*	Cypress	6	5	18
xxiii)	*Dalbergia latifohia*	Rosewood	19	8.5	23
xxiv)	*Dalberia sissoo*	Sissoo	14.5	7.5	19
xxv)	*Dipterocarpus macrocarpus*	Hollong	17	7	20
xxvi)	*Dipterocarpus spp.*	Gurjan	19	9	19.5
xxvii)	*Dillenia pertagyna*	Dillenia	16.5	12	16
xxviii)	*Diospyros melanoxylon*	Ebony	26.5	10	30.5
xxix)	*Duabanga grandiflora*	Lampati	15	5	12
xxx)	*Dysoxylum binectariferum*	White Cedar	7.5	5	14.5

Sl No.	**Species of Wood**		**For Permanent Construction Strength per Nail**		**For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)**
	Botanical Name	Trade Name	Lengthening Joints $N \times 10^2$	Node Joints $N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
xxxi)	*Eucalyptus eugenioides*	Eucalyptus	17	10	30
xxxii)	*Garuga pinnata*	Garuga	11.0	7.5	21.0
xxxiii)	*Gmelina arborea*	Gaman	8	4	9.5
xxxiv)	*Grerillea robusta*	Silver oak	12.0	7.0	10.5
xxxv)	*Grewia tilifolia*	Dhaman	13	5	24
xxxvi)	*Lagerstroemia spp.*	Jarul	24.5	21.5	22.5
xxxvii)	*Holoptelea integrifolia*	Kanju	12.5	9.5	20.5
xxxviii)	*Hopea parviflora*	Hopea	31.5	13	28.5
xxxix)	*Lagerstroemia spp.*	Lendi	19	5	26
xl)	*Madhuka Logifera (Syn. Barfia Latifolia)*	Mahua	23	7.5	26
xli)	*Mangifera indica*	Mango	11	9	16
xlii)	*Maniltoa polyandra*	Ping	26	23.5	32
xliii)	*Mesua ferrea*	Mesua	26	8	41
xliv)	*Michelia spp.*	Champ	13	9	20
xlv)	*Millingtonia spp.*	Phulsopa	10.5	6	17
xlvi)	*Morus alba*	Mulberry	13	10.5	22.5
xlvii)	*Melia azedarach*	Persian lilac (bakain)	10.5	2.5	10.5
xlviii)	*Morus alba*	Mulberry	13	10.5	22.5
xlix)	*Ougeinia oojeinensis*	Sandan	17	11	18
l)	*Phoebe spp.*	Bonsum	12	6	13
li)	*Pinus roxburghii*	Chir	11	10	16
lii)	*Pinus wallichiana*	Kail	7	3	9
liii)	*Planchonia andamanica*	Red bombwe	14	13	29
liv)	*Planchonia valida (Syn. P. andamonica)*	Red bombwe	14.5	13	29.5
lv)	*Poeciloneuron indicum*	Ballagi	16	7	15.5
lvi)	*Populus deltoides*	Poplar	16	11.5	17.5
lvii)	*Protium serratum (Syn. Burserra Serrata) A.P.*	–	25.5	7.0	22.5
lviii)	*Pterocarpus marsupium*	Bijasal	15	12	27
lix)	*Pterocarpus dalbergiodes*	Pauduak	19	14	23
lx)	*Quercus spp.*	Oak (Assam)	21	10	37.5

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints $N \times 10^2$	Node Joints $N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
lxi)	*Quercus spp.*	Oak (U.P.)	11	10.5	26.5
lxii)	*Scheichera cleosa*	Kusum	23	16	39.5
lxiii)	*Schima wallachi*	Chillauni	19.5	9.5	25.5
lxiv)	*Shorea assamica*	Makai	12.5	7.5	15.0
lxv)	*Shorea robusta*	Sal (M.P.)	23	15.5	19.5
lxvi)	*Shorea robusta*	Sal (U.P.)	10	5	19
lxvii)	*Stereospenmum chelonoides*	Padriwood	16	8	19.5
lxviii)	*Syzygium spp.*	Jamum	15	12	25
lxix)	*Tectona grandis*	Teak	14	8	13
lxx)	*Terminalia alata*	Sain	16	16	29
lxxi)	*Terminalia arjuna*	Arjun	8.5	7	16.5
lxxii)	*Terminalia bellirica*	Bahera	10	10	14
lxxiii)	*Terminalia biolata*	White chuglam	18	9	21
lxxiv)	*Terminalia chebula*	Myrobalan	16.5	5.5	22.5
lxxv)	*Terminalia procera*	Badam	18	10.5	20
lxxvi)	*Terminalia manii*	Black chuglam	23	10	33
lxxvii)	*Terminalia myriocarpa*	Hollock	13	10	19.5
lxxviii)	*Toona spp.*	Toona	10	8	21
lxxix)	*Xylia xylacarpa*	Irul	23	6	33
lxxx)	*Toona ciliata*	Toon	16	9	21

NOTES

1 Nails of 3.55 mm (9 SWG) diameter are most commonly used. The above values can also be used for 4 mm (8 SWG) diameter 100 mm long nails.

2 The values in Newton (N) are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

3 Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of [6-3A(7)].

Table 3 Permissible Lateral Strengths (In Double Shear) of Nails 5.00 mm Dia (6 SWG), 125 mm and 150 mm Long
(*Clause* 4.3)

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
			N x 10^2	N x 10^2	N x 10^2
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Abies pindrow*	Fir	16.5	4.5	21
ii)	*Acacia catechu*	Khair	42	25	71.5
iii)	*Acacia nilotica*	Babul	27	13.5	53
iv)	*Alibizia procera*	Safed siris	35	18	-
v)	*Alibizia odoratissima*	Kala siris	27.5	17.5	45
vi)	*Alstonia scholaris*	Chatian	9.5	5.5	27
vii)	*Anogeissus latifolia*	Axlewood	22.5	13	46.5
viii)	*Azadirachata indica*	Neem	23.5	16	47
ix)	*Cupressus torulosa*	Cypress	20	7	27
x)	*Cullenia rosayroana*	Karani	11	9.5	30
xi)	*Dalbergia sissoo*	Sissoo	17	15	43
xii)	*Diptrocarous spp.*	Gurjan	19.5	9.5	33
xiii)	*Eucalyptus Prob. E. Tereticornis*	–	37.5	28.5	47
xiv)	*Hardwickia binata*	Anjan	32	19	59
xv)	*Hopea perviflora*	Hopea	60.5	25	61.5
xvi)	*Holoptelea integrifolia*	kanju	18	12.5	37.5
xvii)	*Mangifera indica*	Mango	22.5	15	32
xviii)	*Mesua ferrea*	Mesua	24	15.5	57.5
xix)	*Michelia champaca*	Champ	26	12.5	39
xx)	*Pterocarpus marsupium*	Bijasal	20.5	15	43
xxi)	*Pinus roxburghii*	Chir	9	6	24
xxii)	*Shorea robusta* (U.P.)	Sal	19.5	17	37
xxiii)	*Shorea robusta*	Sal	30.5	20	41
xxiv)	*Schleichera cleosa*	Kusum	15	14	55
xxv)	*Stereospimum personatum*	Padriwood	22	8	34
xxvi)	*Syzygium cumini*	Jamum	18	14.5	38.5
xxvii)	*Terminalia myriocarpa*	Hollock	27.5	9	41
xxviii)	*Tectona grandis*	Teak	28	13	30
xxix)	*Toona ciliata*	Toon	19	7	32.5

Sl No.	**Species of Wood**		**For Permanent Construction Strength per Nail**		**For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)**
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
			N x 10^2	N x 10^2	N x 10^2
(1)	(2)	(3)	(4)	(5)	(6)
xxx)	*Hopea utilis*	Karung kangoo	31	10	58
xxxi)	*Phoebe spp.*	Bonsum	20	7.5	30
xxxii)	*Pterocarpus dalbergiodes*	Padauk	27.4	13.4	37.7
xxxiii)	*Populus deltoides*	Poplar	21	15	38.5

NOTES

1 Nails of 5.00 mm diameter are most commonly used.

2 The values in Newton (N) are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

3 Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of [6-3A(7)].

Table 4 Permissible Percentage Moisture Content Values
(*Clause* 4.4)

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

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 in the country, tolerances, etc, reference may be made to good practice [6-3A(4)].

4.5 Sawn Timber

4.5.1 *Sizes*

Preferred cut sizes of timber for use in structural components shall be as given in Table 5, Table 6 and Table 7.

Table 5 Preferred Cut Sizes of Structural Timber for Roof Trusses
(Span from 3 m to 20 m)
(*Clause* 4.5.1)

Sl No.	**Thickness** mm	**Width** mm							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	20	40	50	60	80	100	-	-	-
ii)	25	40	50	60	80	100	120	140	160
iii)	30	40	50	60	80	100	120	140	160
iv)	35	-	-	60	80	100	120	140	160
v)	40	-	-	60	80	100	120	140	160
vi)	50	-	-	60	80	100	120	140	160
vii)	60	-	-	-	80	100	120	140	160
viii)	80	-	-	-	-	100	120	140	160

NOTES

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

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

Table 6 Preferred Cut Sizes of Structural Timber for
Roof Purlins, Rafters, Floor Beams, etc
(*Clause* 4.5.1)

Sl No.	**Thickness** mm	**Width** mm						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	50	80	100	120	140	-	-	-
ii)	60	80	100	120	140	160	-	-
iii)	80	-	100	120	140	160	-	-
iv)	100	-	-	-	140	160	180	200

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

Table 7 Preferred Cut Sizes of Structural Timber for Partition Framing and Covering, and for Centering
(*Clause* 4.5.1)

Sl No.	**Thickness** mm	**Width** mm								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	10	40	50	60	80	-	-	-	-	-
ii)	15	40	50	60	80	100	-	-	-	-
iii)	20	40	50	60	80	100	120	160	200	-
iv)	25	40	50	60	80	100	120	160	200	240
v)	30	40	50	60	80	100	120	160	200	240
vi)	40	40	-	60	80	100	120	160	200	240
vii)	50	-	50	-	80	100	120	160	200	240
viii)	60	-	-	60	80	100	120	160	200	240
ix)	80	-	-	-	80	100	120	160	200	240

NOTE – Preferred lengths of timber: 0.5 m, 1 m, 1.5 m, 2 m, 2.5 m and 3 m.

4.5.2 *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 : $^{+3}_{-0}$ mm

2) Above 100 mm : $^{+6}_{-3}$ mm

b) For length : $^{+10}_{-0}$ mm

4.6 Grading of Structural Timber

4.6.1 Cut sizes of structural timber shall be graded, after seasoning, into three grades based on permissible defects given in Table 8:

a) Select Grade,
b) Grade I, and
c) Grade II.

Table 8 Permissible Defects for Cut Sizes of Timber for Structural Use
(*Clauses* 4.6.1 *and* 4.6.2.2)
All dimensions in millimetres

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, Max	*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*	
	Narrow Faces and ¼ 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 ¼ of the Width Face Close to Edges of Cut Size of Timber	The Remaining Central Half of the Width of the Wide Faces	Narrow Faces and ¼ of the Width Face Close to Edges of Cut Size of Timber	Remaining Central Half of the Width of the Wide Faces
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

v) Checks and shakes:

Width of the Face of the Timber Max	*Permissible Depth Max*	*Permissible Depth Max*	*Permissible Depth Max*
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

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.

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.

4.6.2.2 *Permissible Defects*

Defects to the extent specified in Table 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.

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, in accordance with the accepted standard [6-3A(5)].

4.7 Suitability

4.7.1 *Suitability in respect of Durability and Treatability for Permanent Structures*

There are two choices as given in **4.7.1.1** and **4.7.1.2**.

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.

4.7.1.2 *Second choice*

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

4.7.2 *Choice of Species for Load-Bearing Temporary Structures or Semi-Structural Components at Construction Site*

The species shall be any one of the following:

a) Heartwood of low durability and Class ‘e’ treatability; or
b) The species whose durability and/or treatability is yet to be established, as listed in Table 1.

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.

NOTE – Synthetic adhesives are able to achieve for timber what welding has achieved for steel.

4.9 Requirements of Structural Timber

The various other requirements of structural timber for use in building shall be in accordance with the accepted standard [6-3A(5)].

5 PERMISSIBLE STRESSES

5.1 Fundamental stress values of different groups of timber are determined on small clear specimen according to good practices [6-3A(2)]. These values are then divided by the appropriate factors of safety to obtain the permissible stresses. Values of these factors of safety for different strength characteristics are as per the relevant table of the accepted standard [6-3A(5)].

5.2 The permissible stresses for Groups A, B and C for different locations applicable to Grade I structural timber shall be as given in Table 9 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 to good practice [6-3A(6)]; and
c) The loads should be continuous and permanent and not of impact type.

5.3 The permissible stresses (excepting *E*) given in Table 9 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

5.3.1 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.

Table 9 Minimum Permissible Stress Limits (in N/mm²) in Three Groups of Structural Timbers (For Grade I Material)
(*Clauses* 5.2 *and* 5.3)

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	1.5	0.91	0.70
iii)	Compression parallel to grain	Inside 1)	11.7	7.8	4.9
iv)	Compression perpendicular to grain	Inside 1)	4.0	2.5	1.1

Sl No.	Strength Character	Location of Use	Group A	Group B	Group C
(1)	(2)	(3)	(4)	(5)	(6)
v)	Modulus of elasticity (x 10^3 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.

5.4 Modification Factors for Permissible Stresses

5.4.1 *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 1 shall be multiplied by modification factor K_1 for different slopes of grain as given in Table 10.

Table 10 Modifications Factor K_1 to Allow for Change in Slope of Grain
(*Clause* 5.4.1)

Sl No.	Slope	Modification Factor K_1	
		Strength of Beams, Joists and Ties	Strength of Posts or Columns
(1)	(2)	(3)	(4)
i)	1 in 10	0.80	0.74
ii)	1 in 12	0.90	0.82
iii)	1 in 14	0.98	0.87
iv)	1 in 15 and flatter	1.00	1.00

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

5.4.2 *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.

NOTE – The strength properties of timber under load are time-dependent**.**

Table 11 Modification Factor K_2, for Change in Duration of Loading
(*Clause* 5.4.2)

Sl No.	**Duration of Loading**	**Modification Factor K_2**
(1)	(2)	(3)
i)	Continuous (Normal)	1.0
ii)	Two months	1.15
iii)	Seven days	1.25
iv)	Wind and earthquake	1.33
v)	Instantaneous or impact	2.00

5.4.2.1 The factor K_2 is applicable to modulus of elasticity when used to design timber columns, otherwise they do not apply thereto.

5.4.2.2 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.

NOTE – In any structural timber design for dead loads, snow loads and wind or earthquake loads, members may be designed on the basis of total of stresses due to dead, snow and wind loads using modification factor K_2 = 1.33 for the permissible stresses (*see* Table 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 factor K_2 = 1.00.

5.4.2.3 Modification factor K_2 shall also be applied to allowable loads for mechanical fasteners in design of joints, when the wood and not the strength of metal determines the load capacity.

6 DESIGN CONSIDERATIONS

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' of the Code, without exceeding the limits of relevant stresses specified in this Subsection.

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.

6.3 Net Section

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.

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 an imaginary plane or a series of connected planes transversely through the members.

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

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.

6.4 Loads

6.4.1 The loads shall conform to those given in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

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.

6.5 Flexural Members

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.

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.

6.5.3 Usual formula for flexural strength shall apply in design:

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

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:

$$K_3 = 0.81\left(\frac{D^2 + 89\,400}{D^2 + 55\,000}\right)$$

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 K_4 shall be obtained by using the formula:

$$K_4 = 0.8 + 0.8y\left(\frac{D^2 + 89\,400}{D^2 + 55\,000} - 1\right)$$

where,

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

c) *Solid circular cross sections* – For solid circular cross sections the form factor K_5 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 K_6 shall be taken as 1.414.

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.

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.

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.

6.5.7 *Shear*

6.5.7.1 The following formula 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:

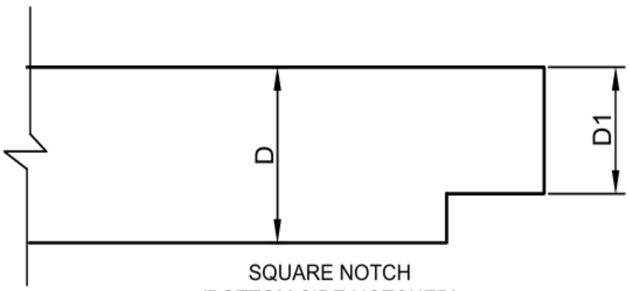
$$H = \frac{VQ}{Ib}$$

b) For rectangular beams:

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

c) For notched beams, with tension notch at supports (*see* **6.5.7.3**):

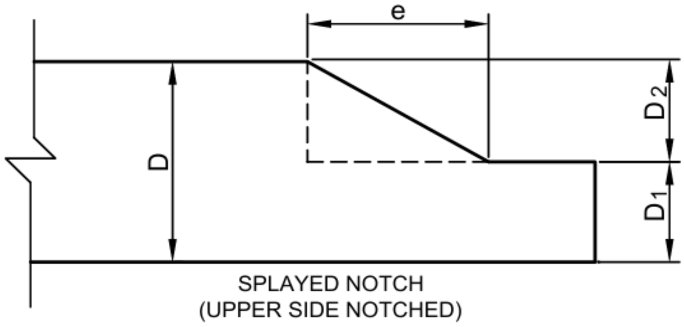
$$H = \frac{3VD}{2bD_1^2}$$



SQUARE NOTCH
(BOTTOM SIDE NOTCHED)

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

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



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

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

6.5.7.2 For concentrated loads:

$$V = \frac{10C(l-x)(x/D)^2}{9l[2+(x/D)^2]} \text{ and}$$

For uniformly distributed loads:

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

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

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

6.5.7.3 In determining the vertical reaction *V*, the following deductions in loads may be 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 nearest 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 12.

Table 12 Reduction Factor for Concentrated Loads in the Vicinity of Supports
[*Clause* 6.5.7.3 (c)]

Distance of Load from the Nearest Support	*1.5 D or Less*	*2 D*	*2.5 D*	*3 D or More*
Reduction factor	0.60	0.40	0.20	No reduction

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

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 may be 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 (*see* Fig. 1)

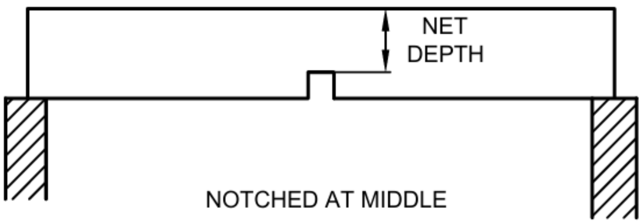


FIG. 1 NOTCHED BEAMS

6.5.8 *Bearing*

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.

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.

6.5.8.3 *Bearing stress*

6.5.8.3.1 *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 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. 2, the permissible stress may be multiplied by the modification factor K_7 given in Table 13.
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 13 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:

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

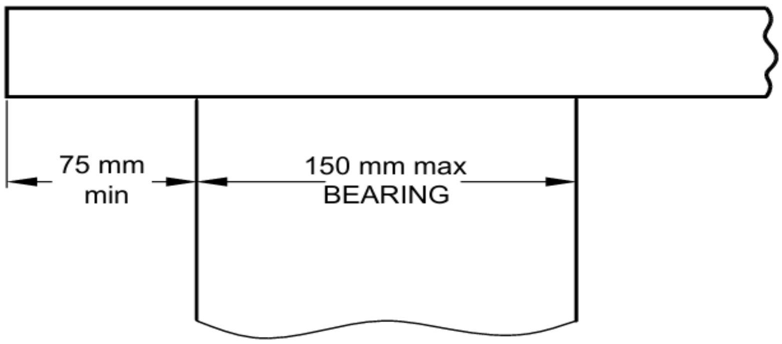


FIG 2. POSITION OF END BEARINGS

Table 13 Modification Factor K_7 for Bearing Stresses
[*Clause* 6.5.8.3.1 (c) *and* (f)]

Length of Bearing 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

6.5.9 Purlin is a structural member, essentially a beam subjected to transverse loads and rests on the top chord of roof truss. Being under bi-axial bending, vertical loads are resolved into two components, that is, perpendicular to and parallel to roof slopes (*see* Fig. 3). The effect of normal and tangential components of the vertical load is worked out separately and the in fibre stress in bending, shall be the algebraic sum of both.

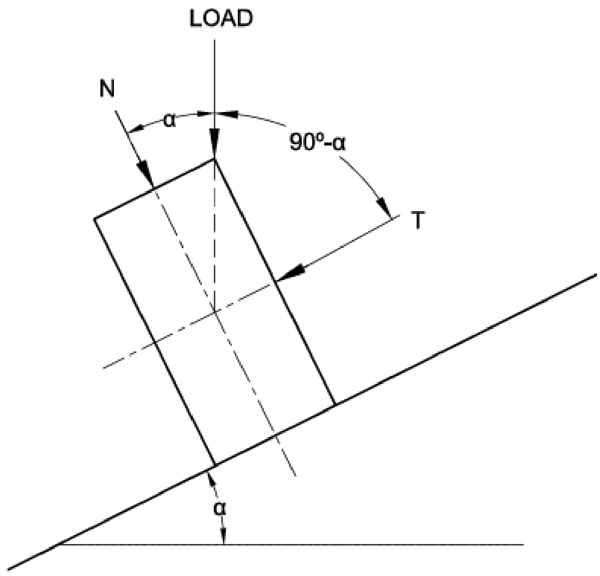


FIG. 3 PURLIN

6.5.10 *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.

6.5.10.1 Usual formula for deflection shall apply*:*

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

K-value = 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.

6.5.10.2 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.

NOTE – The tendency of flexural members to acquire larger permanent deflections under long continued loadings has to be taken care of either by considering double the dead load in calculations of deflection or by giving a factor of safety to MOE.

6.5.10.3 Self weight of beam shall be considered in design.

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.

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_8, and
c) *Long columns* – Where *S*/*d* is greater than K_8.

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

$$f_c = f_{cp}$$

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

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_8 d}\right)^4\right]$$

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

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

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

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, where side of square is equal to 0.886 times the diameter

6.6.1.6 For determining *S*/*d* ratio of a tapered column, such as for wooden poles, 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.

6.6.2 *Built-up Columns*

6.6.2.1 *Box column*

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

a) *Short columns* – Where $\dfrac{S}{\sqrt{d_1^2 + d_2^2}}$ is less than 8;

b) *Intermediate columns* – Where $\dfrac{S}{\sqrt{d_1^2 + d_2^2}}$ is between 8 and K_9; and

c) *Long columns* – Where $\dfrac{S}{\sqrt{d_1^2 + d_2^2}}$ is greater than K_9;

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

$$f_{\mathrm{c}} = q f_{\mathrm{cp}}$$

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

$$f_{\mathrm{c}} = q f_{\mathrm{cp}} \left[1 - \frac{1}{3} \left(\frac{S}{K_9 \sqrt{d_1^2 + d_2^2}} \right)^4 \right]$$

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

$$f_{\mathrm{c}} = \frac{0.329 UE}{\left(\dfrac{S}{\sqrt{d_1^2 + d_2^2}} \right)^2}$$

6.6.2.5 The following values of *U* and *q*, depending upon plank thickness (*t*) in **6.6.2.3** and **6.6.2.4**, shall be used for width of plank not greater than 5 times the plank thickness:

t mm	*U*	*q*
25	0.80	1.00
50	0.60	1.00

6.6.3 *Spaced Columns*

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.

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

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

6.6.3.3 For long spaced columns, the permissible compressive stress shall be:

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

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

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.

6.7 Tension Member (Ties)

The stress is axial tension parallel to grain of wood shall be calculated on the basis of net-section area which shall not exceed the safe permissible value in tension parallel to grain

$$f_{at} = \frac{\text{Maximum force prevailing}}{\text{Area of cross section}} \leq f_t$$

6.8 Structural Members Subject to Bending and Axial Stresses

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

$$\frac{f_{ac}}{f_c} + \frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

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

$$\frac{f_{at}}{f_t} + \frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

6.9 Timber Roof Truss

Trusses are framed structures in which separate straight members are so arranged and connected at their ends that members form triangles. The external loads cause direct stresses in the members. Essentially a plane structure which is very stiff in the plane of the members but very flexible in every other direction. For members subjected to reversal of stresses, design has to be for one stress and tested for the other applied at the panel points. Eccentricity of meeting members at joint may result in the increased stresses in design.

7 DESIGN OF COMMON STEEL WIRE NAIL JOINTS

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. Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of good practice [6-3A(7)].

7.2 Dimensions of Members

The dimension of an 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 be 20 mm for web members and 25 mm for chord members.
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.

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.

7.4 Specification and Diameter of Nails

7.4.1 The nails used for timber joints shall conform to Part 5 'Building Materials' of the Code. The nails shall be diamond pointed.

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.

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

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 **7.5.1** and **7.5.2.**

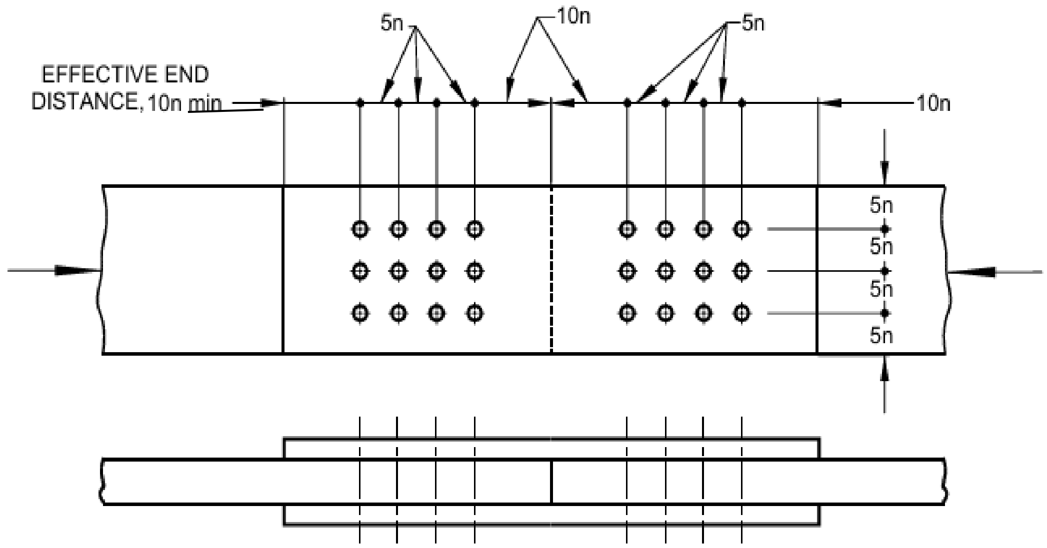
7.5.1 *Lengthening Joints*

The requirement of spacing of nails in a lengthening joint shall be as given in Table 14 (*see also* Fig. 4):

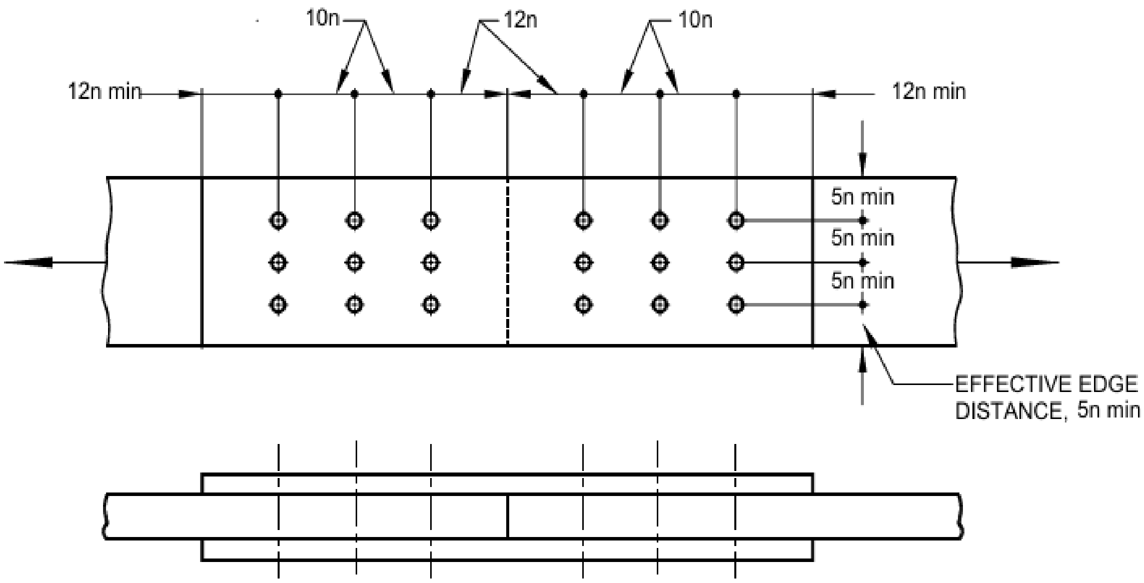
Table 14 Spacing of Nails
(*Clause* 7.5.1)

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

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

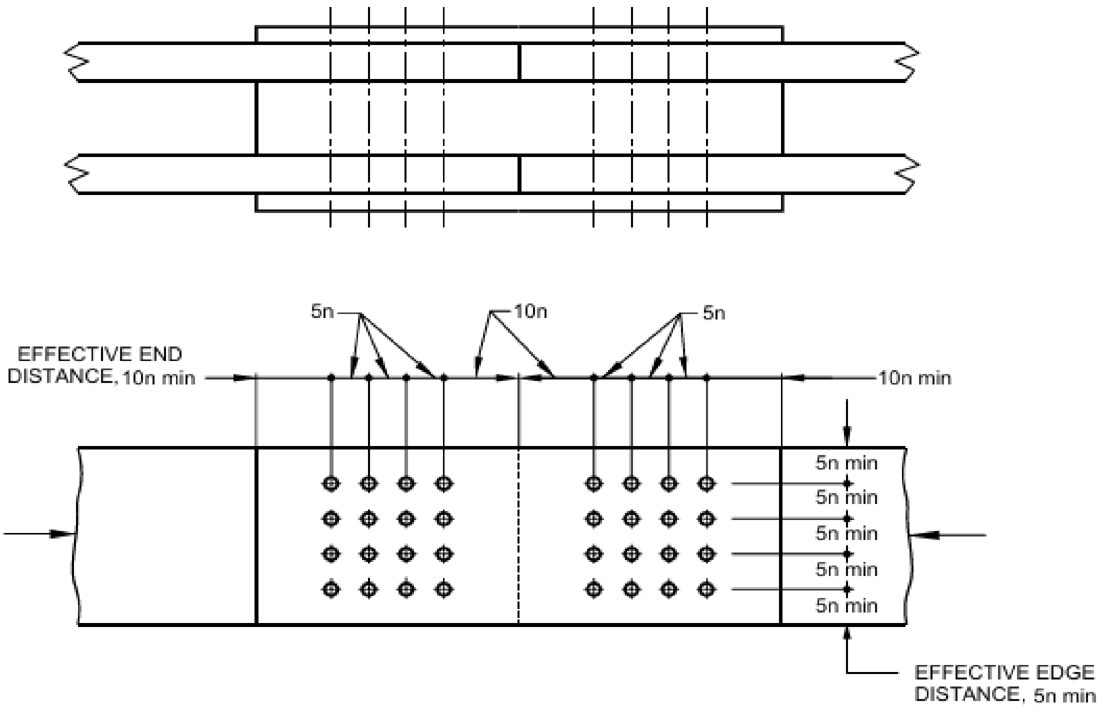


4A MONOCHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION

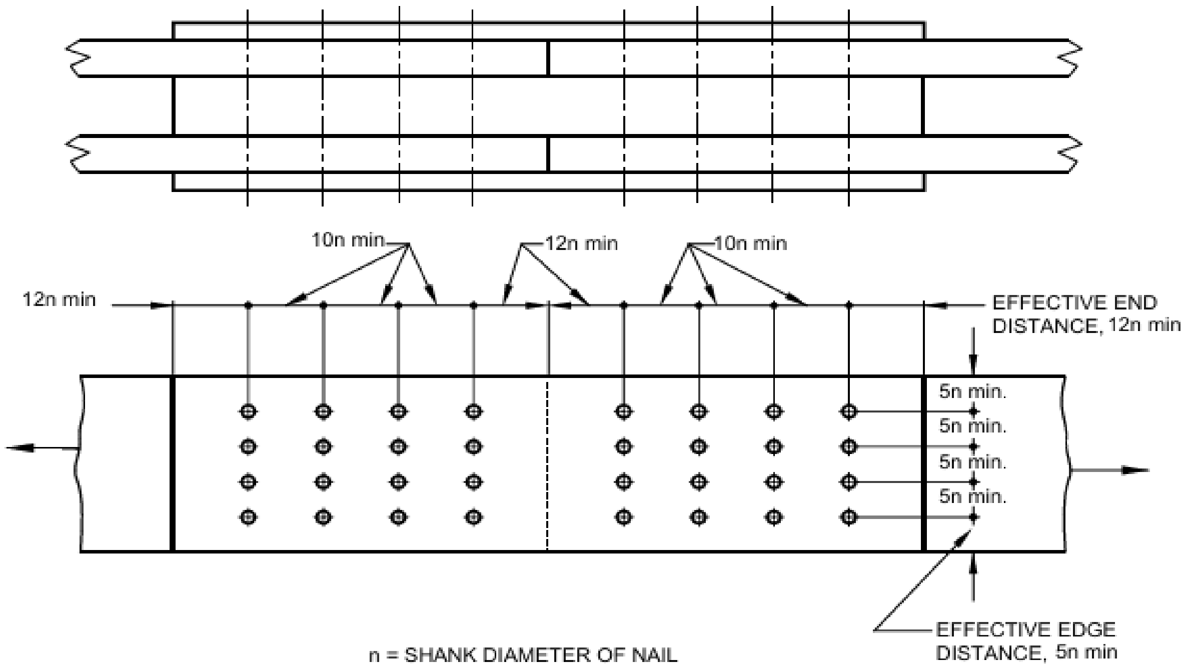


n = SHANK DIAMETER OF NAIL

4B MONOCHORD TYPE BUTT JOINT SUBJECT TO TENSION



4C SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION

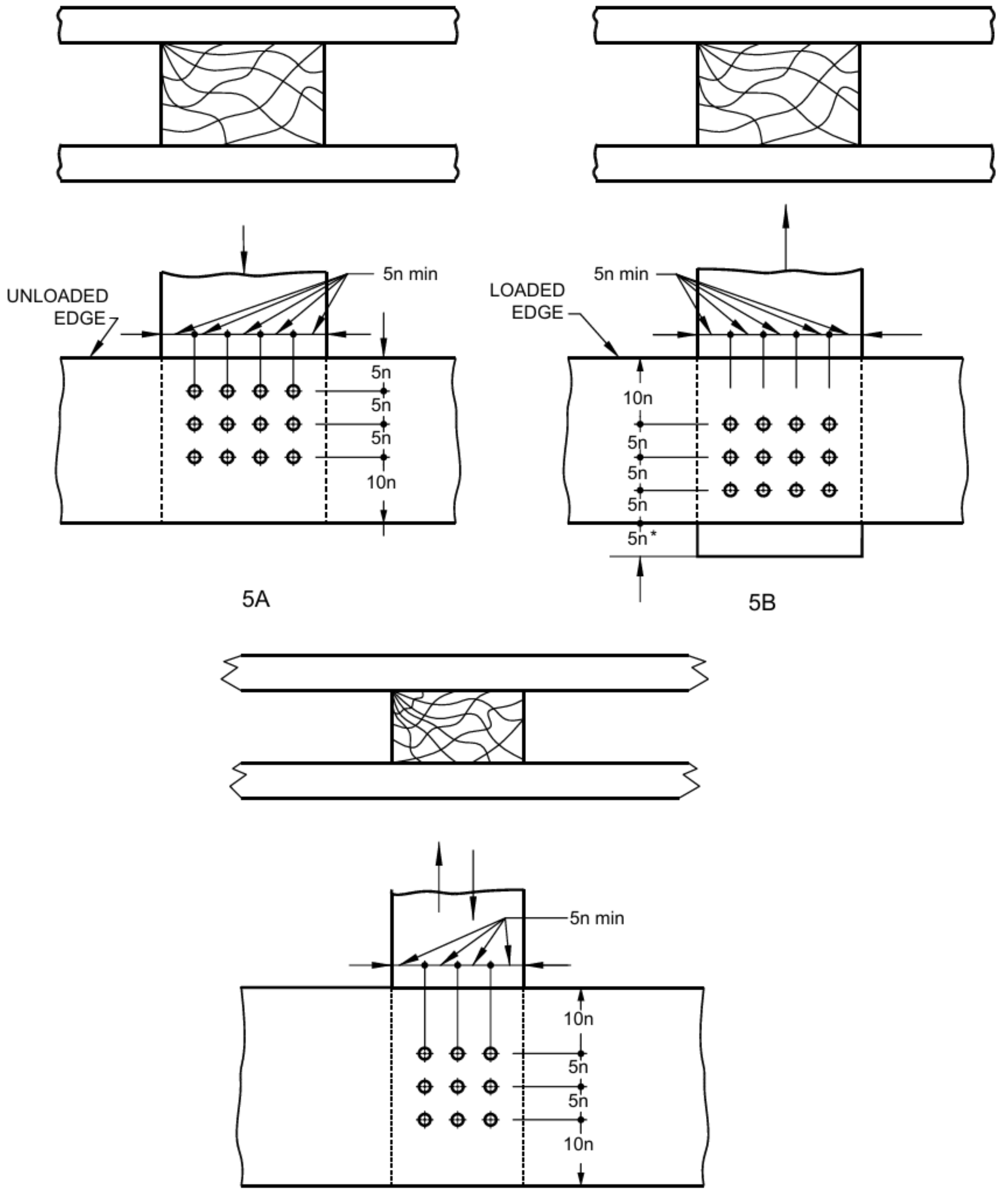


4D SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO TENSION

FIG. 4 SPACING OF NAILS IN A LENGHTHENING JOINT

7.5.2 *Node Joints*

The requirement for spacing of nails in node joints shall be as specified in Fig. 5 where the members are at right angle and as in Fig. 6 where the members are inclined to one another at angles other than 90º and subjected to either pure compression or pure tension.



n = SHANK DIAMETER OF NAIL

*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

5C

FIG. 5 SPACING OF NAILS WHERE MEMBERS ARE AT RIGHT ANGLES TO ONE ANOTHER

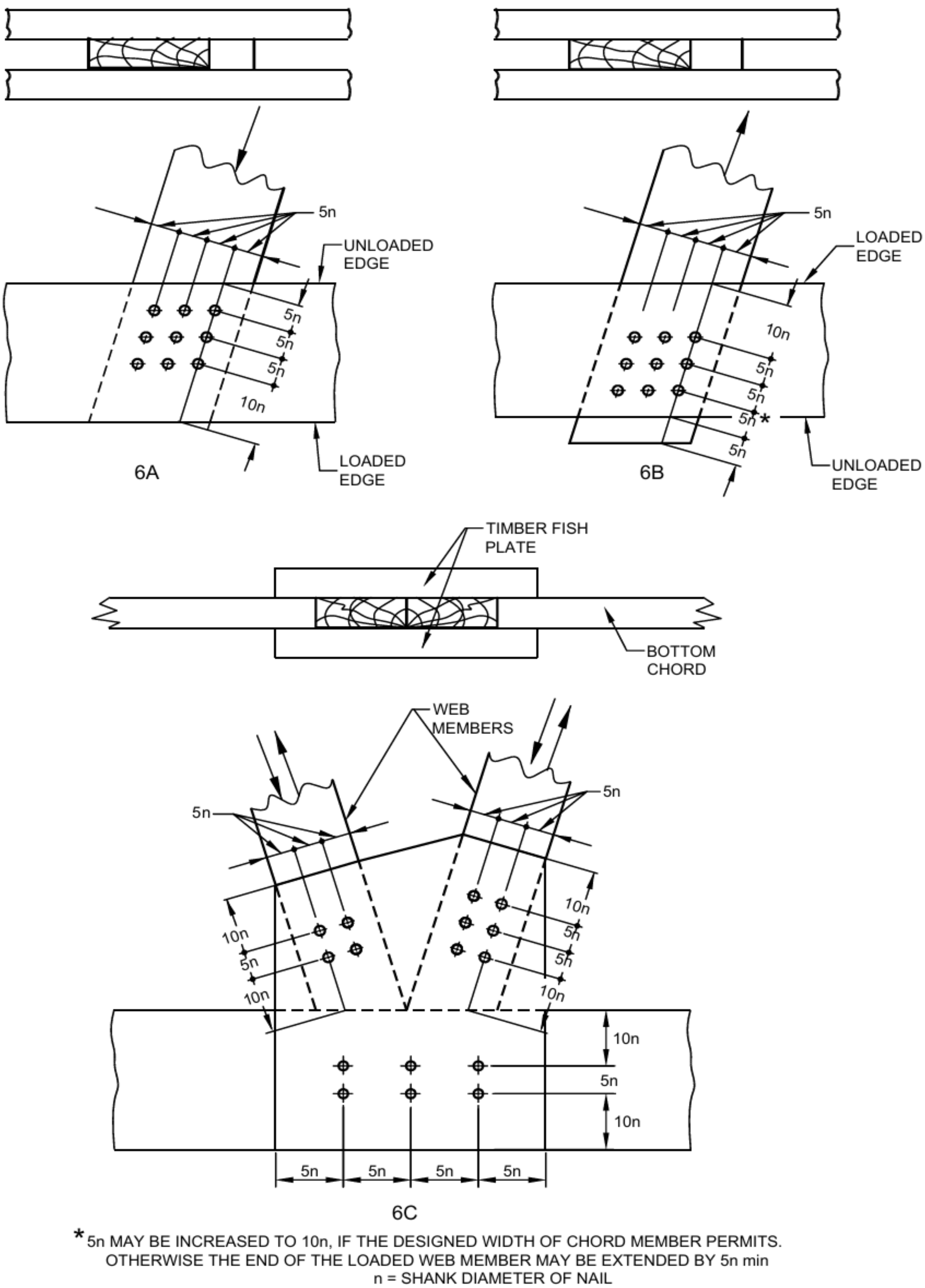


FIG. 6 SPACING OF NAILS AT NODE JOINTS WHERE MEMBERS ARE INCLINED TO ONE ANOTHER

7.6 Penetration of Nails

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.

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

7.7 Design Considerations

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.

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.

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

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

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

7.7.6 The permissible lateral strength (in double shear) of mild steel common wire for different species of timber shall be as per **4.3**.

7.8 Special Consideration in Nail-Jointed Truss Construction

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.

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.

NOTES

1 The allowable load or lateral strength values of nails shall be those as given in Table 2 and Table 3.

2 The strength data for joints given in the Subsection apply to gusset or splice or fish plates of solid wood; however, materials other than solid wood may be used for gusset when field tests are made and their strength requirements have been established.

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.

7.9 Fabrication

The fabrication of nail-jointed timber construction shall be done in accordance with good practice [6-3A(7)].

8 DESIGN OF NAIL LAMINATED TIMBER BEAMS

8.1 Method of Arrangement

8.1.1 The beam shall be 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. 7).

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

8.2 Sizes of Planks and Beams

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

8.2.2 In case of nailed laminated timber beam the maximum depth and length of planks shall be limited to 250 mm and 2 000 mm, respectively.

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 15. The protruding portion of the nail shall be cut off or clenched across the grains.

8.3 Design Considerations

8.3.1 Nail laminated beams shall be designed in accordance with **6** and provisions in the good practice [6-3A(8)].

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.

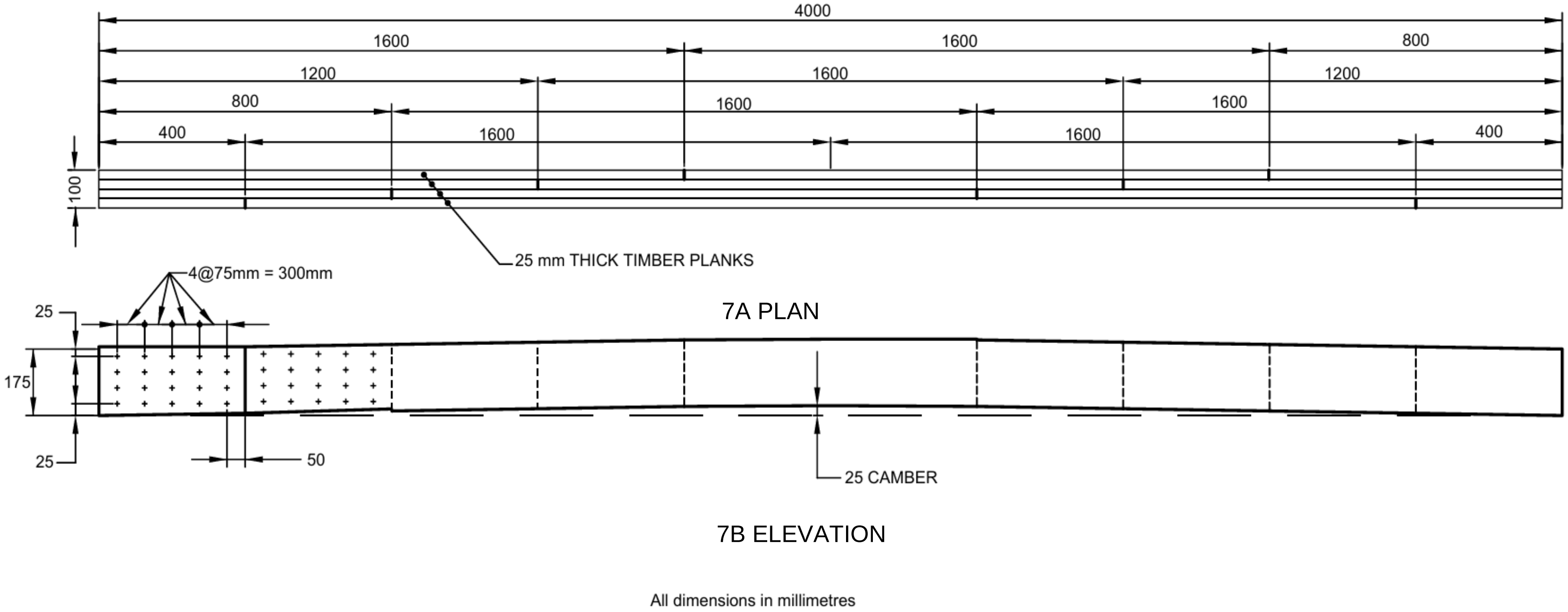


FIG. 7 PLAN AND ELEVATION OF A TYPICAL NAILED LAMINATED TIMBER BEAM

8.3.2 Permissible lateral strength of diamond pointed mild steel wire nails shall be as given in Table 2 and Table 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.

Table 15 Number and Size of Planks and Nails for Nailed Laminated Beams
(*Clause* 8.2.3)

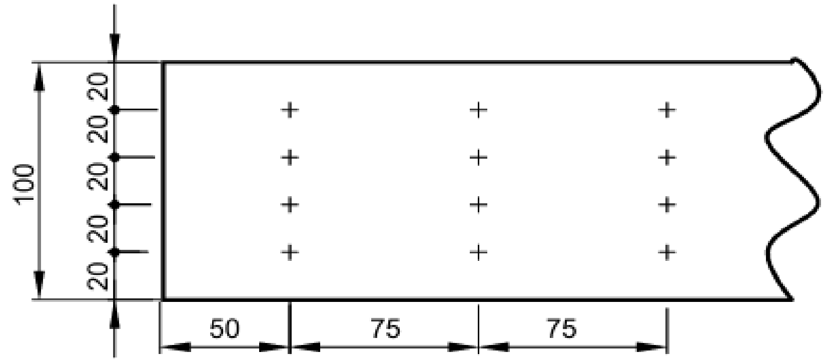
Sl No. (1)	**Overall Width of Beam** mm (2)	**No. of Planks** (3)	**Thickness of Each Plank** mm (4)	**Type and Size of Nail to be Used** mm (5)
i)	50	2	25	80 long 3.55 dia
ii)	60	3	20	- do -
iii)	70	3	(2 x 25) (1 x 20)	- do -
iv)	80	4	20	100 long 4.0 dia
v)	90	3	30	- do -
vi)	100	4	25	125 long 5.0 dia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

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

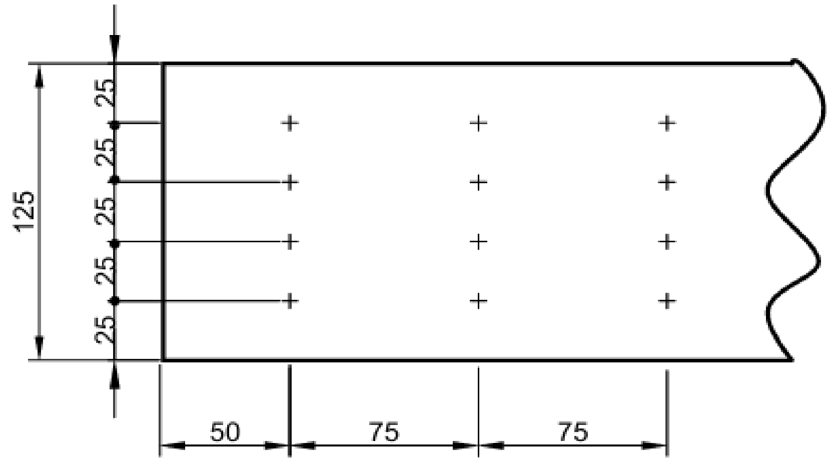
8.3.3 *Arrangement of Nails*

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 lengthening joints of the planks this distance may, however, be limited to 50 mm instead of 75 mm.

8.3.3.2 Shear shall be calculated at various points of the beam and the 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. 8.



8A FOR 3.55 mm AND 4 mm DIAMETER NAILS



8B FOR 5 mm DIAMETER NAILS

All dimensions in millimetres

FIG. 8 STANDARD LENGTHWISE SPACING IN NAILED LAMINATED BEAM

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

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

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.

8.4 Fabrication

The fabrication of nailed laminated timber beams shall be done in accordance with good practice [6-3A(8)].

9 DESIGN OF BOLTED CONSTRUCTION JOINTS

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 riveted joints in steel structures.

9.2 Design Considerations

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.

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'/d_3 ratio. The percentage of safe working compressive stress of timber on bolted joints for different t'/d_3 ratios shall be as given in Table 16.

Table 16 Percentage of Safe Working Compressive Stress of Timber for Bolted Joints in Double Shear
(*Clause* 9.2.2)

Sl No.	**t'/d_3 Ratio**	**Stress Percentage**	
		Parallel to Grain λ_1	Perpendicular to Grain λ_2
(1)	(2)	(3)	(4)
	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

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.

9.2.2.2 The factors for different bolt diameter used in calculating safe bearing stress perpendicular to grain in the joint shall be as given in Table 17.

Table 17 Bolt Diameter Factor
(*Clause* 9.2.2.2)

Sl No. (1)	**Diameter of Bolt** mm (2)	**Diameter Factor (d_f)** (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

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.

9.2.4 *Bolts and Bolting*

a) The diameter of bolt in the main member shall be so chosen to give larger slenderness (t'/d_3) 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.

9.3 Arrangement of Bolts

9.3.1 The following spacings in bolted joints shall be followed (*see* Fig. 9):

a) *Spacing of bolts in a row* – For parallel and perpendicular to grain loading = 4 d_3

b) *Spacing between rows of bolts*

1) *For perpendicular to grain loading* – 2.5 d_3 to 5 d_3 (2.5 d_3 for t'/d_3 ratio of 2 and 5 d_3 for t'/d_3 ratio of 6 or more. For ratios between 2 and 6 the spacing shall be obtained by interpolation.
2) *For parallel to grain loading* – At least (N - 4) d_3 with a minimum of 2.5 d_3. 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* – 7d_3 for softwoods in tension, 5 d_3 for hardwoods in tension and 4 d_3 for all species in compression.

d) *Edge distance*

1) For parallel to grain loading 1.5 d_3 or half the distance between rows of bolts, whichever is greater.
2) For perpendicular to grain loading, the loaded edge distance shall be at least 4 d_3.

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.

9.3.3 The bolts shall be arranged in such a manner so as to pass the centre of resistance of bolts through the intersection of the gravity axis of the members.

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.

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.

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.

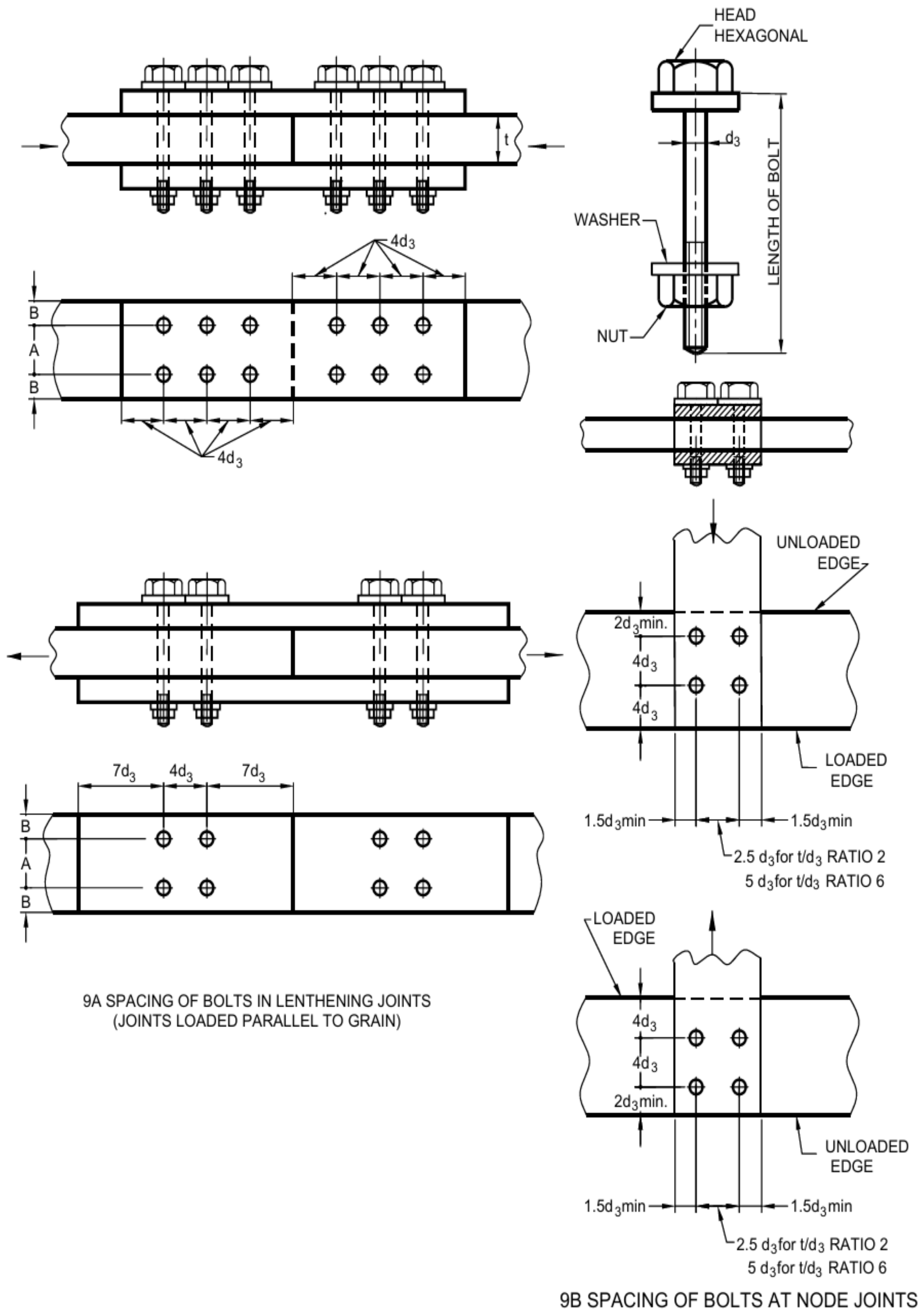


FIG. 9 TYPICAL SPACING OF BOLTS IN STRUCTURAL JOINTS

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*

$$R = f_{cn} \, a \, \lambda_2 \, d_f$$

c) *For loads at an angle to grain*

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

9.5 Fabrication

The fabrication of bolt jointed construction shall be in accordance with good practice [6-3A(9)].

To meet the specific requirements of 'all-timber construction' for structures where chemical corrosion of steel elements is a problem, and in order to erect anti-magnetic laboratories, sheds, etc, design should be made on the basis of mild steel bolt joints with the following reductions for timber bolts and bamboo pins:

Allowable safe working load per hardwood timber bolt	=	66 percent of the safe working load per mild steel bolt
Safe working load per solid bamboo pin	=	56 percent of the working load per mild steel bolt

10 DESIGN OF TIMBER CONNECTOR JOINTS

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 (*see* Fig. 10).

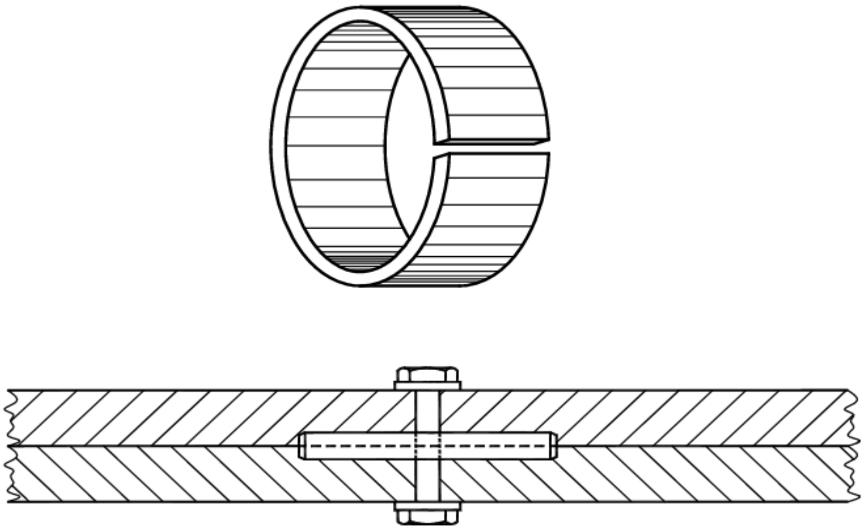


FIG. 10 SPLIT RING CONNECTOR

10.1.1 *Dimensions of Members*

Variation of thickness of central (main) and side members affect the load carrying capacity of the joint. The thickness of main member shall be at least 57 mm and that of side member 38 mm with length and width of 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.

10.1.2 *Design Considerations*

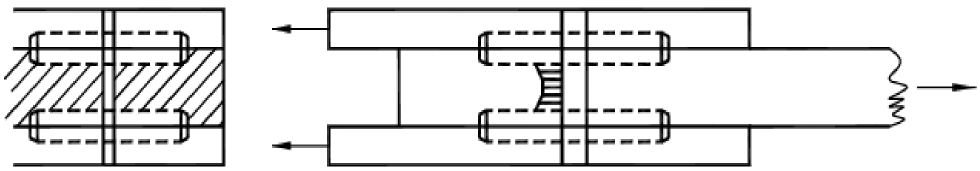
The primary stresses in a split ring connector joint under tension are illustrated in Fig. 11. The shaded areas represent the part of wood in shear, compression and tension. Related formulae for the same are given in **10.1.2.1**.

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.

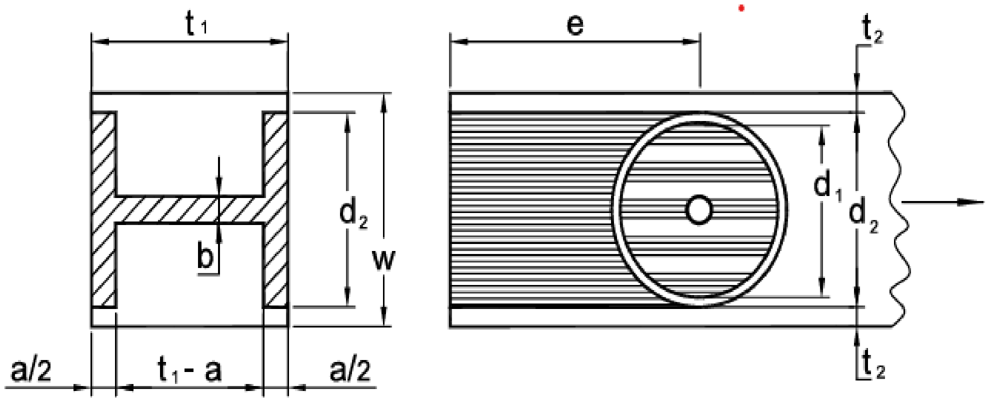
Theoretical safe loads in design shall be corroborated with sample tests done in accordance with a [6-3A(10)].

NOTE – A pilot study on determination of strength of improvised split ring connector joint in a compression test for a specific design problem conducted using *Mesua ferrea* (Mesua), yielded the data which is given below, for guidance:

No. and Diameter of Ring Used in a Joint		*No. and Size of Bolt Used in a Joint*		*Side Member*		*Central Member*		*Load Direction with respect to Grains of Wood*	*End Distance*	*Inter-mediate Distance*	*Load Per Pair of Connector*
No.	Size mm	No.	Size mm	Thickness mm	Width mm	Thickness mm	Width mm		mm	mm	kgf
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2	63	1	12x125	31	92	38	92	Parallel	63	-	3 930
2	63	1	12x125	31	92	38	92	Parallel	75	-	4 185
2	63	1	12x150	38	92	63	92	Parallel	75	-	4 010
2	63	1	12x150	38	117	63	117	Parallel	75	-	4 450
2	63	1	12x125	31	138	38	92	Perpen-dicular	69	-	2 520
2	63	1	12x125	38	138	38	92	Perpen-dicular	69	-	3 515
2	100	1	19x175	38	138	66	138	Parallel	100	-	7 075
2	100	1	19x175	38	138	66	138	Parallel	125	-	7 370
2	100	1	19x175	41	138	75	138	Parallel	100	-	7 220
2	100	1	19x175	41	138	75	138	Parallel	125	-	7 645
4	100	2	19x200	38	138	66	138	Parallel	100	150	5 655
4	100	2	19x200	41	138	75	138	Parallel	100	150	5 925
4	100	2	19x200	41	138	75	138	Parallel	125	200	7 135



11A VERTICAL STRESS DITRBUTION



11B HORIZONTAL STRESS DITRBUTION

NOTE – Symbols are exclusive to this figure.

FIG. 11 STRESS DISTRIBUTION IN A SPLIT RING CONNECTOR

10.1.2.1 Strength of joint is controlled by one or another or combination of three properties:

a) Tension area (*see* Fig. 11A):

$$t_1 w - \left[2\left(\frac{ad_2}{2} \right) + b(t_1 - a) \right]$$

b) Compression area (*see* Fig. 11B and Fig.11C):

$$2\left(\frac{ad_2}{2} \right) + b(t_1 - a)$$

c) Shear area (*see* Fig. 11D):

1) *Within core* : $2\left(\frac{\pi d_1^2}{4} \right)$

2) *Below core* : $2\left[d_2 e - \frac{1}{2}\left(\frac{\pi d_2^2}{4} \right) + 2\left(\frac{ae}{2} \right) \right]$

where

d_1	=	inside diameter of connector;
d_2	=	outside diameter of connector;
e	=	end distance from centre of connector to end of member;
a	=	depth of connector;
b	=	diameter of bolt;
t_1	=	thickness of member;
t_2	=	thickness of metal; and
w	=	width of member;

10.2 Wooden Disc-Dowel

10.2.1 It is a circular hardwood disc generally 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.

As timber always fails by shearing or crushing in front of bolts, the function of disc-dowel incorporated in the joint is to distribute the shearing stresses on a larger area of wood so as to transmit the full amount of stresses.

10.2.2 *Dimensions of Members*

The thickness of dowel may vary from 25 mm to 35 mm and 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 radial (quarter sawn) planks of seasoned material.

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 and having high shear strength. Species recommended include,

a) Babul,
b) Dhaman,
c) Irul,
d) Sissoo,
e) Rose wood,
f) Sandal,
g) Axle-wood,
h) Padauk, and
i) Yon.

NOTE – Data on the above species are as per Table 1.

10.2.4 *Design Considerations*

The forces on dowel in a lap joint and butt joint are illustrated in Fig. 12. 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 the Fig. 12 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.

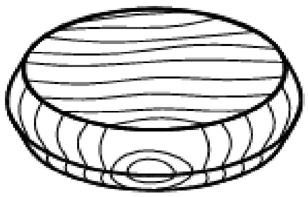
Theoretical safe loads in design shall be confirmed through sample tests.

NOTE – Some experimental studies have indicated the following safe loads, in kN, for dowels bearing parallel to the grain, which are given here for guidance only.

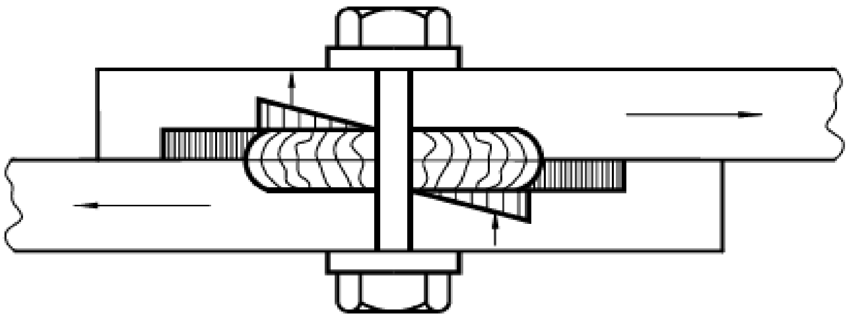
Species		Safe Loads for Dowels Bearing Parallel to the Grain, in kN Size of Dowel (mm)					
Members	Dowels	62 x25	75 x 25	87 x 25	100 x 31	112 x 37	125 x 37
Sal	Babul	6.671	9.810	13.342	17.805	22.269	27.566
Sal	Sissoo	5.346	7.554	10.251	13.342	16.922	20.895

10.2.4.1 Rigid specifications regarding use of particular planks for fabrication of wooden disc-dowels, and the specific alignment of grains to be in line with grains of members forming the joint, can be relaxed. Application of appropriate factors in design of such joints whatever be the angle of load and members etc, would eliminate risks involved by providing 60 percent more number of dowels at a joint. Thus, decrease the calculated load per dowel to 60 percent.

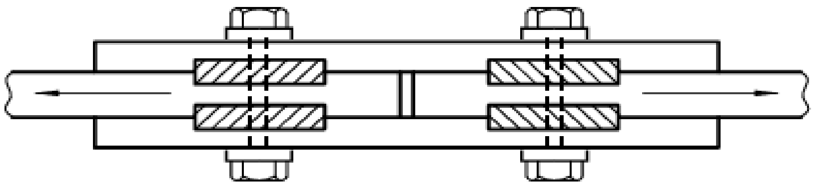
10.2.4.2 Analysis of variance for safe load in case of dowel joints made with MS bolt, timber bolt, bamboo pin as joiners showed no significant difference. Thus the concept of 'all-timber construction' hold good for chemical industries where corrosion due to acid fumes is a recurring problem.



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 to this figure.

FIG. 12 DISTRIBUTION OF FORCES IN DOWEL JOINT

11 GLUED LAMINATED CONSTRUCTION

11.1 Developments in the field of synthetic adhesive have brought gluing 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 Glulam. 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 length of the member.

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. For choice of glues, reference may be made to good practice [6-3A(11)]. However, it is important that only boiling water proof (BWP) grade adhesives shall be used for fabrication of glulam in tropical, high humid climates like India.

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 the following 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
j) Finishing, protection and storage.

11.1.3 The information with regard to block shear test results on glued timber joints is given in Table 18.

Table 18 Block Shear Test Results on Glued Timber Joints
(*Clause* 11.1.3)

Sl No.	Timber Species	Ultimate Shear Stress (Inside location) N/mm^2		
		Solid Timber Along The Grain (Un-Jointed)	With Urea Formaldehyde	With Phenol Formaldehyde
(1)	(2)	(3)	(4)	(5)
i)	*Abies pindrow* (Fir)	5.984	7.652	9.614
ii)	*Acacia catechu* (Khair)	15.107	7.456	-
iii)	*Acacia milotica* (Babul)	14.126	5.199	3.237
iv)	*Albizia odoratissima* (Karasiris)	15.009	14.126	5.984
v)	*Azadirachta indica* (Neem)	12.557	7.259	8.240
vi)	*Casteanopsis hystrix* (Chestnut)	8.044	1.668	-
vii)	*Cedrus deodar* (Deodar)	6.867	4.218	3.237
viii)	*Dalbergia sissoo* (Sissoo)	10.595	15.107	9.320
ix)	*Eucalyptus eugenioides* (Eucalyptus)	12.164	10.987	5.101
x)	*Grewia tiliefolia* (Dhawan)	8.927	10.889	6.475
xi)	*Hopea utilis* (Karunkangoo)	14.813	9.320	-
xii)	*Hopea glabra & H. parviflora* (Hopea)	15.009	13.832	0.491
xiii)	*Mangifera Indica* (Mango)	9.418	9.418	3.826
xiv)	*Madhuca longifolia* (Mahua)	9.810	0.883	7.456
xv)	*Mesua ferrea* (Mesua)	12.164	1.079	2.256
xvi)	*Morus alba* (Mulberry)	9.810	13.734	8.142
xvii)	*Pinus wallichiana* (Kail)	5.494	6.377	7.259
xviii)	*Pinus roxburghii* (Chir)	6.082	6.769	7.750
xix)	*Poecilone indicum* (Ballagi)	14.911	5.297	5.984
xx)	*Pterocarpus mersupium* (Bijasal)	9.221	5.003	6.671
xxi)	*Quercus spp.* (Oak)	8.142	10.791	5.396
xxii)	*Ougeinia oojeinensis* (Sanetan)	13.440	5.396	9.516
xxiii)	*Shorea robusta* (Sal) M.P	9.123	5.003	-

Sl No.	**Timber Species**	**Ultimate Shear Stress (Inside location)** N/mm^2		
		Solid Timber Along The Grain (Un-Jointed)	With Urea Formaldehyde	With Phenol Formaldehyde
(1)	(2)	(3)	(4)	(5)
xxiv)	*Shorea robusta* (Sal) UP	12.361	5.396	1.472
xxv)	*Sterospermum chelonoides* (Padriwood)	11.674	9.221	8.829
xxvi)	*Syzygium cuzainii* (Jaman)	10.791	9.418	10.301
xxvii)	*Terminalia alata* (Sain)	9.320	13.538	8.142
xxviii)	*Tectona grandis* (Teak)	10.987	5.984	6.377
xxix)	*Terminalia myriocarpa* (Hollock)	8.339	9.221	9.810
xxx)	*Toona ciliata* (Toon)	6.867	4.905	6.180

NOTE – The information given in the above table is based on the block shear test results on glued timber joints conducted on the basis of BS 4169:1970 'Specification for manufacture of glued-laminated timber structural members' (since revised and subsequently superseded by BS EN 392:1995, BS EN 391:1995, BS EN 386:1995), and the failures observed with regard to glue line and the wood. Ultimate shear stresses for 29 species were studied keeping design glue shear strength at least one-third of ultimate. Glue mixing, spreading, pressing and curing was done as per the instructions of adhesive manufacturers under improvised techniques locally developed. Sustainable period before delamination of glue bond (urea formaldehyde) in weathering tests was recorded for over a year. Limited number of species survived with most of them failed within a period of six months.

11.2 Design of Glued Laminated Beams

11.2.1 *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 (*see* Fig. 13). 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.

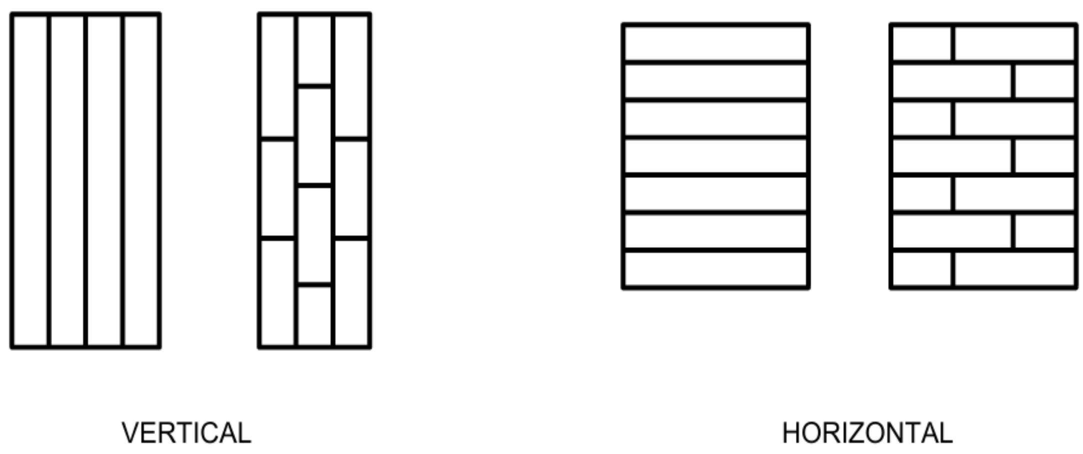


FIG. 13 POSSIBLE ORIENTATION OF PLANKS IN GLULAM

11.2.2 *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. Glulam allows the engineers to mix grades within a beam. Obviously, the lower tensile portion should be of high grade material. However, it is possible to incorporate a considerable volume of lower grade material near the neutral axis taking care of the horizontal shear stress. Similarly, species can also be mixed depending upon the modulus of elasticity.

Straight beams that will be simply supported should be cambered during fabrication to allow for deflection due to dead loads over a period of time. The usual camber is $\frac{span}{400}$, unless otherwise specified.

11.2.2.1 *Design outline for horizontally laminated beams*

A design outline for horizontal laminated beams, specifying data required and a possible solution is given below.

Data required:

a) Span (*L*), loads including self weight of beam (*W*), species of timber, thickness of lamination proposed; and
b) Mechanical properties of timber species (permissible extreme fibre stress in bending-tension, permissible compressive stress perpendicular to grain, modulus of elasticity, permissible shear stress parallel to grain).

The permissible shear stress at the glue line is at least the same as the permissible shear stress parallel to grain of the species in design, unless otherwise tested.

Solution:

a) Let, b = width of beam, and d = depth of beam, for lateral stability, $b : d = 1 : 4$ (*say*).
b) Determine bending moment on the basis of span, loading and support conditions (say, $WL/8$ for beams with both ends fixed).
c) Also, Bending moment (M) = Bending stress (f_b) × Section modulus (Z).

Therefore, $$M = f_b \times \frac{bd^2}{6} = \frac{WL}{8}$$

or $bd^2 = \frac{WL}{8} \times \frac{6}{f_b}$

d) From bd^2 obtained at (c) and b:d assumed at (a), arrive at appropriate values of b and d.
e) Check for deflection of beam. Since dead load is for long term, double this for deflection check, that is,

W = (2 × *Dead load*) + *Imposed load*

Deflection is to be limited to the specified requirement, say 0.003 of span. Substituting values of b and d from (d) and I (= $bd^3/12$) in the formula for deflection, perform check against the limit for deflection.
f) Decide the number and thickness of laminations for the required depth of section.

11.2.3 *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 gluing. The moisture content of individual laminations in a structural member shall not differ by more than 3 percent at the time of gluing. Glue shall be of type suitable for the intended service of a structural member.

11.2.4 *Fabrication/Manufacture*

In order to assure a well-bonded and well-finished member of true shape and size, all equipment, 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.

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

11.2.5 *Testing*
Quality control, inspection and testing during production is essential to structural glulam. Special attention needs to be given to members exposed to weather.

For examining the quality of glue and its relative strength *vis-à-vis* species of timber in glued laminated construction, it is necessary to conduct block shear and other related tests in accordance with accepted standard [6-3A(11)]. Structural loading tests on prototype sizes provide information on the strength properties, stiffness or rigidity against deflection of a beam. Information on different strength functions as obtained from such indigenous tests carried out on laminated timber beams are given in Table 19, for guidance in design.

Table 19 Laminated Timber Beams – Structural Bending Test Under three Point Loading
(*Clause* 11.2.5)

Species – *Pinus wallichiana* (Kail),
Effective span – 2.3 m, Cross section: 100 × 240 mm, and
Adhesive – Urea formaldehyde

Sl No.	**Strength Functions**	**Nail Laminated Vertical Laminates with Four Full Size Planks Using 8 SWG, 100 mm Long Nails**	**Glue Laminated**		**Solid (Control) Specimen**
			Vertical Laminates Four Planks, Each 25 mm Thick	Horizontal Laminates Eight Planks, Each 30 mm Thick	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Modulus of rupture, N/mm^2	27.439	31.363	21.568	30.509
ii)	Modulus of elasticity (x 10^3 N/mm^2)	8.167	8.903	8.210	7.554
iii)	Fibre stress at limit of proportionality, N/mm^2	18.136	14.166	13.259	18.276
iv)	Maximum horizontal shear stress, N/mm^2	1.723	1.967	1.319	1.906

12 LAMINATED VENEER LUMBER

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 600 to 750 kg/m^3 which is manufactured in accordance with accepted standard [6-3A(12)].

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 3 mm in the width and thickness and 12 mm in the length.

12.1.2 *Permissible Defects*

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

b) Slope of grain : Not exceeding 1 in 10 in the face layers.

c) Tight knot : Three numbers up to 25 mm diameter in 1 m^2 provided they are spaced 300 mm or more apart.

d) Warp : Not exceeding 1.5 mm per metre length.

12.1.3 *Strength Requirements*

The strength requirements for laminated veneer lumber shall be as per Table 20.

Table 20 Requirements of Laminated Veneer Lumber
(*Clause* 12.1.3)

Sl No. (1)	**Properties** (2)	**Requirement** (3)
i)	Modulus of rupture, N/mm^2*, Min*	50
ii)	Modulus of elasticity, N/mm^2, *Min*	7 500
iii)	Compressive strength parallel to grain, N/mm^2, *Min*	35
iv)	Horizontal shear :	
	a) Parallel to laminae, N/mm^2, *Min*	6
	b) Perpendicular to laminae, N/mm^2, *Min*	8
v)	Tensile strength parallel to grain, N/mm^2, *Min*	55
vi)	Screw holding power :	

Sl No. (1)	Properties (2)	Requirement (3)
	a) Edge (N), *Min*	2 300
	b) Face (N), *Min*	2 700
vii)	Thickness swelling in 2 h water soaking (percent), *Max*	3

13 GLUED FINGER JOINTS

13.1 Finger joints are glued joints connecting timber members end-to-end (*see* Fig. 14). 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, gluing the interfaces and then mating 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. To improve the long-term durability and performance of glued finger joints, the timber used should be well-seasoned to maintain dimensional stability. Additional protective treatments may be required for finger-jointed timber used in outdoor or high-moisture environments to prevent decay and degradation of the adhesive bonds.

13.1.1 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.

13.1.1.1 The fingers 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. The choice of adhesive should consider the wood species being used, as different timber species may exhibit varying adhesive compatibility. For example, denser species may require stronger bonding adhesives, while lower-density woods may work well with more flexible adhesives. Testing of specific adhesives with the wood species used should be recommended to ensure optimal joint strength and performance.

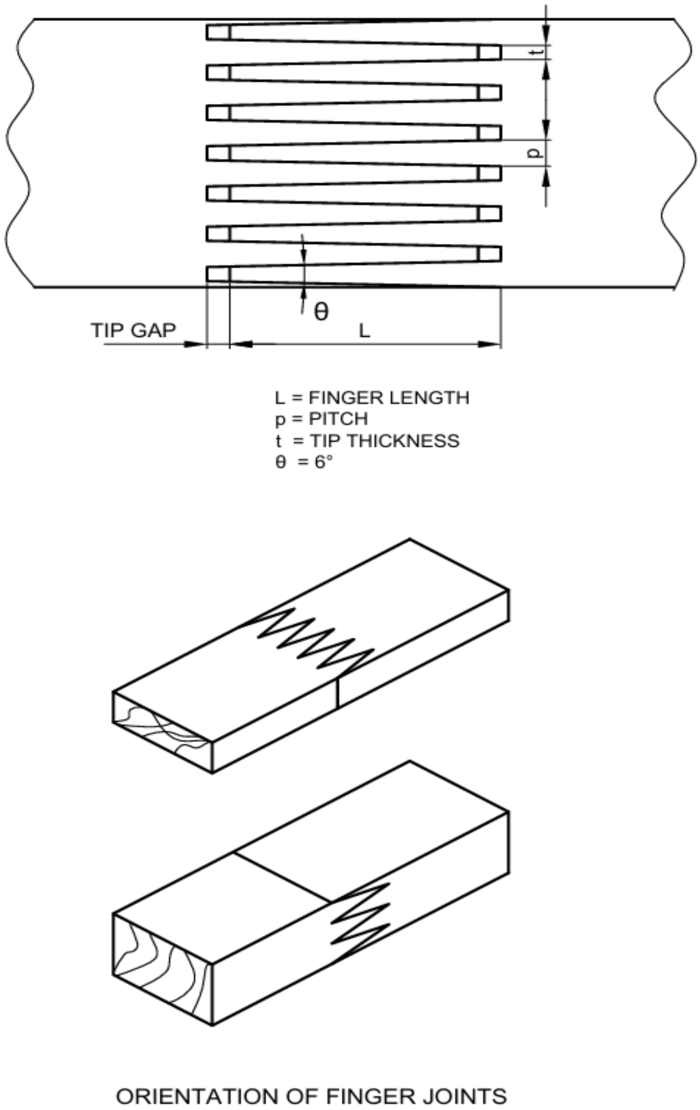


FIG. 14 TYPICAL FINGER JOINT GEOMETRY

13.1.1.2 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 and assessed in accordance with accepted standard [6-3A(11)]. The environmental impact of adhesives used in finger-jointed construction should also be considered. Where possible, the use of low-VOC (volatile organic compounds) or environmentally friendly adhesives should be promoted, particularly in indoor applications, to reduce emissions and promote healthier indoor air quality. (*see* also Part 11 ‘Approach to Sustainability’ of the Code)

13.1.2 *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
h) Planing of finger-jointed planks for smooth surface

For higher precision and productivity, modern manufacturing facilities could implement CNC (computer numerical control) machines for cutting finger joints. Automation helps achieve consistent profile geometry, improves the quality of adhesive application, and reduces the margin for human error during production.

13.1.3 *Strength*

Strength of finger joints depends upon the geometry of the profile for structural purpose; this is generally 50 mm long, 12 mm pitch. Research into alternative finger joint profiles or adhesive types that offer higher bonding strength without increasing production costs should be encouraged.

13.1.3.1 The strength properties of glued finger joints are given in Table 21 for information and guidance in design.

13.1.3.2 Tip thickness shall be as small as practically possible.

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 which should be manufactured in accordance with accepted standards [6-3A(13)] are given in **14.1** to **14.3**.

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.

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) (*see* Fig. 15 and Fig. 16) stressed skin panels (*see* Fig. 17) used for flooring and walling and pre-fabricated houses, cabins, etc. Gluing can be carried out by nail gluing 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 spans. 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.

Table 21 Strength Characteristics of Glued Finger Joints
(*Clause* 13.1.3.1)

Timber species – *Pinus wallichiana* (Kail)
(Averaged test results)

Sl No.	**Character → Treatment ↓**	**Compressive Parallel to Grain Tests**			**Tension Parallel to Grain Tests**			**Static Bending Tests**											
								Central Point Loading						Two Point Loading					
								Edge-wise			Flat-wise			Edge-wise			Flat-wise		
		Maximum Compressive Stress (N/mm^2)	Fibre Stress at EL (N/mm^2)	MOE (×10^3 N/mm^2)	Maximum Tensile Stress (N/mm^2)	Tensile Stress at EL (N/mm^2)	MOE (×10^3 N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE (×10^3 N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE (×10^3 N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE (×10^3 N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE (x10^3 N/mm^2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	UL_1	31.196	16.971	10.202	30.019	23.446	10.202	20.993	29.136	6.769	39.142	46.401	8.142	25.114	28.743	8.044	32.471	38.553	9.516
ii)	UL_2	37.474	17.462	11.282	30.607	23.642	10.301	20.209	31.686	6.671	35.120	46.205	7.161	23.446	42.085	7.652	41.202	51.306	9.712
iii)	UL_3	35.905	19.914	10.595	32.667	23.838	10.006	22.171	35.022	6.867	38.750	47.480	8.437	25.898	29.234	7.848	29.626	38.357	8.633
iv)	PL_1	28.743	21.484	9.908	20.895	17.560	10.497	20.699	23.446	8.142	22.955	27.076	9.123	18.443	21.876	7.848	25.506	27.174	8.927
v)	PL_2	28.743	19.424	10.006	18.149	17.069	9.614	16.285	18.639	5.984	24.133	26.095	8.731	16.579	17.854	7.259	26.389	28.547	8.535
vi)	PL_3	27.860	20.111	9.908	24.721	19.326	10.497	15.009	17.069	7.652	21.680	26.193	8.829	10.301	11.183	6.867	26.487	30.313	11.183
vii)	C	35.512	27.959	10.301	31.490	23.152	10.104	25.506	45.518	7.063	36.788	57.192	7.063	31.883	44.537	7.946	38.161	52.582	9.221

MOE – Modulus of elasticity (values rounded off for decimals)
MOR – Modulus of rupture
EL – Elastic limit
U – Urea formaldehyde with liquid hardener
P – Cold setting phenolic glue with hardener
L_1 – Finger length 38 mm
L_2 – Finger length 50 mm
L_3 – Finger length 62 mm
C – Control (unjointed specimen)

NOTE – The information given in the above table is based on the tests conducted on glued finger joints of varying lengths/pitch with two types of adhesives.

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 earthquake 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 mm to 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 to 12 mm thick structural plywood can be very well used as nailed or bolted gussets in fixing members of trusses or lattice girders or trussed rafters.

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

15 TRUSSED RAFTER

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 are required to be supported only at their ends so that there is no need to provide load bearing internal walls, purlins, etc. In comparison with traditional methods of construction they use less timber and considerably reduce on-site labour, and mass production of reliable units can be carried out under workshop controls.

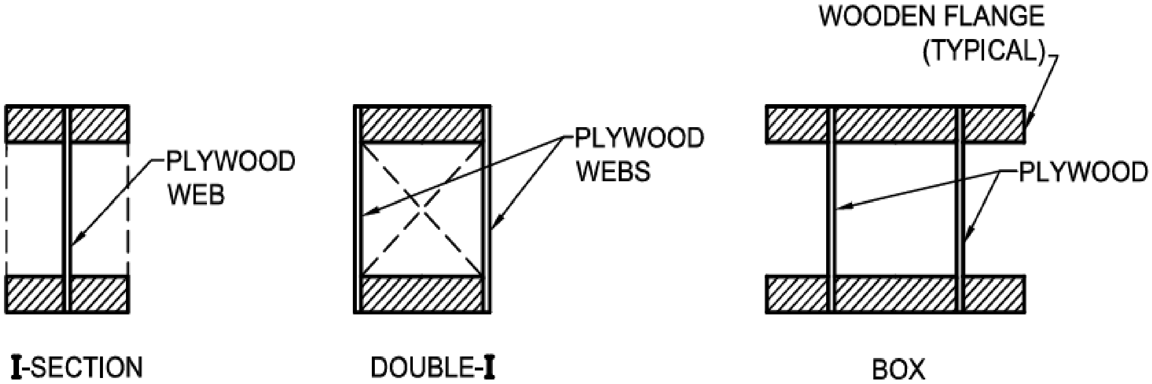


FIG. 15 TYPICAL CROSS SECTION OF WEB BEAMS

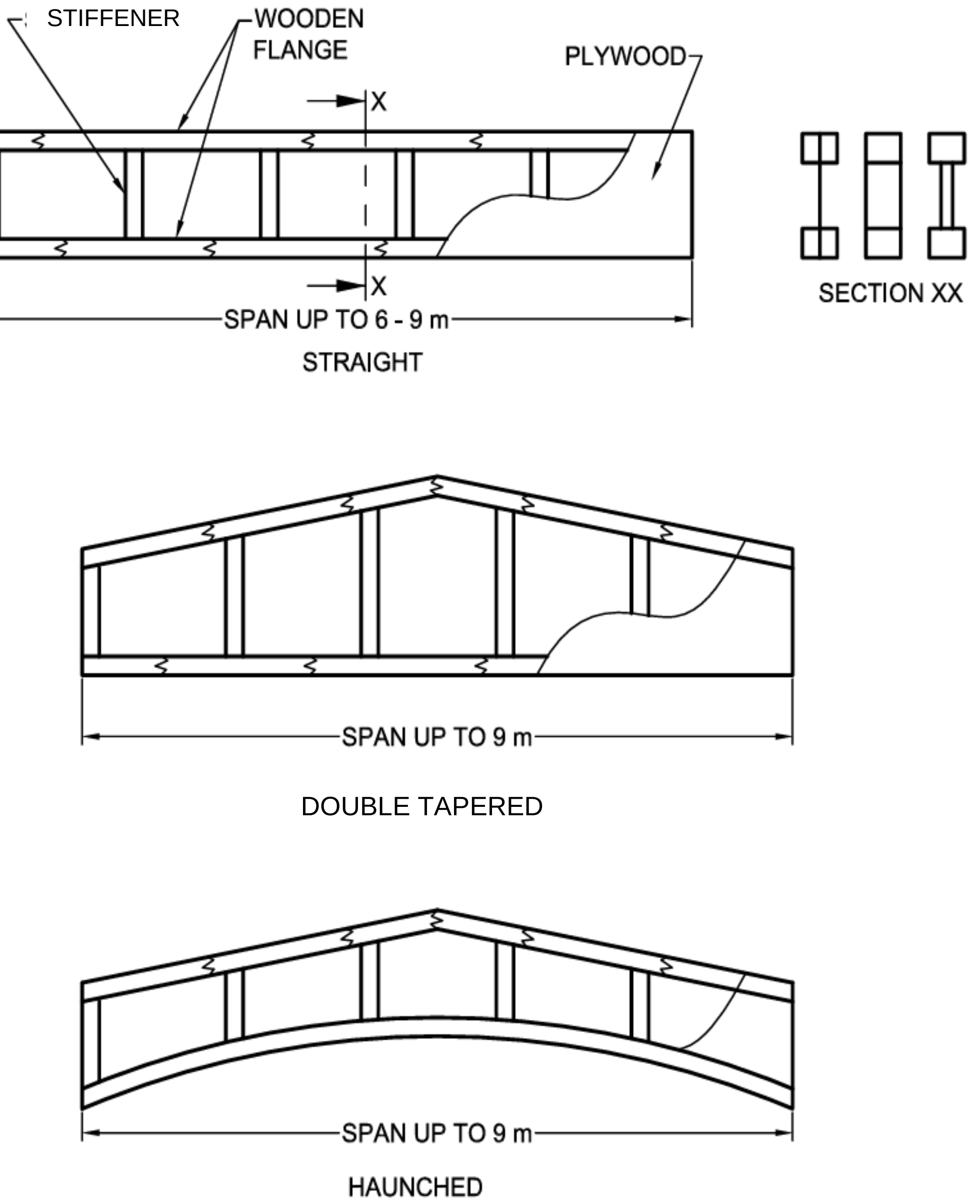


FIG. 16 WEB BEAM CONFIGURATIONS

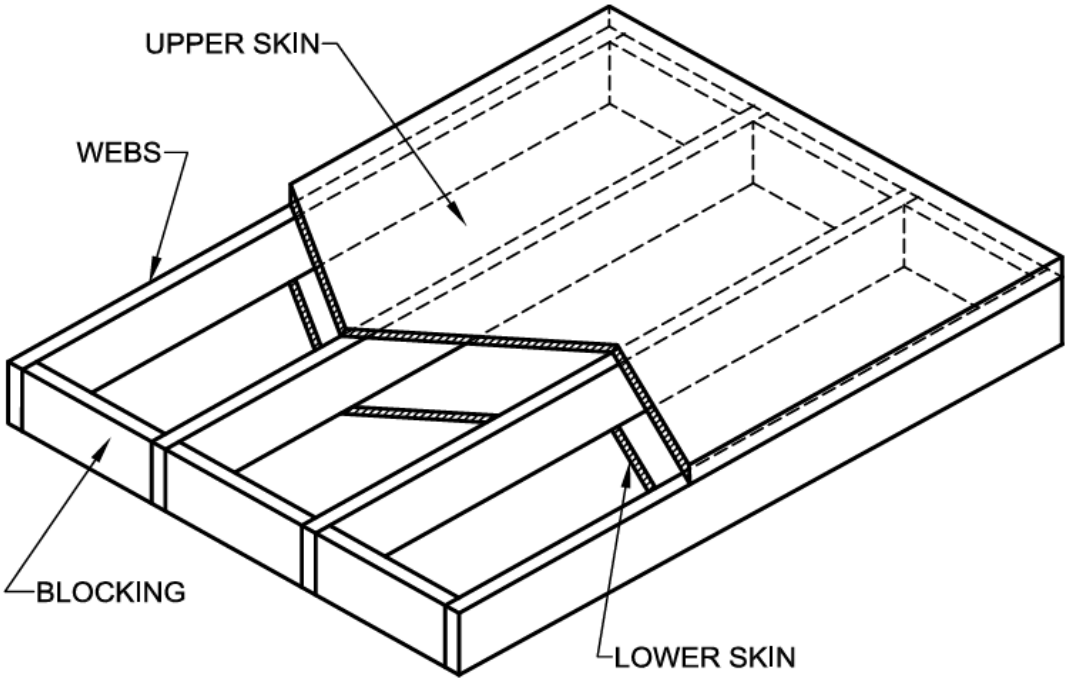


FIG. 17 STRESSED SKIN PANEL CONSTRUCTION (SINGLE SKIN OR DOUBLE SKIN)

Additional consideration may include:

a) *Climatic Suitability* – Trussed rafters should be designed with consideration for India's diverse climatic zones. Timber species suitable for humid, dry, and coastal regions should be preferred to prevent issues related to swelling, shrinkage, or decay due to moisture variations.

b) *Use of Local Timber Species* – Indian species such as Teak (*Tectona grandis*), Sal (*Shorea robusta*), Neem (*Azadirachta indica*), and other durable hardwoods should be prioritized. The use of locally available plantation-grown timber helps reduce transportation costs and supports sustainability.

c) *Fire and Termite Resistance* – Due to the prevalence of termites in many regions of India, timber rafters should be treated with appropriate termite-resistant chemicals. Similarly, the risk of fire in construction should be mitigated through the application of fire-retardant coatings.

15.2 Design

15.2.1 The design may be based on the use of Group ‘C’ species of standard grade timber in accordance with good practice [6-3A(7)] for nail jointed timber construction. As the strength and stiffness of any framing depends upon efficiency of joints, design calls for proper size and number of fasteners, their spacings and thickness of gusset plates for transfer of stress from one member to the other.

Trussed rafter shall be designed to sustain the dead and imposed loads specified in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code 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 may be assessed to be given by an idealized pin-jointed frame-work, fully loaded with maximum dead and imposed load in the combination in which they may reasonably be expected to occur.

NOTE – Some trussed rafters with plywood gusseted joint, span 6 m, designed in *Pinus roxburghii* (Chir) were tested in prototypes at Forest Research Institute, Dehradun for structural adequacy as under, in accordance with accepted standards [6-3A(14)]:

a) destructive test (short-term); and
b) proof test (long-term).

Results demonstrated an apparent factor at safety of 4 and actual factor of safety of 3. Deflection was well within the allowable deflection at design load. A pre-camber of 1/240 of span at the bottom chord was recommended.

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 1. Moisture contents shall be as per zonal requirements in accordance with **4.4**.

15.4 Plywood

Boiling water proof (BWP) grade preservative treated plywood shall be used in accordance with accepted standards [6-3A(13)]. 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 [6-3A(15)].

15.5 Some design data on the lateral load bearing strength of common wire nails in plywood-to-wood joints are presented for timber species, Sal and Chir in Table 22, for guidance in design.

16 STRUCTURAL SANDWICHES

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 (*see* Fig. 18). The thin facings are usually of strong dense material since that are the principal load carrying members of the construction. The core should 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 gluing 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.

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.

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 may be expected in normal usages.

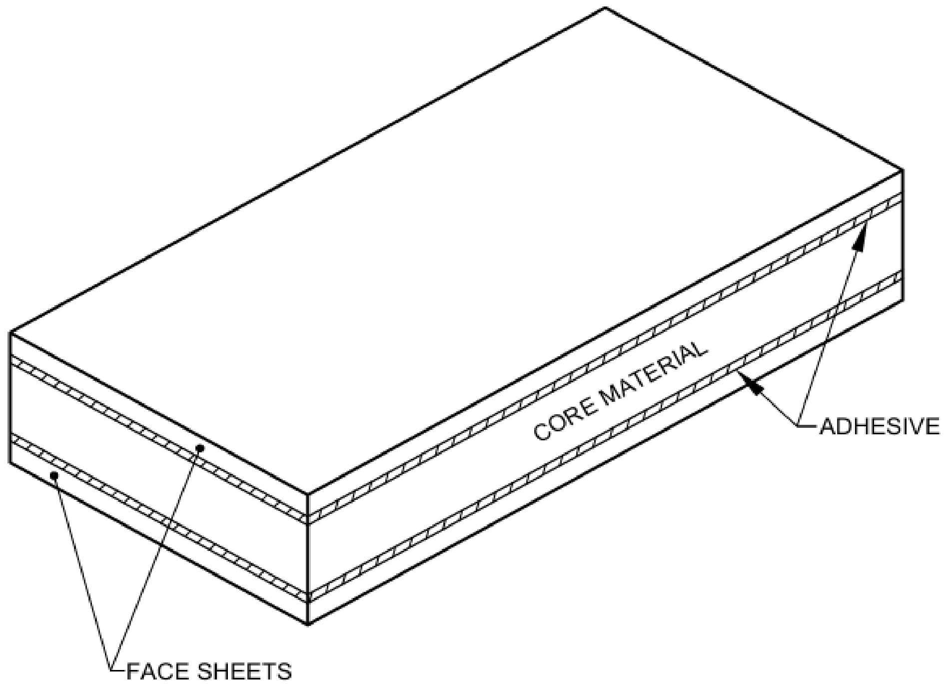


FIG. 18 SANDWICH CONSTRUCTION IN STRUCTURAL APPLICATIONS

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.

Table 22 Lateral Load Bearing Strength of Wire Nails in Plywood-to-Wood Composite Joints Permissible Lateral Strength of 9 SWG (3.55 mm dia) Nail in Double Shear (kg) Safe Load per Nail

(*Clause* 15.5)

Thickness of Members (mm)		**Facing Veneer of Plywood Along the Loading Direction (Loading Direction in the Main Member of the Joint)**								**Across Loading Direction (Loading Direction in the Main Member of the Joint) Loaded Parallel to Grain**	
Main Member Timber	Side Members Plywood	Parallel to Grain		Perpendicular to Grain		At 60° Inclination to Grain		At 30° Inclination to Grain			
		Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
						Species: *Shorea robusta* (Sal)					
30		109	121	135	156	151	168	140	164		
40	9	123	124	121	166	142	181	145	158	142	151
50		89	123	157	167	162	170	99	139		
30		157	177	150	154	164	179	111	171		
40	12	179	191	145	193	154	194	132	192	135	180
50		151	183	149	191	155	202	128	182		
30		245	283	Larger thickness of plywood is generally not recommended to be used in structures unless heavily stressed							
40	19	259	264							150	209
50		231	316								
						Species: *Pinus roxburghii* (Chir)					
30		102	127	112	141	60	125	92	124		
40	9	103	148	100	153	98	142	101	141	107	148
50		87	133	119	150	50	168	50	114		
30		133	163	116	111	80	132	127	150		
40	12	114	173	112	136	64	157	137	174	118	174
50		99	194	117	138	90	170	119	161		
30		219	309	Larger thickness of plywood generally not used in structures unless heavily stressed.							
40	19	238	306							158	249
50		236	333								

NOTES

1 Plywood shall be of shuttering grade as per the accepted standard [6-3A(16)].

2 Subject to satisfying all the design requirements in structures,

a) For denser species, timber thickness of 30 mm may be used by means of a plywood of 9 mm thickness for all practical purposes. For species like Chir, plywood thickness of 12 mm may be used with 30 mm or 40 mm timber thickness.

b) Regarding aligning the veneers of plywood plate; nail strength data may be used as design function irrespective of alignment of face veneer to overcome practical difficulties.

c) While prebore is essential to drive nail in structural timber as per the good pratice [6-3A(7)], plywood plates need not be prebored for nailing.

16.5 Tests

Panels of sandwich construction shall be subject to testing in accordance with accepted standards [6-3A(17)]. Tests shall include, as applicable, one or more of the following:

a) Flexural strength/stiffness,
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.

17 LAMELLA ROOFING

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 (*see* Fig. 19 and Fig. 20).

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 sheathing (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 should be taken into account.

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 lamellas or bearings under the head or washer of bolts are not exceeded.

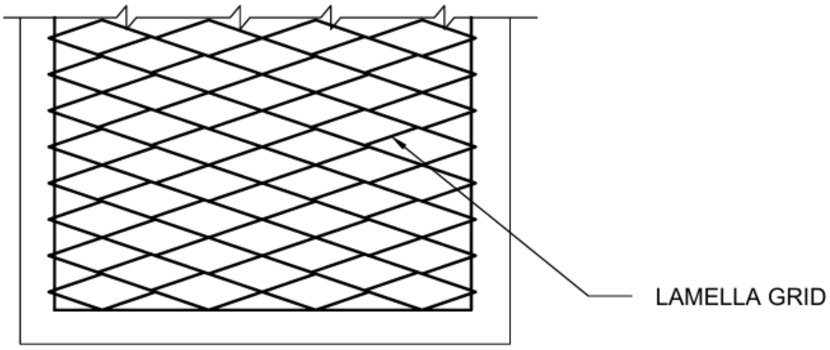
17.2.1 *Design Sequence and Methods*

A lamella roof is essentially an arch (segmental, parabolic or elliptical) formed by a system of intersecting skewed arches, built up of relatively short members of small dimensional planks called 'lamellas'. The arch is designed as a two hinged arch with a depth equal to the depth of the individual lamella and a width equal to the span of the building of certain length. For design purposes, a unit length of the given span forming a single arch is considered loaded with the given loads. For the particular arch, curvature offers resultant outward suction on the roof to be less than its self weight to facilitate design and construction for economy. (This is possible only when the semi-angle of arch is less than 42°).

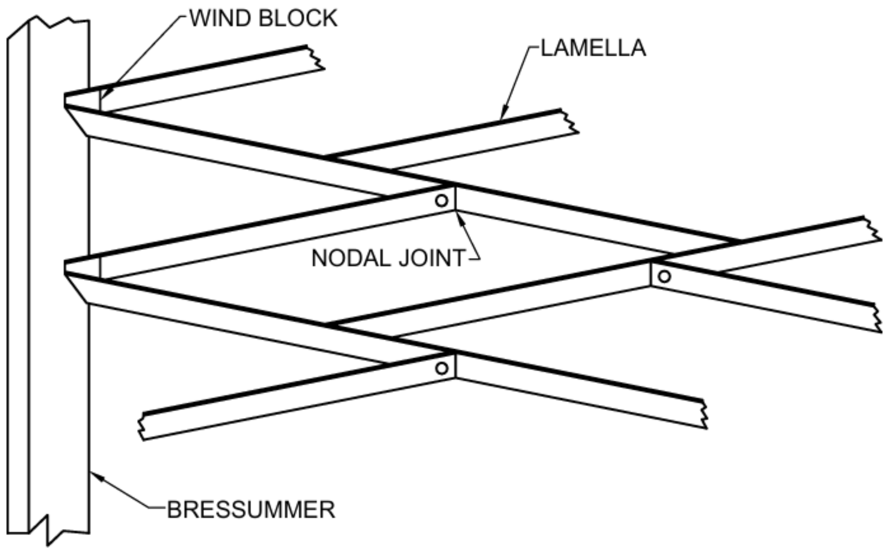
Some design assumptions that should be considered include:

a) Self weight of timber components (in particular species), namely lamella planks, roof boarding, wall plates, etc is assumed for the particular timber section.
b) Imposed loads as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code for curved roofs where slope at springing point is greater than 10°. Take the reduced worked out values of imposed loads for actual design for timber components as per this Subsection.
c) Wind load is taken as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code for structures with large openings, that is, openings larger than 20 percent of wall area (or as the case may be).
d) Stresses developed in curved lamella planks should not exceed the allowable safe stresses of timber species used.
e) Range of various sizes of timber planks for lamellas shall be as under:
    1) *Length* – 1.0 m to 2.5 m
    2) *Section*:
        i) *Thickness* – 25 mm to 50 mm
        ii) *Width of uncurved plank* – 100 mm to 250 mm

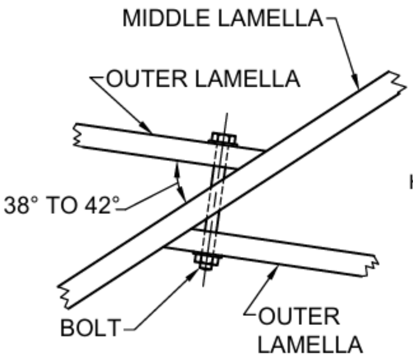
f) Limitations to be observed for spacing of lamellas over wall plate (or bressummer):
    1) i) For skew angle of 21° (diamond angle 42°).
       ii) For 2.5 m length of plank, spacing shall be 870 mm maximum.
       iii) For 1.0 m length, spacing shall be 360 mm maximum.
    2) i) For skew angle of 19° (diamond angle 38°).
       ii) For 2.5m length of plank, spacing shall be 800 mm maximum.
       iii) For 1.0 m length of plank, spacing shall be 320 mm maximum.



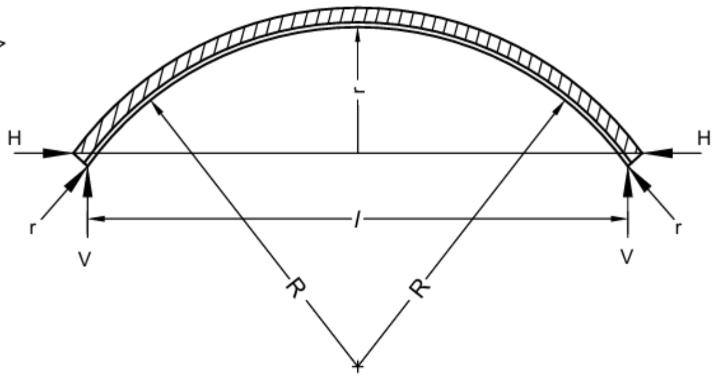
19A LAMELLA GRID



19B LAMELLA NODAL JOINT

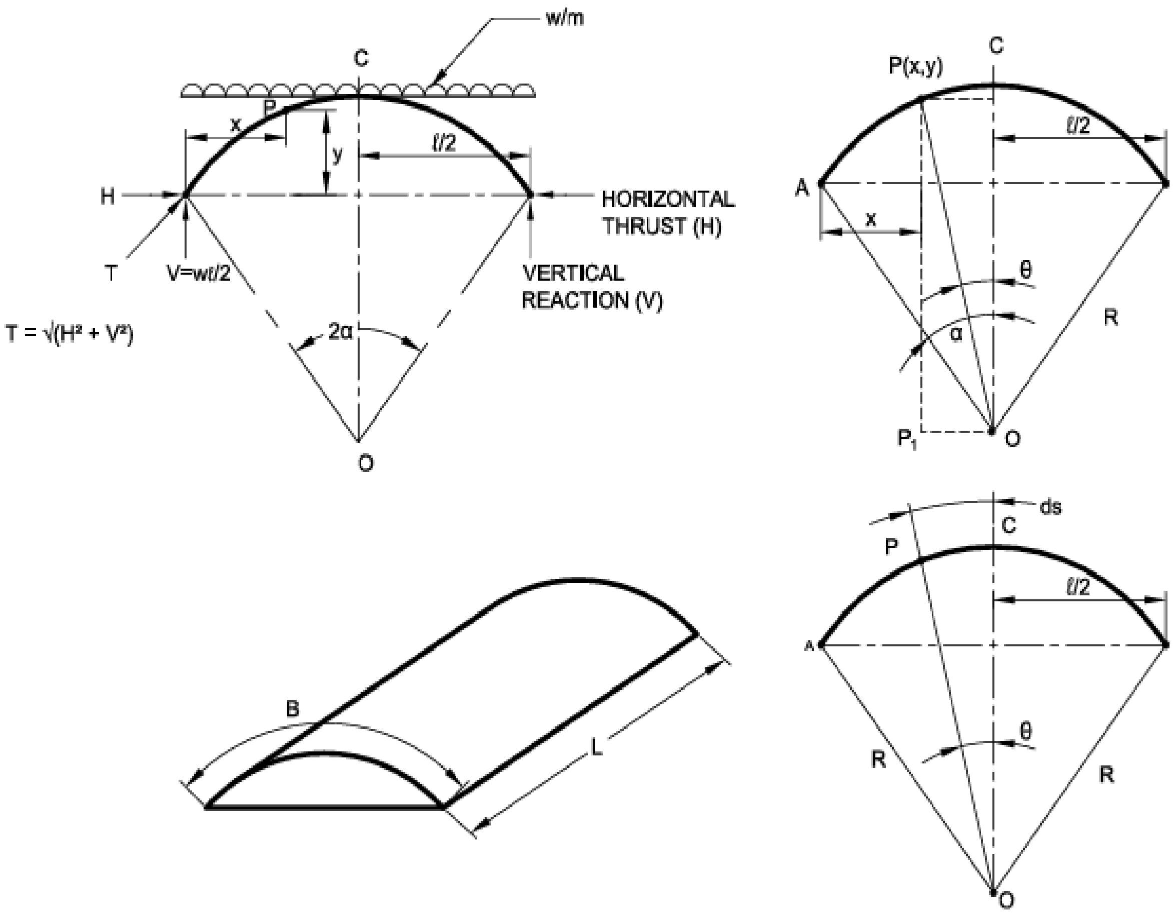


19C BOLT ORIENTATION



19D LOAD REACTION DIAGRAM

FIG. 19 TYPICAL ARRANGEMENT OF LAMELLA ROOFING



NOTES

1 When the ratio of the length of the structure (*L*) to the circumference of the arch (*B*) increases, stability of the structure decreases. The roof should be designed as,

a) short roof (say, *L*/*B* = 1), or
b) long roof (say, *L*/*B* = 1.5).

Shorter roofs have an advantage over long roofs for economical design. However, there is no such advantage beyond *L*/*B* of 4.

2 Due to stiff roof covering material, stiffness is induced in an arch, which results in safer design.

FIG. 20 STABILITY OF LAMELLA ARCH ROOF

g) Value of horizontal thrust, resultant thrust and maximum bending moment, are taken on per metre length of structure in case of transverse direction of arch.
h) Bending moment may be suitably reduced, if so desired by the designer, by applying stability factor if the ratio of the length of structure to the curved length of arch so warrants (as this ratio increases, the stability of the structure decreases).
j) The thrust in the skewed direction of arch, within one spacing of lamellas is shared by two lamella-lines in skewed direction.

k) More than one bolt (MS) shall be used for nodal joint. For design check of bolt against tension, half the value of thrust in skewed direction will be considered for calculations purposes in light of (j) [in case of stiff roof covering material (that is, corrugated galvanized iron (CGI) sheet, close boarding, etc) all lamella planks will be held jointly- behaving as a monolithic unit to a large extent and the actual stresses developed in bolt will be reduced resulting in lesser actual tension in bolts than the calculated design value].

17.2.1.1 *Horizontal thrust*

Any of the known methods for solving a statically indeterminate structure is used to evaluate horizontal thrust, bending moment, etc, to which a segmental arch will be subjected under the given condition of loadings. For 60° segmental arch, the radius of an arch will be equal to the span of the arch. Horizontal thrust can be calculated by the following two methods:

a) *Method 1*

Horizontal thrust (H_B) per length of one bay (that is, distance between 'tie-rod spacing' or 'column centres'):

$$H_B = (DL + IL) \times \left[\frac{l^2 + s_t^2}{8r}\right]$$

where

H_B = horizontal thrust, in N;
DL = dead load, in N;
IL = imposed load, in N;
l = span of arch, in m;
s_t = tie-rod spacing, in m; and
r = rise of roof arch, in m.

b) *Method 2*

Horizontal thrust (H_1) per metre length of structure (in N):

$$H_1 = C \times w \times R$$

where

C = coefficient varying with the angle of arch and radius of arch;
w = equivalent distributed load per metre of span (in N/m); and
R = radius of circular arch (in m).

Horizontal thrust (H_1) is evaluated as:

$$H_1 = \frac{\int \mu y ds}{\int y^2 ds}$$

where

H_1 = horizontal thrust (per metre length of structure), in N.
μ = bending moment at any point '*P*' distance 'x' metre from one end of springing point of arch and for vertical loads only (consider arch as a beam simply supported carrying the same load).

y = height of point 'P' above springing line of arch.
θ = angle which the point 'P' makes at the centre of arch with the vertical.
$ds = Rd\theta$

Now solution for numerator,

$$\mu = \frac{wl}{2}x - wx\frac{x}{2}$$

$$= \frac{wx}{2}(l - x)$$

where

$$x = \frac{l}{2} - R\sin\theta$$

$$= \frac{R}{2} - R\sin\theta$$

$$= R\left(\frac{1}{2} - \sin\theta\right)$$

and $y = R\cos\theta - R\cos\alpha$

$$y = R(\cos\theta - \cos\alpha)$$

and $ds = Rd\theta$

Substitute the values in expression

$$\int \mu y ds = \int \frac{wx(l-x)}{2} R(\cos\theta - \cos\alpha)Rd\theta$$

Solve for limits of θ from $-\alpha$ to $+\alpha$ = $\int_0^\alpha wR^4(\frac{1}{4} - \sin^2\theta)(\cos\theta - \cos\alpha)d\theta$

Again for denominator,

$$\int y^2 ds = \int_{-\alpha}^{+\alpha} R^2(\cos\theta - \cos\alpha)^2 Rd\theta$$

$$= 2R^3\int_0^\alpha (\cos\theta - \cos\alpha)^2 d\theta$$

Therefore, $H_1 = \dfrac{\int \mu y ds}{\int y^2 ds}$

$$= \frac{wR^4 \int_0^\alpha \left(\frac{1}{4} - \sin^2\theta\right)(\cos\ \theta - \cos\alpha)d\theta}{2R^3 \int_0^\alpha (\cos\ \theta - \cos\alpha)^2 d\theta}$$

On simplification of the above equation for a particular arch, α = 30°, $R = \ell$ (α in radian = 0.5 approx),

sin α = 1/2
cos α = √3/2

H_1 = 0.923 wR

Vertical reaction, $V_1 = \frac{Total load \times span}{2}$ at each end of arch due to dead and live loads per metre length (curved strip) of arch roofing.

17.2.1.2 *Resultant thrust*, T_1

Due to horizontal thrust and the vertical reaction, resultant transverse thrust, in kg per metre length on the arch can be worked out:

$$T_1 = \sqrt{H_1^2 + V_1^2}$$

17.2.1.3 *Maximum bending moment*

Bending moment at any point 'P' on arch making an angle of θ with the vertical line OC is, $BM = \mu - (H \times y)$

$$= \frac{wR^2}{2}\left(\frac{1}{4} - \sin^2\theta\right) - 0.923 wR^2\left(\cos\theta - \frac{\sqrt{3}}{2}\right)$$

Differentiating the above expression for BM, we get

$$\frac{dM}{d\theta} = (-\sin\theta\cos\theta + 0.923\sin\theta)wR^2$$

It is well known that $\frac{dM}{d\theta} = \text{shear force}$

This shear is zero when BM is maximum, that is,
either θ = zero
or cos θ = 0.923

Therefore, $\theta = \cos^{-1} 0.923 = 22.6°$

Substituting these values in the above equation of bending moment, we get maximum BM, that is, the maximum BM occurs at,

a) crown of arch, and
b) at 22.6° from the central line OC.

Thus when θ = 0

$$BM = \frac{wR^2}{2} \times \frac{1}{4} - 0.923wR^2\left(1 - \frac{\sqrt{3}}{2}\right)$$

$$= wR^2(0.125 - 0.12368)$$

$$= 0.001\ 32wR^2$$

When θ = 22.6°, sin θ = 0.384

$$BM = \frac{wR^2}{2}\left(\frac{1}{4} - 0.384\right)^2 - 0.923wR^2(0.923 - 0.866)$$

$$= wR^2(0.125 - 0.073\ 728) - 0.923 \times 0.057wR^2$$

$$= -0.001\ 339wR^2 \text{ or say } -0.001\ 34wR^2$$

The arch has to be designed for the greater of the two values (subject to the longitudinal stiffness coefficient on the basis of ratio L/B of length of the structure to the circumference of the arch) for economical design.

NOTE – Value of horizontal thrust, H_1, resultant thrust, T_1 and bending moment, M_1 shall be for 1 m length of building.

17.2.1.4 *Spacing of lamellas*

Lengthwise spacing of lamellas depends upon the angle of skew lamellas and the length of the planks used for lamellas (As a general guidance it may be stated that the angle enclosed between the intersecting skewed arches should not exceed 45°. An angle between 38° and 40° is always preferred.)

17.2.1.5 *Design of lamella sizes*

Net section of each of lamellas is assumed in curved profile conforming to the curvature of the roof surface.

Maximum BM = M_S over 600 mm spacing of lamella in the direction of skew angle, for example

$$= \frac{0.6M_1 \times 10}{cos 19°} \text{ Nm}$$

where

M_1 = maximum bending moment per metre length of structure in transverse direction.

And maximum thrust N (in Newton) on this strip of 600 mm in skewed direction is:

$$N = \frac{0.6T_1}{cos 19°} \times \frac{1}{2}$$

(as the force T_1 is shared by two lines of lamellas) where

N = maximum thrust on 600 mm strip in skewed direction.
T_1 = resultant thrust in transverse direction (in N) per metre length of structure.

Now total compressive and flexural stresses should not exceed the allowable safe stress of timber species used for lamella plank. For fulfilling this condition the following equation should be checked:

$$\frac{N/A}{f_{c\,\mathrm{II}}} + \frac{M_S/Z}{f_t} \leq 1$$

where

N = maximum thrust in skewed direction on strip of 600 mm (in N) corresponding to the maximum bending moment;
Z = section modulus of lamella plank, in mm^3;
A = cross-sectional area of lamella plank, in mm^2;
$f_{c\,\mathrm{II}}$ = safe compression strength of timber fibre parallel to grain, N/mm^2;
f_t = safe tensile strength of timber parallel to grain, N/mm^2; and
M_s = bending moment over 600 mm strip of arch in skewed direction, Nmm;

NOTE – In case the lamella plank is under stressed, the minimum section for practical reasons shall be 25 mm × 100 mm subject to satisfying minimum edge and intermediate distances for accommodating bolts at nodal joints.

17.2.1.6 *Design of bolts for nodal joint*

To avoid any possibility of hinge action with the use of bolts, it is imperative to adopt two or more bolts of smaller diameter and adequately spaced in accordance with the good practice [6-3A(9)].

Assume diameter of bolt '*d*' in mm, and length of bolt in one plank '*t*' mm, that is, thickness of middle lamella plank.

Area of contact of bolt with timber plank = $d \times t$ mm^2

a) *Check against crushing of timber at contact point of bolt* – For the bolt to transmit load without crushing the timber fibres, the following condition shall be satisfied:

   $t \times d \times$ compressive stress perpendicular to grain for the timber species $> P$

   where

   P = total load to be transmitted through bolt, in N.

b) *Check against tension in bolt* – Arrangement of bolts at the junction of lamellas result in pure tension in bolt as bolt line is at right angle to the outer two lamellas. Therefore, $Z_t = N \times \cot 2\phi$

where

Z_t = tension in bolt, in N.

N = normal thrust corresponding to maximum moment M_s (in N)

$$= \frac{T_1}{\cos\phi} \times \frac{1}{2}$$

T_1 = resultant thrust in transverse direction (in N) per metre length of structure.

Therefore,

Area of bolt (A_t) × tensile stress of steel (F_t) ≥ Z_t

Area of bolt required for safe design = Z_t/F_t

Select the diameter to engage at least two bolts.
(Required area of bolt is the effective area after considering reduction of area at the threaded end, which is generally 17 percent of the actual bolt diameter)

17.2.1.7 *Design of steel washer at joints*

Area of steel plate = A_t mm^2

Stress perpendicular to grain of wood at the point of contact with steel plate washer
= Z_t/A_t N/mm^2

If Z_t/A_t ≤ compressive stress perpendicular to grain of the species of timber used, the assumed section is safe.

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. To avoid excessive deformation in a lamella system, all joints should be carefully fitted and well tightened.

18 NAIL AND SCREW HOLDING POWER OF TIMBER

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 non-structural purposes in form 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 in good practice [6-3A(7)]. 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.

18.2 Nails

Nails are probably the most common and familiar fastener. They are of many types and sizes in accordance with the accepted standard [6-3A(18)]. 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.

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 in accordance with the accepted standards [6-3A(19)].

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.

18.4 Nail and screw holding power is one of the very important properties of timber which governs its utilization in diverse industrial and engineering fields. This has been evaluated by experimental method followed for evaluation of such properties as per normal procedure given in the accepted standards [6-3A(20)], using,

a) *Specimen* – Of size 150 mm × 50 mm × 50 mm;
b) *Nail* – Diamond pointed wire nail of 50 mm length and 2.50 mm shank diameter;

c) *Screw* – Galvanized gimlet pointed, No. 8; and
d) *Conditions* – Penetration 25 mm.
While nails were driven by a hand hammer, screws were driven by a screw driver in a 2.5 mm diameter prebore on radial, tangential and end faces.

Composite nail and screw holding power of some Indian timbers, evaluated as above, is presented in Table 23 for guidance in design.

Table 23 Composite Nail and Screw Holding Power of Some Indian Timbers
(*Clause* 18.4)

Sl No.	**Timber Species**	**Locality**	**Standard Specific Gravity (Weight Oven Dry)/Volume Green**	**Composite Holding Power** N	
				Nail	Screw
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Acacia catechu* (Khair)	UP	0.888	2 119	5 454
ii)	*Acacia ferruginea*	Maharashtra	0.876	1 893	5 700
iii)	*Acacia leucophloea*	MP	0.660	1 776	4 503
iv)	*A. nilotica* (Babul)	UP	0.670	1 815	5 219
v)	*Acrocarpus fraxinifolius* (Mundani)	UP	0.662	1 020	2 865
vi)	*Adina oligocephala*	Arun. Pr.	0.612	1 795	3 453
vii)	*Aesculus indica* (Horse chestnut)	HP	0.428	755	2 119
viii)	*Albizia lucida*	Arun. Pr.	0.501	1 462	3 188
ix)	*Anogeissus sericea*	MP	0.738	1 570	4 944
x)	*Aphanamixis polgstachya* (Pitraj)	WB	0.557	1 648	3 110
xi)	*Araucaria cunning hanvil*	UP	0.486	1 128	2 943
xii)	*Aritocarpus lakoocha* (Lakooch)	UP	0.530	1 050	2 982
xiii)	*Azadirachta indica* (Neem)	UP	0.693	2 001	5 219
xiv)	*Betula alnoides* (Birch)	WB	0.569	1 648	3 237
xv)	*Broussonetia papyrifera*	UP	0.394	746	1 383
xvi)	*Canarium strictum* (White dhup)	Assam	0.486	1 207	2 619
xvii)	*Cassia fistula* (Amaltos)	UP	0.746	2 109	4 748
xviii)	*Cassia siamea*	MP	0.697	1 315	3 649
xix)	*Castanopsis indica* (Indian chestnut)	Megh.	0.591	1 697	3 090
xx)	*Cupressus cashmeriana*	UP	0.409	903	2 325
xxi)	*Dipterocarpus bourdilloni* (Gurjan)	Kerala	0.577	912	2 766
xxii)	*Dipterocarpus indicus* (Gurjan)	Karnataka	0.618	1 109	2 904
xxiii)	*Eucalyptus hybrid*	UP	0.632	1 736	2 453

Sl No.	**Timber Species**	**Locality**	**Standard Specific Gravity (Weight Oven Dry)/Volume Green**	**Composite Holding Power N**	
				Nail	Screw
(1)	(2)	(3)	(4)	(5)	(6)
xxiv)	*Exbucklandia –populnea* (Pipli)	WB	0.558	1 403	3 443
xxv)	*Fraxinus udheri*	UP	0.539	1 354	3 483
xxvi)	*Gluta travancorica* (Gluta)	TN	0.621	1 324	2 923
xxvii)	*Grewia tiliifolia* (Dhaman)	Karnataka	0.679	1 746	2 884
xxviii)	*Holarhena antidysenterica* (Kurchi)	UP	0.445	1 020	2 698
xxix)	*Lagerstroemia specicosa* (Jarul)	Kerala	0.531	1 697	2 717
xxx)	*Lannea coromendelica* (Jhingan)	Rajasthan	0.497	1 216	2 894
xxxi)	*Magnolia hookeri*	Arun. Pr.	0.403	1 128	1 746
xxxii)	*Mangifera indica* (Mango)	UP	0.411	1 383	2 433
xxxiii)	*Manglietia spp.*	Assam	0.409	912	2 031
xxxiv)	*Mesna assamica* (Sianhor)	Assam	0.687	1 795	3 502
xxxv)	*Michelia champaca* (Champ)	Assam	0.488	1 128	2 737
xxxvi)	*Mimusops elengi*	Karnataka	0.762	2 158	5 101
xxxvii)	*Morus alba* (Mulberry)	UP	0.557	1 030	4 091
xxxviii)	*Morus laevigata* (Bola)	Assam	0.567	932	2 600
xxxix)	*Morus spp.*	UP	0.594	1 589	3 129
xl)	*Nephelium litchi*	UP	0.762	1 825	4 238
xli)	*Oroxylum indicum*	Andaman	0.370	961	1 736
xlii)	*Ougenia oogeinensis* (Sandan)	UP	0.701	1 570	5 317
xliii)	*Pinus kesiya*	Nagaland	0.489	1 089	2 354
xliv)	*Pinus kesiya*	Orissa	0.453	1 118	2 325
xlv)	*Pinus roxburghii* (Chir)	UP	0.453	1 128	2 482
xlvi)	*Pinus wallichiana* (Kail)	HP	0.468	873	1 521
xlvii)	*Pistacia integerrima*	J & K	0.733	1 324	4 120
xlviii)	*Polyalthia spp.* (Debdara)	MP	0.586	1 452	2 953
xlix)	*Pometa pinnata*	Andaman	0.636	1 579	3 532
l)	*Prunus nepalensis* (Arupati)	WB	0.482	1 099	2 531
li)	*Pterocarpus marsupium*	Bihar	0.587	1 305	2 982
lii)	*Pterygota alata* (Narikel)	Assam	0.475	1 403	3 463
liii)	*Pterygota alata* (Narikel)	Kerala		1 089	2 639
liv)	*Robinia spp.*	J & K	0.629	2 227	3 777
lv)	*Sageraea elliptica* (Chooi)	Andaman	0.682	1 805	4 522

Sl No.	Timber Species	Locality	Standard Specific Gravity (Weight Oven Dry)/Volume Green	Composite Holding Power N	
				Nail	Screw
(1)	(2)	(3)	(4)	(5)	(6)
lvi)	*Schleichera oleosa* (Kusum)	Bihar	0.841	1 884	4 277
lvii)	*Shorea robusta* (Sal)	UP	0.774	1 216	3 620
lviii)	*Soymida ferifuga*	TN	0.965	1 687	6 033
lix)	*Tectona grandis* (Teak)	UP	0.574	1 020	3 404
lx)	*Tectona grandis* (Teak)	TN	0.633	1 364	3 483
lxi)	*Tectona grandis* (Teak)	Maharashtra	0.526	971	3 728
lxii)	*Terminalia alata* (Laurel)	UP	0.806	2 521	3 806
lxiii)	*Terminalia citrina*	Assam	0.629	1 540	3 855
lxiv)	*Terminalia paniculata* (Kindal)	Kerala	0.630	1 982	3 257
lxv)	*Tetrameles nudiflora* (Maina)	Assam	0.289	667	1 413
lxvi)	*Thespesia populnea* (Bhendi)	Maharashtra	0.647	1 923	5 425
lxvii)	*Tsuga brunonsiana*	WB	0.380	540	2 050
lxviii)	*Ulmus coallichiana* (Elm)	HP	0.455	834	1 766
lxix)	*Zanthoxylum spp.*	WB	0.496	1 138	3 071

19 PROTECTION AGAINST TERMITE ATTACK IN BUILDINGS

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.

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(21)].

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.

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 in case of metal fasteners; and
g) Influence on plastics, rubber, tiles and concrete.

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.

20 CROSS-LAMINATED TIMBER (CLT)

Cross-Laminated Timber (CLT) is an engineered wood product used as a structural component in mass timber construction. CLT panels shall consist of not less than three layers of solid-sawn lumber or structural composite lumber, with adjacent layers cross-oriented and bonded with structural adhesives to form a solid wood element.

20.1 General Requirements

20.1.1 *Material Specifications*

CLT panels shall be manufactured to meet stringent performance criteria for mechanical properties, including load-bearing capacity, dimensional tolerances, and adhesive bond durability to ensure structural reliability. Panels should also demonstrate resistance to delamination and other essential physical properties through rigorous testing to validate long-term performance under various environmental conditions.

The timber used for CLT production shall be kiln-dried to a moisture content of 12 percent ± 2 percent, ensuring stability and resistance to deformation.

20.1.2 *Dimensions*

CLT panels shall have a minimum thickness of 50 mm, with thicknesses ranging up to 500 mm for structural applications. The typical panel dimensions for commercial use may be up to 18 000 mm in length and 3 000 mm in width.

The number of layers shall be odd (for example, 3, 5, 7), with layer thicknesses adjusted according to structural requirements.

20.2 Physical Properties

20.2.1 *Delamination Resistance*

Delamination testing shall be conducted to ensure that total delamination ($Delam_{tot}$) shall not exceed 10 percent, and maximum delamination ($Delam_{max}$) shall not exceed 40 percent, ensuring durability and structural integrity.

Results from studies indicate that CLT made from plantation-grown hardwoods such as Rubberwood, *Meliadubia*, and Eucalyptus meets these requirements, with delamination values comparable to Radiata pine, a commonly used species in CLT production.

20.2.2 *Water Absorption and Swelling Properties*

CLT panels shall be evaluated for water absorption (WA), thickness swelling (TS), and volumetric swelling (VS) using the water soaking method. These parameters shall be assessed to ensure that the panels meet acceptable limits for moisture-induced dimensional changes, maintaining stability under varying environmental conditions.

Reference to results from studies (Table 24 and Table 25) shows that hardwood species demonstrate comparable performance to Radiata pine, indicating their suitability for structural applications.

Table 24 Physical Properties of Polyurethane (PUR) Bonded Homogenous CLT in Comparison to R. Pine CLT
(*Clause* 20.2.2)

Sl No.	**Type of CLT**	$Delam_{tot}$ Percent	$Delam_{max}$ Percent	**WA** Percent		**TS** Percent		**VS** Percent	
		CLT	**CLT**	**CLT**	**Solid wood**	**CLT**	**Solid wood**	**CLT**	**Solid wood**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Rubber wood	6.49 *(0.98)*	29.01 *(2.90)*	31.23 *(4.19)*	52.91 *(5.47)*	3.26 *(0.93)*	9.93 *(1.82)*	3.26 *(0.93)*	9.93 *(1.82)*

Sl No.	**Type of CLT**	***Delam*tot** Percent	***Delam*max** Percent	**WA** Percent		**TS** Percent		**VS** Percent	
		CLT	**CLT**	**CLT**	**Solid wood**	**CLT**	**Solid wood**	**CLT**	**Solid wood**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ii)	Melia	6.77 *(0.78)*	26.65 *(3.86)*	23.51 (3.48)	39.98 (9.94)	4.38 *(2.28)*	9.15 *(3.29)*	7.86 *(1.89)*	13.58 *(6.85)*
iii)	Silver oak	8.08 *(1.21)*	21.3 *(4.13)*	14.10 *(3.66)*	35.88 *(12.28)*	5.05 *(1.02)*	13.19 *(1.89)*	8.37 *(1.43)*	20.83 *(2.62)*
iv)	Eucalyptus	6.61 *(2.29)*	34.10 *(3.28)*	25.68 *(7.57)*	38.97 *(7.57)*	4.06 *(1.24)*	15.08 *(7.76)*	7.39 *(1.70)*	17.92 *(7.74)*
v)	Radiata Pine	6.63 *(0.86)*	26.70 *(3.63)*	29.35 *(5.46)*	40.03 *(7.20)*	4.29 (0.29)	12.47 *(3.01)*	14.09 *(0.66)*	20.62 *(2.82)*

NOTE – Values in the parentheses indicate standard deviation.

Table 25 Physical Properties of Hybrid CLT in Comparison to Radiata Pine CLT

(*Clause* 20.2.2)

Sl No.	**Type of CLT**	***Delam*tot** Percent	***Delam*max** Percent	**WA** Percent	**TS** Percent	**VS** Percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Hybrid with Eucalyptus (E) and Melia dubia(M) (EME)	7.68 *(0.57)*	31.62 *(4.37)*	26.43 *(3.66)*	6.33 *(1.77)*	15.86 *(1.47)*
ii)	Hybrid with Melia dubia (M) and Eucalyptus (E) (MEM)	6.68 *(0.53)*	28.65 *(3.82)*	24.35 *(6.86)*	5.59 *(1.38)*	8.85 *(1.93)*
iii)	Hybrid with Melia dubia (M) and Silver oak (S) (MSM)	7.06 *(1.22)*	28.96 *(1.12)*	21.86 *(5.09)*	5.43 *(1.84)*	7.04 *(3.94)*
iv)	Hybrid with Silver oak (S) and Melia dubia (M) (SMS)	7.65 *(0.23)*	26.62 *(1.45)*	15.51 *(5.6)*	8.43 *(2.30)*	8.24 *(2.96)*
v)	Radiata pine	6.63 *(0.86)*	26.70 *(3.63)*	29.35 *(5.46)*	4.29 *(0.29)*	14.09 *(0.66)*

NOTE – Values in the parentheses indicate standard deviation.

20.2.3 *Density*

The density of CLT panels shall be determined according to the timber species and adhesive used. The density of CLT panels shall range from 5 500 kg/m³ to 8 500 kg/m³, depending on the species (for example Rubberwood, Eucalyptus). Table 26 provides the density values for different species used in CLT production.

Table 26 Density of CLT panels
(*Clause* 20.2.3)

Sl No.	**Species**	**Density of Wood (12 percent moisture content)** kg/m³	**Density of CLT** kg/m³
(1)	(2)	(3)	(4)
i)	Rubber wood	6 200 *(0.05)*	6 500 *(0.08)*
ii)	Melia wood	5 100 *(0.04)*	5 500 *(0.01)*
iii)	Eucalyptus	8 000 *(0.05)*	8 500 *(0.03)*
iv)	Silver oak	6 200 *(0.02)*	6 800 *(0.02)*
v)	Radiata pine	4 200 *(0.03)*	4 500 *(0.03)*
vi)	EME	---	7 700 *(0.02)*
vii)	MEM	---	6 400 *(0.03)*
viii)	MSM	---	5 500 *(0.02)*
ix)	SMS	---	6 700 *(0.01)*

NOTE – Values in the parentheses indicate standard deviation.

20.3 Mechanical Properties

20.3.1 *Bending, Compression, and Shear Strength*

Mechanical testing shall include four-point bending tests, compression parallel to grain tests, and block shear tests. The results shall comply with the minimum strength requirements for structural applications as specified in Part 6 Section 1 of this Code.

Table 27 and Table 28 present the mechanical properties of homogeneous and hybrid CLT panels, showing adequate performance for structural uses. Rubberwood CLT exhibited higher mechanical properties than hybrid configurations in some tests.

20.3.2 *Impact of Adhesive Type on Mechanical Performance*

The choice of adhesive (for example phenol resorcinol formaldehyde, PUR) shall be considered, as it affects the bonding strength and durability. Mechanical properties of CLT bonded with different adhesives, indicating that PRF-bonded panels have superior performance.

Table 27 Mechanical Properties of Homogeneous CLT Panels
(*Clause* 20.3.1)

Sl No.	**CLT made from**	**MoE** MPa	**MoR** MPa	**Compression parallel to grain** MPa	**Block shear strength** MPa
(1)	(2)	(3)	(4)	(5)	(6)
i)	Rubberwood	8600 *(328.3)*	48.7 *(13.8)*	25.0 *(2.3)*	6.7 *(1.4)*
ii)	Melia wood	6758 *(598.6)*	44.8 *(5.7)*	23.0 *(1.8)*	6.3 *(0.7)*
iii)	Silver oak	8835 *(739.5)*	64.2 *(6.9)*	26.34 *(2.0)*	6.7 *(0.5)*
iv)	Eucalyptus	13811 *(1468.7)*	81.6 *(8.3)*	35.40 *(6.7)*	6.65 *(0.6)*
v)	Radiata Pine	4542 *(1024.3)*	49.6 *(10.3)*	16.4 *(2.3)*	3.1 *(0.5)*

NOTE – Values in the parentheses indicate standard deviation.

Table 28 Mechanical Properties of Hybrid CLT panels
(*Clause* 20.3.1)

Sl No.	**CLT made from**	**MoE** MPa	**MoR** MPa	**Compression parallel to grain** MPa	**Block shear strength** MPa
(1)	(2)	(3)	(4)	(5)	(6)
i)	EME	10943 *(1074.8)*	70.0 *(7.2)*	30.5 *(3.7)*	5.8 *(0.6)*
ii)	MEM	7770 *(938.5)*	47.0 *(4.5)*	24.6 *(2.2)*	5.8 *(0.6)*
iii)	SMS	7701 *(600.5)*	61.6 *(7.5)*	33.5 *(4.0)*	5.6 *(0.5)*
iv)	MSM	6328 *(652.8)*	45.5 *(4.3)*	24.2 *(3.1)*	5.3 *(0.5)*

NOTE – Values in the parentheses indicate standard deviation.

20.4 Fire Safety Requirements

20.4.1 *Fire Resistance Ratings*

CLT panels shall have a fire-resistance rating of 1 hour to 3 hour, depending on building type and height, as per NBC Part 4' Fire and Life Safety' of the Code. This shall be achieved through inherent fire resistance, encapsulation with materials like gypsum board (minimum thickness 13 mm), or a combination of methods.

The charring rate of CLT shall be considered in fire design calculations, with a recommended charring rate of 0.65 mm/min for calculating the load-bearing capacity during fire exposure.

20.4.2 *Protection of Connections*

Steel connectors and other metal components shall be protected with fire-resistant coatings or encased in non-combustible materials to ensure structural integrity during a fire.

20.5 Durability and Biological Resistance

20.5.1 *Preservative Treatments*

CLT panels shall be treated with preservatives like bifenthrin or copper chrome borate to enhance resistance to biological degradation. Testing has shown that preservative-treated CLT has improved resistance to termite and fungal attacks compared to untreated samples (*see* Table 29 for termite degradation results).

Table 29 Degradation of Samples due to Termite Attack
(*Clause* 20.5.1)

Sl. No.	**CLT sample**	**Average Degradation Percent**	**Duration of exposure** months
(1)	(2)	(3)	(4)
i)	Control Solid wood	100	6
ii)	Control CLT	100	9
iii)	Calcium channel blockers (CCB) treated CLT	60	36
iv)	Bifenthrin treated CLT	0	36

20.5.2 *Performance Under Biological Exposure*

Durability testing shall include assessments for resistance to termites, white rot, and brown rot fungi. Untreated rubberwood is highly susceptible to biological degradation, while treated samples showed minimal degradation after prolonged exposure.

20.5.3 *Effect of Preservatives on Mechanical Properties*

The use of preservatives should not adversely affect the mechanical properties of CLT. Block shear strength tests indicate that treated panels retain comparable mechanical performance to untreated panels.

20.6 Handling, Storage, and Installation

20.6.1 *Moisture Protection*

During construction, CLT panels shall be protected from moisture exposure. Panels should be stored in a dry environment, and water infiltration during transportation and installation shall be minimized.

20.6.2 *On-Site Assembly*

CLT elements shall be assembled on-site using engineered connectors, dowels, or bolts, ensuring continuous load transfer. Construction practices shall follow guidelines for mass timber installation, with proper fire protection and moisture management strategies.

21 MASS TIMBER

Structural elements primarily composed of solid, built-up, panelized, or engineered wood products are categorized as products include, but are not limited to, cross-laminated timber (CLT), glued-laminated timber (glulam), and laminated veneer lumber (LVL). It consist of multiple layers of wood, mechanically or adhesively bonded together to create large, strong, and stable components suitable for load-bearing and non-load-bearing uses in construction. Mass Timber elements can be used for structural framing, walls, floors, roofs, and columns. It applies to the construction of residential, commercial, and public buildings where structural elements, including floors, walls, roofs, and columns, are made from engineered wood products like cross-laminated timber (CLT), glued-laminated timber (glulam), and other solid or panelized wood products.

These load-bearing and non-load-bearing products include:

a) Cross-laminated timber (CLT)

b) Glued-laminated timber (Glulam)

c) Nail-laminated timber (NLT)

d) Laminated veneer lumber (LVL)

These products are used for the construction of walls, floors, roofs, beams, and columns and are capable of meeting structural and fire-resistance requirements as specified in this clause.

21.1 Design and Structural Integrity

21.1.1 *Structural Design Requirements*

a) *Load-Bearing Capacity* – Mass timber elements shall be designed to carry the vertical and lateral loads imposed on the building in compliance Part 6 'Structural Design, Section 1 Loads, Forces, and Effects' of the Code. The design shall account for dead loads, live loads, wind loads, seismic loads, and other imposed loads.

b) *Cross-Sectional Dimensions* – The minimum cross-sectional dimensions for mass timber elements (for example, columns, beams, floor slabs) shall be specified based on building height, function, and occupancy. For example, CLT panels used for floor slabs should meet a minimum thickness of 100 mm, depending on the structural requirements.

c) *Deflection Limits* – The design of mass timber structures shall ensure that the deflection under service load conditions remains within acceptable limits as defined in with Part 6 'Structural Design, Section 1 Loads, Forces, and Effects' of the Code.

21.1.2 *Hybrid Systems*

Where mass timber is used in conjunction with steel or concrete, the design should ensure that load paths are continuous and that materials are compatible. Load transfer mechanisms shall be adequately designed to prevent failure at the connection points between materials.

21.1.3 *Seismic Performance*

Mass timber buildings located in seismic zones should be designed to accommodate lateral loads and displacements as per Part 6 '(Structural Design, Section 1 Loads, Forces, and Effects' of the Code. Timber's flexibility can offer good seismic performance, but connections and structural integrity should be robustly designed to prevent failure.

21.2 Fire Resistance and Safety

21.2.1 *Fire Resistance of Mass Timber Elements*

Mass timber structural components shall meet fire resistance standards *(see* Table 30 for fire resistance ratings) appropriate for the building's type, use, and height, in line with the following categories:

a) *Type IV-A* – Mass timber elements shall be fully covered with non-combustible materials to achieve the highest fire resistance. This category is suitable for buildings with high occupancy or greater height requirements, where complete encapsulation allows the structure to withstand severe fire scenarios without exposing the timber.
b) *Type IV-B* – Limited exposed timber surfaces may be allowed, provided they are separated to reduce fire risk. Timber in these areas shall meet fire standards through either its natural properties or additional protective coatings, with key building sections requiring non-combustible protection.
c) *Type IV-C* – Interior timber elements may remain fully exposed, relying on the inherent fire resistance of mass timber. However, concealed spaces, shafts, and similar areas shall have non-combustible protection, and the exterior faces of mass timber should also be clad with non-combustible materials.

Table 30 Required Fire Resistance rating of Mass Timber Building Elements
(*Clause* 21.2.1)

Sl. No.	**Construction Types**	**Fire Resistance Rating for Min**			
		Exterior Walls	**Structural Frame**	**Floor Protection**	**Roof Protection**
(1)	(2)	(3)	(4)	(5)	(6)
i)	Type IV-A- Fully protected exterior and interior	180	180	120	90
ii)	Type IV-B- mass timber protected exterior, limited exposed interior	120	120	120	60
iii)	Type IV -C- mass timber protected exterior, exposed timber interior	120	120	120	60

21.2.2 *Charring Rate and Structural Integrity During Fire*

The predictable charring rate of mass timber shall be used in fire design calculations to ensure structural integrity during the duration of the fire. Charring rates for mass timber shall be based on standard fire tests, and the remaining structural capacity of the uncharred wood core should meet the load-bearing requirements.

21.2.3 *Sprinkler Systems and Fire Safety Features*

Buildings utilizing mass timber shall be equipped with automatic sprinkler systems as per the fire safety requirements outlined in Part 4 'Fire and Life Safety' of the Code. These systems will limit fire spread and protect the structural integrity of the timber elements.

Smoke control systems and fire-rated compartmentalization shall be implemented to reduce the risk of fire spread within the building.

21.2.4 *Protection of Connections*

All steel connectors, bolts, and fasteners used in mass timber construction shall be protected with fire-resistant coatings or enclosed within non-combustible materials to prevent failure during fire exposure.

21.3 Minimum Dimensions and Thickness of Mass Timber Elements

21.3.1 *Columns and Beams*

Mass timber columns and beams shall be designed to meet the structural load requirements with a minimum cross-sectional dimension of 200 mm for columns and 150 mm for beams, depending on the span and load requirements.

21.3.2 *Floor and Roof Panels*

CLT panels used for floor and roof assemblies should meet a minimum thickness of 100 mm for floor systems and 85 mm for roof systems to achieve the required fire and structural performance.

21.3.3 *Wall Panels*

CLT or NLT wall panels shall meet a minimum thickness of 125 mm to ensure fire resistance and structural stability under lateral and vertical loads.

21.4 Construction Practices

21.4.1 *Handling and Installation of Mass Timber Elements*

During construction, care should be taken to protect mass timber elements from moisture. Elements shall be stored in dry conditions and protected from water exposure during construction to prevent damage and degradation.

21.4.2 *Assembly and Connections*

Connections between mass timber elements (for example, floor-to-wall, beam-to-column) should be engineered to handle both static and dynamic loads. These connections shall be made using metal connectors, dowels, or bolts designed to prevent movement and ensure continuous load transfer. Special attention should be paid to fire protection at these connection points.

21.4.3 *Fire Sealing of Penetrations*

Any penetrations for services (for example, plumbing, electrical) through mass timber elements shall be sealed with approved fire-rated materials to maintain the integrity of the fire-rated assembly.

21.5 Sustainability and Environmental Benefits

21.5.1 *Environmental Performance*

Mass timber is recognized for its carbon sequestration properties, where wood captures and stores carbon dioxide. Buildings made from mass timber reduce the overall carbon footprint of the construction process compared to traditional materials like steel and concrete.

21.5.2 *Energy Efficiency*

Mass timber inherent thermal insulation properties help to regulate indoor temperatures, thereby reducing energy consumption for heating and cooling. The thermal resistance of wood should be considered in the building envelope design, allowing for thinner wall assemblies with better insulation compared to conventional materials.

22 LIFE CYCLE ASSESSMENT (LCA) OF TIMBER FOR USE IN BUILDINGS

22.1 Timber used in building structures and elements shall undergo a comprehensive life cycle assessment (LCA) to evaluate its environmental impacts across its entire lifecycle, from raw material extraction to disposal or recycling. LCA provides valuable insights into the sustainability of timber and its environmental footprint in building applications. The assessment shall cover the following stages:

a) *Production and Construction*– This stage evaluates the energy and resources required for the extraction, transportation, and processing of raw timber into building materials. It also includes the energy consumption and waste generated during the construction process, as well as the transportation of materials to the construction site.

b) *Use Stage* – The use stage assesses the environmental impacts of timber during the building's operational lifespan. This includes maintenance, repairs, and potential replacement of timber components, considering the durability, performance, and long-term sustainability of the material.

c) *End-of-Life* – At the end of the building's useful life, the timber structure may undergo demolition, with the materials being processed for waste management, recycling, or reuse. This stage assesses the environmental effects of these processes and the potential for timber materials to be repurposed.

d) *Externalized Impacts Beyond the System Boundary* – The incidental effects of recycling, reusing, and recovering energy, water, or materials beyond the system boundaries of the LCA study are included in this stage. These externalized impacts consider how recycled timber or materials might contribute to environmental benefits outside the building's lifecycle.

22.2 Environmental Impact Categories

The LCA shall assess the environmental impact of timber buildings in several categories, which encompass emissions and pollutants generated throughout the lifecycle. These categories include:

a) *Global Warming Potential* – The contribution of greenhouse gas emissions to climate change.
b) *Acidification Potential* – The potential for acidic compounds to form in the environment, affecting ecosystems and infrastructure.
c) *Eutrophication Potential* – The impact of nutrient loading on water bodies, potentially causing excessive algal growth.
d) *Ozone Depletion Potential* – The impact of substances that contribute to the depletion of the ozone layer.
e) *Smog Formation Potential* – The potential for air pollution to contribute to the formation of ground-level ozone and smog.
f) All relevant material and process quantities shall be included in the LCA inventory, and their impacts shall be calculated using recognized tools and methodologies.

22.3 Requirements for Life Cycle Assessment

In the context of building with timber, LCA shall be required for the following purposes:

a) *Decision-Making Support* – Providing building owners and stakeholders with data on the environmental and sustainability aspects of timber, aiding informed decision-making.
b) *Design Evaluation* – Offering insights into material selection and environmental performance across different design possibilities.
c) *Green Building Certification* – Supporting certification processes for green buildings by assessing the environmental credentials of timber products.
d) *Product Comparison* – Demonstrating the environmental advantages of timber in comparison to alternative building materials.
e) *Environmental Benefit Evaluation* – Helping assess the ecological benefits of innovative timber products or policies.
f) *Performance Benchmarking* – Comparing the environmental performance of timber buildings against established benchmarks and sustainability goals.

22.4 Methodology for Conducting LCA

The LCA of timber buildings shall be conducted iteratively, with increasing detail as the design or construction phases progress. The process shall follow these steps:

a) Establish the purpose and scope of the LCA, focusing on the objectives of evaluating timber's environmental impact.
b) Gather data on the timber materials, including their types, quantities, lifespans, and lifecycle stages. Special attention should be given to materials used in the production and use stages.
c) Using LCA tools (for example, SimaPro, MATLAB), assess the environmental impacts of timber buildings. The evaluation shall include biogenic carbon considerations, as timber stores carbon from the atmosphere, contributing to carbon sequestration during its lifecycle.
d) Interpret the LCA results by categorizing environmental impacts by building component, material type, and lifecycle stage. Identify key contributors to the building's overall environmental footprint and visualize the outcomes.
e) Document all findings, including assumptions, methodology, and conclusions, and present the results in reports for stakeholders. The results shall guide sustainable construction practices and decision-making in timber building projects.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of the enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parenthesis indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	707 : 2011	Timber technology and utilization of wood, bamboo and cane — Glossary of terms (*third revision*)
(2)	1708 (Parts 1 to 18) : 1986	Methods of testing small clear specimens of timber (*second revision*)
	2408 : 1963	Methods of static tests of timbers in structural sizes
	2455 : 1990	Methods of sampling of model trees and logs for timber testing and their conversion (*second revision*)
(3)	4970 : 1973	Key for identification of commercial timbers (*first revision*)
(4)	287 : 1993	Recommendations for maximum permissible moisture content of timber used for different purposes (*third revision*)
(5)	3629 : 1986	Specification for structural timber in building (*first revision*)
(6)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)
(7)	2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
(8)	4983 : 1968	Code of practice for design and construction of nail laminated timber beam (*first revision*)
(9)	11096 : 1984	Code of practice for design construction of bolt-jointed construction
(10)	4907 : 2004	Methods of testing timber connector joints (*first revision*)
(11)	9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition
(12)	14616 : 1999	Specification for laminated veneer lumber
(13)	10701 : 2012	Specification for structural plywood (*first revision*)
	4990 : 2024	Plywood for Concrete Shuttering Works — Specification (*fourth revision*)
(14)	4924	Method of test for nail-jointed timber trusses
	(Part 1) : 1968	Destructive test
	(Part 2) : 1968	Proof test
(15)	12120 : 1987	Code of practice for preservation of plywood and other panel products

(16)	4990 : 2011		Specification for plywood for concrete shuttering works (*fourth revision*)
(17)	9307 (Parts 1 to 7) : 1979		Methods of test for wood based structural sandwich construction
(18)	723 : 2023		Specification for steel countersunk head wire nails (*second revision*)
(19)	451 : 1999		Technical supply conditions for wood screws (*fourth revision*)
	6736 : 1972		Specification for slotted countersunk head wood screw
	6739 : 1972		Specification for slotted round head wood screw
	6760 : 1972		Specification for slotted countersunk head wood screws
(20)	1708 (Parts 1 to 18) : 1986		Methods of testing small clear specimens of timber (*second revision*)
(21)	6313		Code of practice for anti-termite measures in buildings
		(Part 1) : 1981	Constructional measures (*first revision*)
		(Part 2) : 2022	Pre-constructional chemical treatment measures (*fourth revision*)
		(Part 3) : 2022	Treatment for existing buildings (*fourth revision*)

****