IS 2366 (1983): Code of practice for nail-jointed timber construction [CED 13: Building Construction Practices including Painting, Varnishing and Allied Finishing]

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Indian Standard

CODE OF PRACTICE FOR NAIL-JOINTED TIMBER CONSTRUCTION

(*First Revision*)

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Indian Standard

CODE OF PRACTICE FOR NAIL-JOINTED TIMBER CONSTRUCTION

(First Revision)

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Indian Standard

CODE OF PRACTICE FOR NAIL-JOINTED TIMBER CONSTRUCTION

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 11 March 1983, after the draft finalized by the Building Construction Practices Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Nail-jointed timber construction is suitable for light timber frames, such as roof trusses for spans up to 18 m. With the facilities of readily available materials and easily understood workmanship, this type of fabrication has a large scope for adoption in timber construction in this country. However, the availability of strength data for nail joints (as applied to Indian Timber) is an important prerequisite for adoption of this type of construction with confidence. This code gives general guidance for nail-jointed timber construction and also furnishes the relevant strength data of nail joints made available by the Forest Research Institute & Colleges, Dehra Dun. Further, the code applies to sawn sections of timber members in monochord and split chord construction only.

0.3 This standard which was first published in 1963, was intended to provide guidance with respect to the construction of nail-jointed timber for structural purposes. The present revision has been taken up to incorporate the improvements found necessary in the light of the usage of this standard and the suggestions made by various bodies implementing it. A number of modifications in the provisions of the standard have been made, important among which are given below:

a) Reference has been drawn to appropriate Indian Standard for requirements and species of timber.

b) The dimensions of any structural member to be used in design have been revised based on actual practice and dimensions of spaced members in split-chord construction has been added.

c) The diameter of nails and arrangement of nails in the joints has been modified.

d) Permissible lateral strength (in double shear) of 5 mm diameter, and 15 cm long nails has been added, along with a method for testing nail joints in timber.

e) An example for design of 4 m span nail-jointed truss has been replaced by that of an example of 12 m span.

0.4 The Sectional Committee responsible for the preparation of this standard has taken into consideration the views of producers, consumers and technologists and has related the standard to the manufacturing and trade practices followed in the country in this field. Due weightage has also been given to the need for international co-ordination among standards prevailing in different countries of the world.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the fabrication, finishing erection and maintenance of nail-jointed timber construction for structural purposes.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Temporary and Permanent Structures — Temporary structures would mean those which are dismantled immediately after use such as in the case of form work, shuttering, structures for exhibitions, etc, where the life of the work is generally of very short duration. All other structures will be classified as permanent structures.

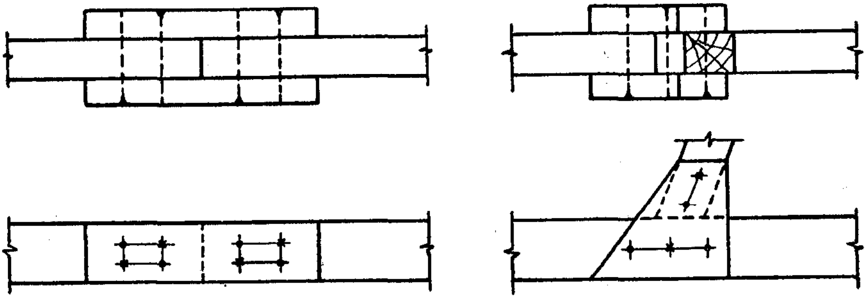
2.2 Diamond Pointed Nail — Nail with point which commonly resembles an octahedron and less commonly a tetrahedron.

2.3 Timber Fish Plate — Timber plates which are used in a joint to hold the members in alignment and also stiffen the joints. The main function of these plates is to assist in transferring stresses from one member to another. These plates are also known as timber gussets or timber splice plates.

2.4 Timber Spacer Block — Thick pieces or blocks of wood which are used in spaces between the structural elements which are connected to keep up the integrity and safety of the members.

*Rules for rounding off numerical values (*revised*).

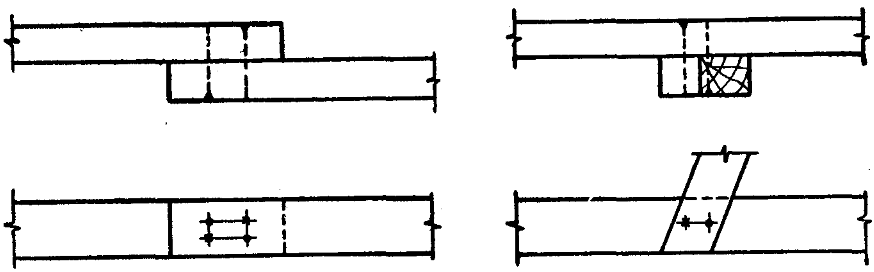
2.5 Monochord Type Butt Joint — This is a type of single member joint as shown in Fig. 1.



1A LENGTHENING JOINT 1B NODE JOINT

Fig. 1 Monochord Type Butt Joint

2.6 Monochord Type Lap Joint — This is a type of single member joint as shown in Fig 2.



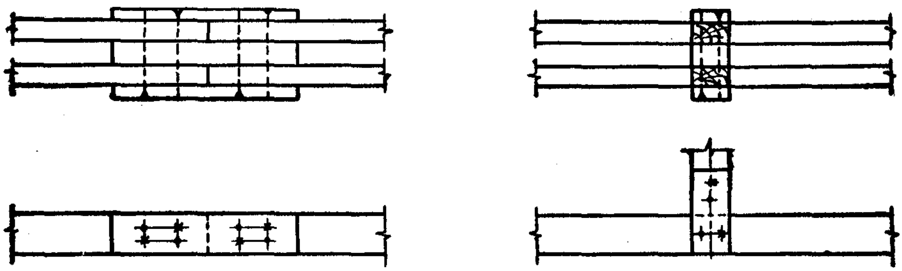
2A LENGTHENING JOINT 2B NODE JOINT

Fig. 2 Monochord Type Lap Joint

2.7 Split-Chord Type Butt Joint — This is a type of multiple member joint as shown in Fig. 3.

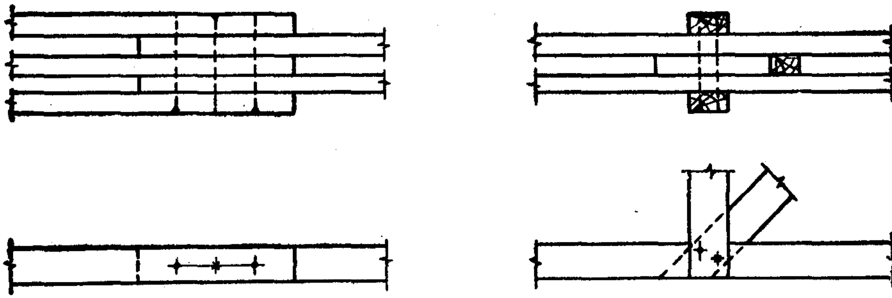
2.8 Split-Chord Type Lap Joint — This is a type of multiple member joint as shown in Fig. 4.

2.9 Clenching — Turning over the projecting point of a nail so as to be flush with the surface of the member, thus increasing holding power of nails and making withdrawal more difficult. Clenching perpendicular to grain gives greater nail holding power than parallel to grain (*see* Fig. 5).



3A LENGTHENING JOINT　　　　3B NODE JOINT

Fig. 3 Split-Chord Type Butt Joint



4A LENGTHENING JOINT　　　　4B NODE JOINT

Fig. 4 Split-Chord Type Lap Joint

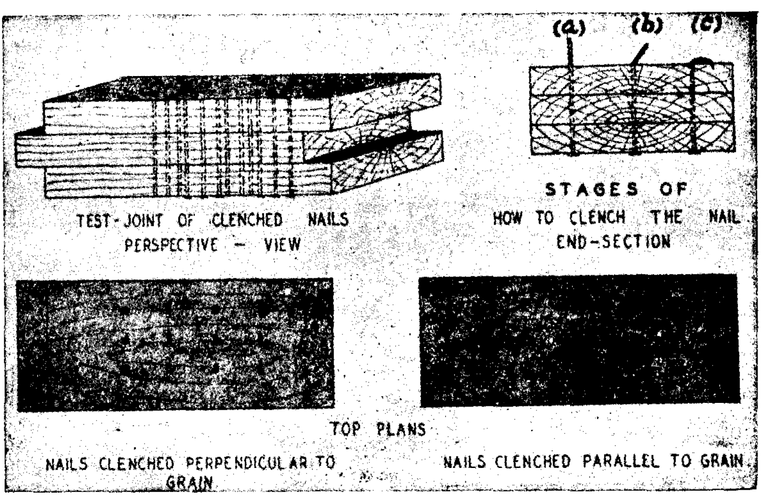
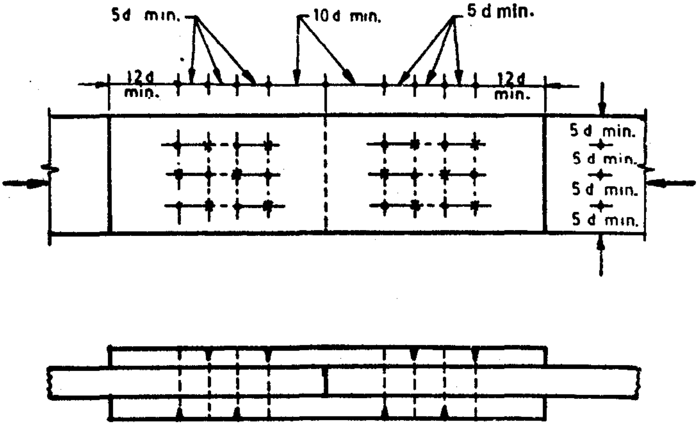
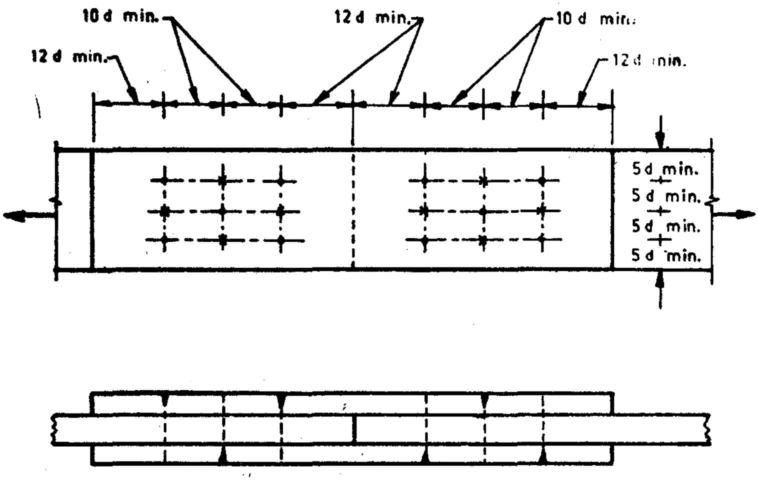


Fig. 5 Clenching of Nails

2.10 Effective Distance — The distance measured parallel to grain (effective end distance) or perpendicular to grain (effective edge distance) from the centre of the nail to the squared end or edge of the member (*see* Fig. 6).



6A Joints in Members Subjected to Pure Compression



6B Joints in Members Subjected to Pure Tension

d = shank diameter of nails

FIG. 6 SPACING OF NAILS IN LENGTHENING JOINTS

3. NECESSARY INFORMATION

3.1 For efficient planning and design of nail-jointed timber fabrication and construction, the following information shall be procured by those responsible for the work:

a) Species and grading of timber used,
b) Moisture content of timber,
c) Details of pretreatment, and
d) Design data.

4. MATERIALS

4.1 Timber — Timber used for nail-jointed construction shall conform to the requirements and species specified in IS : 3629-1966*.

4.2 Nails

4.2.1 The nails used for timber joints shall be plain-head nails conforming to IS : 723-1972†. The nails shall be diamond pointed.

4.2.2 For locations where excess rusting of nails is anticipated such as in sheds for chemical industries manufacturing acids and other chemicals and also where saline climatic effects are prevalent (for example coastal regions) use of galvanized wire nails is recommended so as to avoid rusting of nails and thereby weakening structural efficiency.

5. DESIGN CONSIDERATIONS

5.1 Nailed timber joints may be used both for monochord type and split-chord type structural joints. Reference may be made to IS : 883-1970‡ while designing nail-jointed units.

5.2 Dimensions of Members — The dimensions of any individual piece of timber (that is, any single member) shall be within the range given in **5.2.1** to **5.2.3**.

5.2.1 The minimum thickness of main member in monochord construction shall be 30 mm.

5.2.2 The minimum individual thickness of spaced members in split-chord construction shall be 20 and 25 mm for web and chord members respectively.

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*Specification for structural timber in building.
†Specification for steel countersunk head wire nails (*second revision*).
‡Code of practice for design of structural timber in building (*third revision*).

5.2.3 The space between two spaced members shall be restricted to maximum of 3 times the individual thickness of the member. In case of spaced web members, it may be greater for jointing facilities.

5.3 Preferably no lengthening joint shall be located at a panel point, and generally not more than two, but preferably one lengthening joint, shall be permitted between the two panel points of the members.

5.4 Thickness of Gusset or Splice or Fish Plates

5.4.1 The minimum thickness of timber splice plate shall be 20 mm.

5.4.2 Splice plates should be avoided at the node joints which are liable to crack and warp thus endangering the strength of the joints and the stability of the member. If it is not possible, the splice plates shall be provided in such a way that their grains coincide with the direction of the load to be transmitted.

5.4.3 The total combined thickness of the gusset or splice plates on either side of the joint in a roof truss of monochord type construction shall not be less than one and a half times the thickness of the main member.

5.4.3.1 The strength data for joints given in this standard apply to fish plates of solid wood only. Materials other than solid wood like plywood and particle board in composite structural assemblies, may be used for gussets when their strength requirements have been established.

5.4.4 The total combined thickness of all spacer blocks or plates including outer splice plates or combination of these, at any joint in a roof truss of 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.

5.5 Length and Diameter of Nails — The diameter of the nails shall be between 1/11 to 1/6 of the least thickness of the members beingj ointed. The length of the nails shall be equal to at least the total thickness of the joining members at the joint.

5.6 Strength of Nailed Joints

5.6.1 Where a number of nails are used in a joint, the allowable load in withdrawal or lateral resistance shall be the sum of the allowable loads for the individual nails provided that the centroid of the group of fixing nails lies on the axis of the member and the spacings between nails, end distances and edge distances are sufficient to develop the full strength of each nail. 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.

5.6.2 As far as practicable, the nails shall be arranged so that the line of force in a member passes through the centroid of the group of nails transmitting load to it. Where it is not practicable, suitable allowance shall be made for any eccentricity in computing the maximum load on the fixing nails. This shall be taken as 25 to 30 percent higher.

5.6.3 The permissible lateral strength of mild steel wire shall be as given in Table 1 and Table 2 for different species of timber, which applies to nails that have their points cut flush with the faces. For nails clenched across the grain, the strength may be increased by 20 percent. The values shall be modified by the factor K_2 given in IS : 883-1970* for use in structural design.

5.6.3.1 A method of testing nail joints in timber is given in Appendix A for guidance.

5.6.4 Nails should preferably be driven from opposite faces, that is, the adjacent nails are driven alternatively from either face of joint.

5.6.5 For a rigid joint, minimum of 2 nails for nodal joints and 4 nails for lengthening joints are essential.

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

5.7 Arrangement of Nails in the Joints — The end distance, edge distance and spacing of nails in a nailed joint should be such as to avoid undue splitting of the wood and should not be less than those given in **5.7.1**.

5.7.1 The requirements of spacing of nails is a lengthening joint shall be as shown in Fig. 6.

5.7.1.1 The loaded or unloaded end of any of the members in a lengthening joint shall have an effective end distance as given below:

a) For members subjected to pure tension — 12 *d*, *Min*

b) For members subjected to pure compression — 10 *d*, *Min*

where *d* is shank diameter of nails.

5.7.1.2 The spacing of nails in the direction of grains of the wood shall be as given below:

a) For members subjected to pure tension — 10 *d*, *Min*

b) For members subjected to pure compression — 5 *d*, *Min*

where *d* is shank diameter of nails.

5.7.1.3 The effective edge distance for the nails shall not be less than 5 *d*, where *d* is the nail shank diameter.

*Code of practice for design of structural timber in building (*third revision*).

TABLE 1 PERMISSIBLE LATERAL STRENGTHS (IN DOUBLE SHEAR) OF NAILS 3·55 mm DIA, 80 mm LONG

(*Clauses* 5.6.3 *and* 6.2.1.3)

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (for Both Lengthening Joints & Node Joints)
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
(1)	(2)	(3)	(4)	(5)	(6)
			N × 10² (kgf)	N × 10² (kgf)	N × 10² (kgf)
1.	**Albies pirdrow*	Fir	8 (80)	2 (20)	12 (120)
2.	*Acacia nilotica*	Babul	15 (150)	11 (110)	34 (340)
3.	*Acrocarpus fraxinifolius*	Mundani	18 (180)	9·5 (95)	19·5 (195)
4.	*Adina cordifolia*	Haldu	23·5 (235)	10 (100)	22 (220)
5.	*Albizia lebbeck*	Kokko	20 (200)	7 (70)	24 (240)
6.	*Albizia oderatissima*	Kala Siris	14 (140)	5 (50)	22 (220)
7.	*Anogeissus latifolia*	Axlewood	20 (200)	10 (100)	29 (290)
8.	*Aphanamixis polystachya*	Pitraj	19 (190)	9 (90)	19 (190)
9.	**Calophyllum sp*	Poon	16 (160)	9 (90)	21 (210)
10.	*Canarium euphyllum*	White dhup	9 (90)	8 (80)	10·5 (105)
11.	*Castanopsis sp*	Indian chestnut	18 (180)	10·5 (105)	23·5 (235)
12.	**Cedrus deodara*	Deodar	9 (90)	4 (40)	15 (150)
13.	*Chukrasia tabularis*	Chikrassy	24 (240)	8 (80)	27 (270)
14.	**Cinnamomum sp*	Cinnomon	12 (120)	9 (90)	13 (130)
15.	*Cupressus torulosa*	Cypress	6 (60)	5 (50)	18 (180)
16.	*Dipterocarpus macrocarpus*	Hollong	17 (170)	7 (70)	20 (200)
17.	*Dipterocarpus sp*	Gurjan	19 (190)	9 (90)	19 (190)
18.	*Dillenia pertagyna*	Dillenia	16·5 (165)	12 (120)	16 (160)
19.	*Diospyros melanoxylon*	Ebony	26·5 (265)	10 (100)	30·5 (305)
20.	*Eucalyptus eugenioides*	Eucalyptus	17 (170)	10 (100)	30 (300)

(*Continued*)

TABLE 1 PERMISSIBLE LATERAL STRENGTHS (IN DOUBLE SHEAR) OF NAILS 3·55 mm DIA, 80 mm LONG — *Contd*

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (For Both Lengthening Joints & Node Joints)
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
(1)	(2)	(3)	(4)	(5)	(6)
			$N \times 10^2$ (kgf)	$N \times 10^2$ (kgf)	$N \times 10^2$ (kgf)
21.	**Grewia tilifolia*	Dhaman	13 (130)	5 (50)	24 (240)
22.	*Lagerstroemia sp*	Jarul	24·5 (245)	21·5 (215)	22·5 (225)
23.	*Hopea parviflora*	Hopea	31·5 (315)	13 (130)	28·5 (285)
24.	**Lagerstroemia sp*	Lendi	19 (190)	5 (50)	26 (260)
25.	*Mangifera indica*	Mango	11 (110)	9 (90)	16 (160)
26.	*Maniltoa polyandra*	Ping	26 (260)	23·5 (235)	32 (320)
27.	*Mesua ferrea*	Mesua	26 (260)	8 (80)	41 (410)
28.	*Michelia sp*	Champ	13 (130)	9 (90)	20 (200)
29.	**Millingtonia sp*		10·5 (105)	6 (60)	17 (170)
30.	*Morus alba*	Mulberry	13 (130)	10·5 (105)	22·5 (225)
31.	*Melia azedarach*	Persian lilac (bakain)	10·5 (105)	2·5 (25)	9 (90)
32.	*Ougeinia oojeinensis*	Sandan	17 (170)	11 (110)	18 (180)
33.	**Phoebe sp*	Bonsum	12 (120)	6 (60)	13 (130)
34.	**Pinus roxburghii*	Chir	11 (110)	10 (100)	16 (160)
35.	**Pinus wallichiana*	Kail	7 (70)	3 (30)	9 (90)
36.	*Pterocarpus marsupium*	Bijasal	15 (150)	12 (120)	27 (270)
37.	*Pterocarpus dalbergiodes*	Paduak	19 (190)	14 (140)	23 (230)
38.	*Planchonia andamanica*	Red bombwe	14 (140)	13 (130)	29 (290)
39.	*Quercus sp*	Oak	11 (110)	11 (110)	27 (270)
40.	*Scheichera cleosa*	Kusum	23 (230)	16 (160)	40 (400)
41.	*Shorea roubusta*	Sal (M. P.)	23 (230)	15·5 (155)	19·5 (195)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19 (190)

43.	*Stereospenmum*	Padriwood	16 (160)	8 (80)	19·5 (195)
44.	*Syzygium sp*	Jamun	15 (150)	12 (120)	25 (250)
45.	*Tectona grandis*	Teak	14 (140)	8 (80)	13 (130)
46.	*Terminalia bellirica*	Bahera	10 (100)	10 (100)	14 (140)
47.	*Terminalia biolata*	White chuglam	18 (180)	9 (90)	21 (210)
48.	*Terminalia procera*	Badam	18 (180)	10·5 (105)	20 (200)
49.	**Terminalia manii*	Black chuglam	23 (230)	10 (100)	33 (330)
50.	*Terminalia myriocarpa*	Hollock	13 (130)	10 (100)	19 (190)
51.	*Terminalia alata*	Sain	16 (160)	16 (160)	29 (290)
52.	*Toona sp*	Toona	10 (100)	8 (80)	21 (210)
53.	*Xylia xylacarpa*	Irul	23 (230)	6 (60)	33 (330)
54.	*Toona ciliata*	Toon	16 (160)	9 (90)	21 (210)

*Species requires no preboring for nail penetration.

NOTE 1 — Nails of 3·55 mm diameter are most commonly used. The above values can also be used for 4 mm diameter, 100 mm long nails.

NOTE 2 — The values in N are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9·806 65 N.

TABLE 2 PERMISSIBLE LATERAL STRENGTHS (IN DOUBLE SHEAR) OF NAILS 5·00 mm DIA, 125 mm and 150 mm LONG

(*Clauses* 5.6.3 *and* 6.2.1.3)

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	
(1)	(2)	(3)	(4)	(5)	(6)
			N×10² (kgf)	N×10² (kgf)	N×10² (kgf)
1.	**Abies pindrow*	Fir	16·5 (165)	4·5 (45)	21 (210)
2.	*Acacia catechu*	Khair	42 (420)	25 (250)	71·5 (715)
3.	**Acacia nilotica*	Babul	27 (270)	13·5 (135)	53 (530)
4.	*Alibizia procera*	Safed Siris	35 (350)	18 (180)	— —
5.	**Alibizia odoratissima*	Kala Siris	27·5 (275)	17·5 (175)	45 (450)
6.	*Alstonia scholaris*	Chatian	9·5 (95)	5·5 (55)	27 (270)
7.	*Anogeissus latifolia*	Axlewood	22·5 (225)	13 (130)	46·5 (465)
8.	*Cupressus torulosa*	Cypress	20 (200)	7 (70)	27 (270)
9.	*Cullenia rosayroana*	Karani	11 (110)	9·5 (95)	30 (300)
10.	*Dalbergia sissoo*	Sissoo	17 (170)	15 (150)	43 (430)
11.	*Diptrocarous sp.*	Gurjan	19·5 (195)	9·5 (95)	33 (330)
12.	*Hardwickia binata*	Anjan	32 (320)	19 (190)	59 (590)
13.	*Hopea perviflora*	Hopea	60·5 (605)	25 (250)	61·5 (615)
14.	*Holoptelea integrifolia*	Kanju	18 (180)	12·5 (125)	37·5 (375)
15.	**Mangifera indica*	Mango	22·5 (225)	15 (150)	32 (320)
16.	*Mesua ferrea*	Mesua	24 (240)	15·5 (155)	57·5 (575)
17.	**Michelia champaca*	Champ	26 (260)	12·5 (125)	39 (390)
18.	*Pterocarpus marsupium*	Bijasal	20·5 (205)	15 (150)	43 (430)
19.	**Pinus roxburghii*	Chir	9 (90)	6 (60)	24 (240)

20.	*Shorea robusta* (*U. P.*)	Sal	19·5 (195)	17 (170)	37 (370)
21.	*Shorea robusta*	Sal	30·5 (305)	20 (200)	41 (410)
22.	*Schleichera cleosa*	Kusun	15 (150)	14 (140)	55 (550)
23.	*Stereospimum personatum*	Padriwood	22 (220)	8 (80)	34 (340)
24.	*Syzygium cumini*	Jamun	18 (180)	14·5 (145)	38·5 (385)
25.	*Terminalia myriocarpa*	Hollock	27·5 (275)	9 (90)	41 (410)
26.	*Tectona grandis*	Teak	28 (280)	13 (130)	30 (300)
27.	*Hopea utilis*	Karung Kangoo	31 (310)	10 (100)	58 (580)
28.	**Phoabe spp.*	Bonsum	20 (200)	7·5 (75)	30 (300)

*Species requires no preboring for nail penetration.

NOTE 1 — Nails of 5·00 mm diameter are commonly used.

NOTE 2 — The values in N are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9·806 65 N.

5.7.1.4 The spacing between the rows of nails measured perpendicular to the grains of wood shall not be less than 5 *d*, where *d* is the nail shank diameter.

5.7.2 *Node Joints* — The requirements for spacing of nails in node joints shall be as given in Fig. 7, where the members are at right angle and as in Fig. 8 where the members are inclined to one another at angles other than 90°. Figure 9 shows a node joint with reversible stresses.

5.8 Special Considerations in Nail-Jointed Truss Construction — The stiffness of nail-jointed construction shall be determined in accordance with the provision of IS : 4924 (Part 1)-1968* and IS : 4924 (Part 2)-1968†.

5.8.1 The initial upward camber provided at the centre of the lower chords of nail-jointed timber trusses shall be as follows:

a) For permanent structures using seasoned wood — Not less than $\frac{L}{200}$

b) For temporary structures using unseasoned or partially seasoned wood — Not less than $\frac{L}{100}$

where L = effective span of the truss.

5.9 Example — An example of design of a typical truss with nailed joints is given in Appendix B to illustrate the provisions of **5.1** to **5.8**.

6. FABRICATION

6.1 Preliminary Work

6.1.1 Different members as well as fish plates and spacer blocks shall be first prepared to the required sizes according to the relevant drawings, and shall be properly dressed and fabricated. All the faces of the members shall be given at least one coat of primer in accordance with IS : 2338 (Part 1)-1967‡ and IS : 2338 (Part 2)-1967§. Quantities of nails of various lengths and diameters as described in the relevant drawings shall be procured. Drilling bits of the required diameters appropriate to the nails and species shall be procured.

6.1.2 On a level platform or ground, layout of the structural unit shall be done and the widths of members clearly marked. Required camber shall be provided by shifting the central portion of the bottom chord centre line. The top and bottom chord centre line shall be divided into the required number of panel lengths. The width of each member shall then be marked clearly along the centre line including the position of splice plates and spacer blocks.

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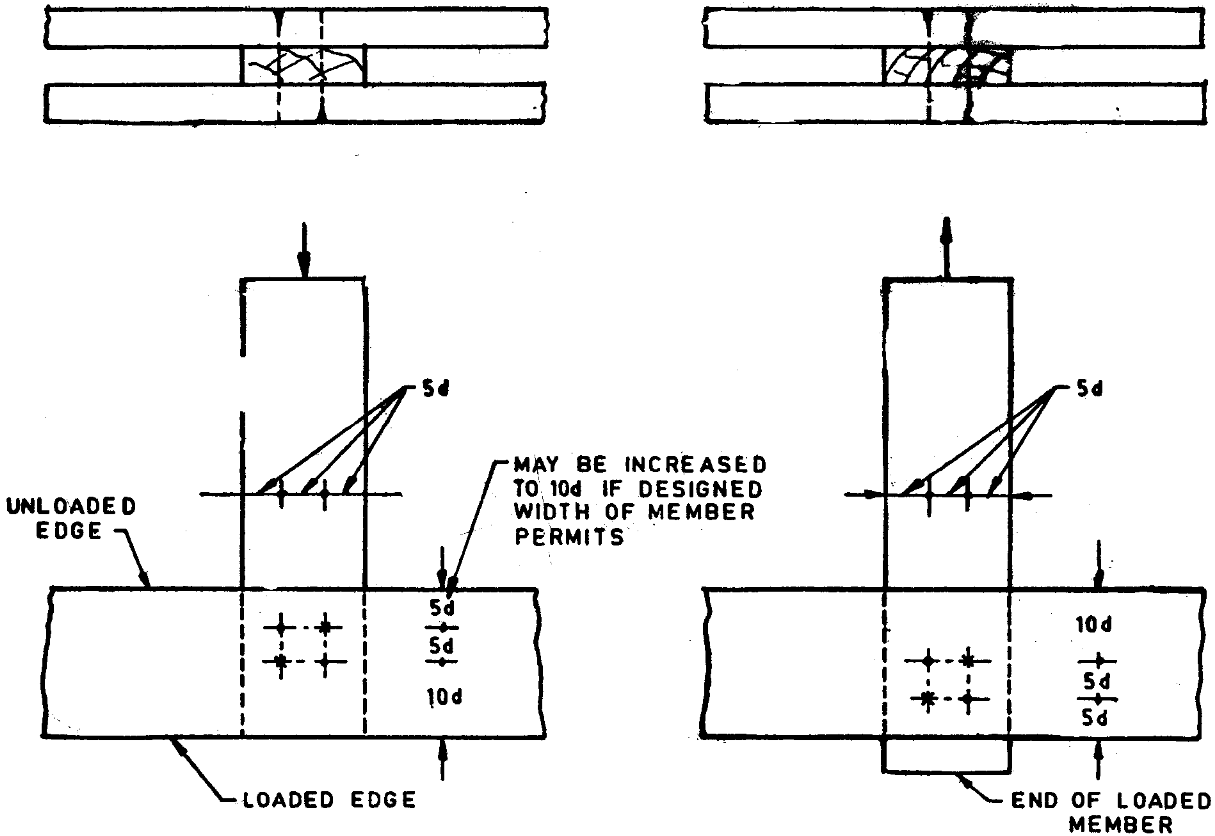
*Method of test for nail-jointed timber trusses: Part 1 Destructive test.

†Method of test for nail-jointed timber trusses: Part 2 Proof test.

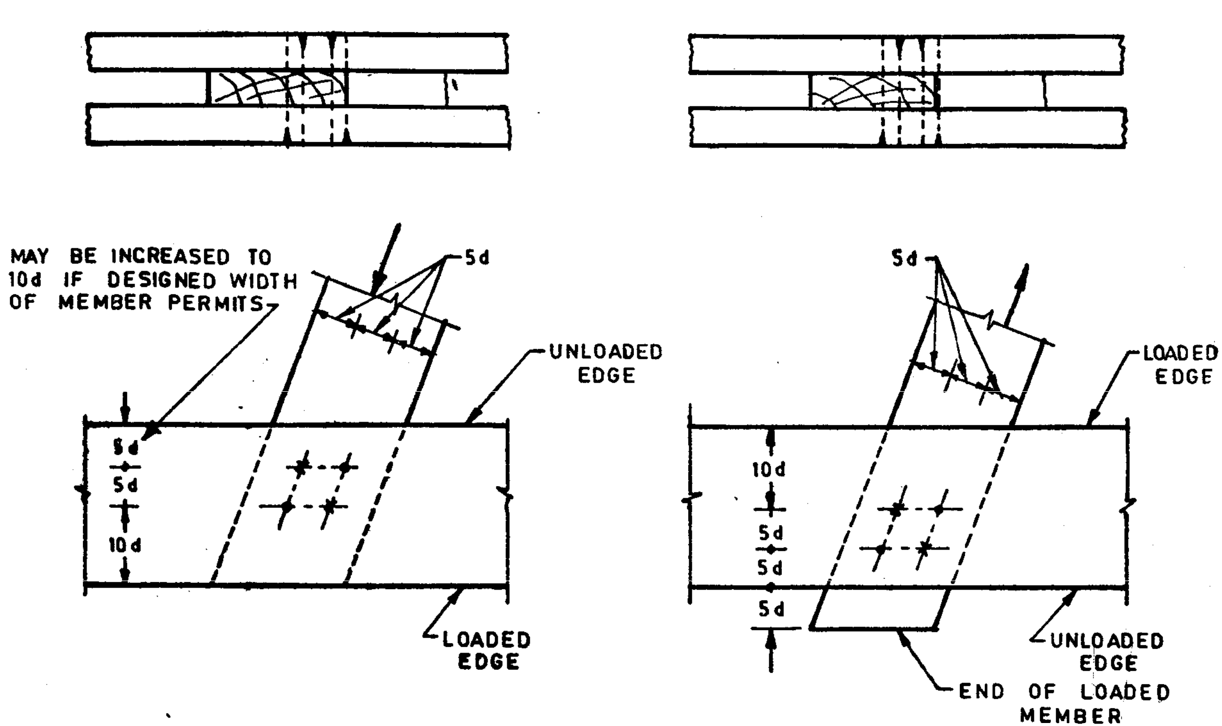
‡Code of practice for finishing of wood and wood-based materials: Part 1 Operations and workmanship.

§Code of practice for finishing of wood and wood based materials: Part 2 Schedules.



d = shank diameter of nails

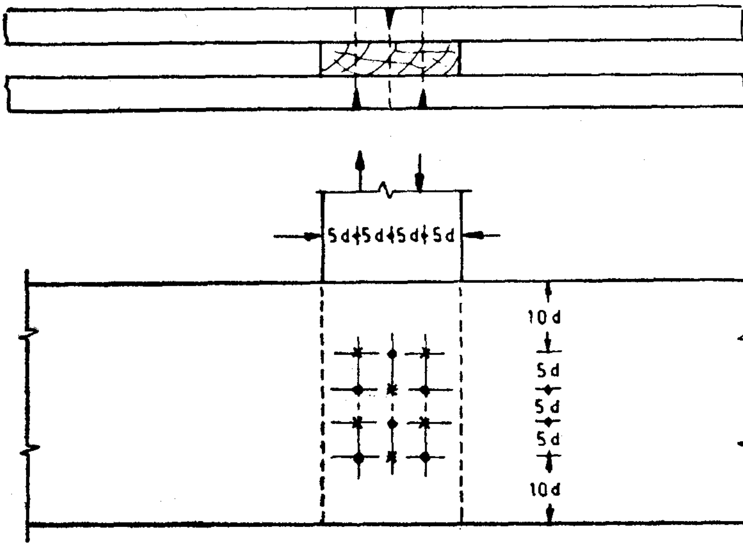
FIG. 7 SPACING OF NAILS IN NODE JOINTS SUBJECTED TO COMPRESSION AND TENSION



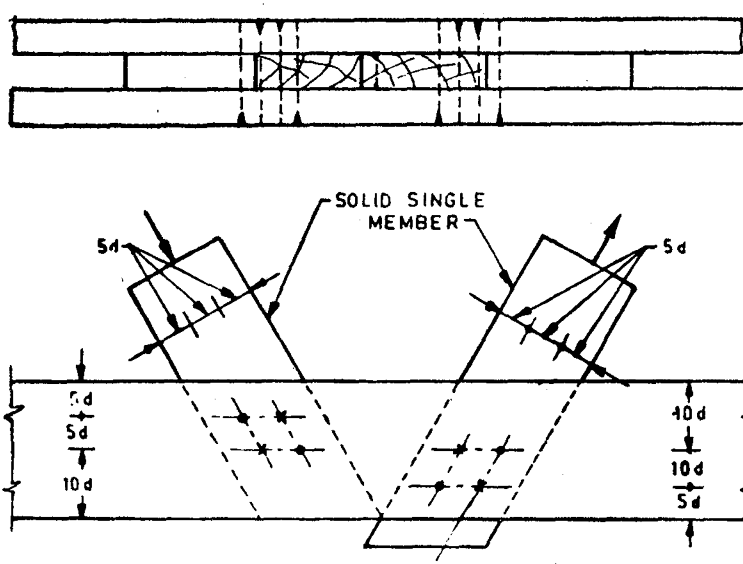
8A Node Joint Subjected to Compression　　8B Node Joint Subjected to Tension

d = Shank diameter of nails

FIG. 8 SPACING OF NAILS IN NODE JOINTS SUBJECTED TO DOUBLE SHEAR

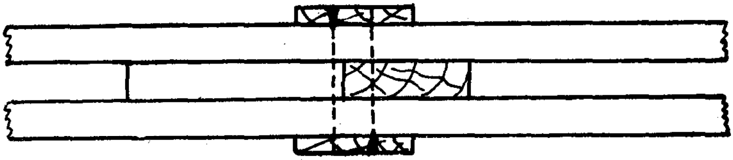


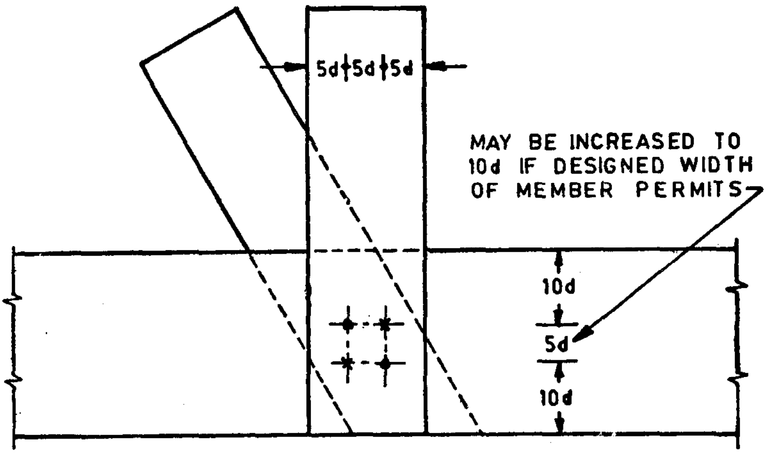
9A Double Shear Joint



9B Node Joint Showing Web and Chord Connection

FIG. 9 SPACING OF NAILS IN NODE JOINTS SUBJECTED TO REVERSIBLE STRESSES — *Contd*





9C Quadruple Shear Joint Showing Wed and Chord Connection

d = Shank diameter of nails

FIG. 9 SPACING OF NAILS IN NODE JOINTS SUBJECTED TO REVERSIBLE STRESSES

6.1.3 The required number of members as given in the drawing shall be placed over the markings already made on the ground. Nails at apex and heal joints shall be driven temporarily, which shall form a complete skeleton of the truss without webs.

6.1.4 Various lengths of webs shall be inserted or placed (as the case may be that is split-chord or monochord construction) in the top and bottom chord.

6.2 Nailing — Nail distances shall be marked on the hardboard or plywood jigs of various sizes according to the drawing. These distances shall be transferred on the splice plates. The above operation shall be carried out in stages successively like measuring the gauge of the nail, measuring the gauge of the prebore, studing the joint on the blue print, making the nail distance on template, marking the nail position on the member with template, placing the members in position for preboring and finally driving the nails conforming to the requirements of **6.2.1** to **6.2.3**. Nails loaded laterally should not be driven slant except in joints where there is no reversal of stress and where the direction of slant is such that the joint will tighten under load.

6.2.1 *Penetration of Nails*

6.2.1.1 *Lap joint (nails in single shear)* — The minimum length of penetration of nail in the thicker member should be one-and-a-half times the penetration in the thinner member. Nails are driven from the side of the thinner member into the thicker member in such cases.

6.2.1.2 *Butt joint (nails in single shear)* — The length of penetration of nails in the middle member should be equal to the penetration in the thinner member.

6.2.1.3 *Butt joint (nails in double shear)* — The length of penetration should be such that the nail penetrates all the members completely.

NOTE — The lateral loads taken by nails as tabulated in Tables 1 and 2 are based on full penetration of nails in all the three members if the butt joint is in double shear.

6.2.2 *Prebore*

6.2.2.1 Prebore is essential to drive nails easily in the structural wood without unnecessary splitting of timber members. Besides ensuring straight penetration, preboring reduces internal damage to wood fibres, thereby maintaining the full lateral strength. The diameter of the prebore corresponding to various nail sizes shall be as recommended in Table 3.

6.2.3 *Finishing of Nails* — The nail points shall be finished in one of the following ways which are given in order of preference from strength point of view as well as other constructional facilities:

a) Clenched across the grain,

b) Clenched along the grain,

c) Protruding from the surface of the joint, and

d) Cut so as to flush with the joint face.

TABLE 3 RECOMMENDED PREBORE FOR VARIOUS NAIL SIZES

(*Clause* 6.2.2.1)

Sl No.	Length of Nail	Diameter of Nail Shank *d*	Diameter of Prebore Suitable for		
			Very Hardwood	Hardwood	Softwood
(1)	(2)	(3)	(4)	(5)	(6)
	mm	mm	mm	mm	mm
i)	50	2·50	2·24	2·00	1·80
ii)	60	2·80	2·50	2·24	2·00
iii)	80	3·55	3·15	2·80	2·50
iv)	100	4·00	3·55	3·15	2·80
v)	125	5·00	4·50	4·00	3·55
vi)	150	5·00	4·50	4 00	3·55

7. FINISHING OF NAIL-JOINTED TIMBER WORK

7.1 After fabrication of the jointed timber work and before erection one more coat of paint shall be supplied in accordance with IS : 2338 (Part 1)-1967* and IS : 2338 (Part 2)-1967†. This paint coat will help in reducing the subsequent moisture variation during the life time of the structure.

8. ERECTION OF NAIL-JOINTED ROOF TRUSS

8.1 Effective bracing is one of the most important and yet most neglected aspect of sound roof construction. Erection of nailed roof truss need careful planning, since no erection stresses are generally catered for in the design calculations. Roof framing presents problem during erection, as the purlins, sheeting and other allied components are installed.

8.1.1 When assembled nail-jointed roof truss should be raised in vertical position (to minimize whipping action). Erection equipment, namely rope-pulley, chain-pulley block and wooden *ballies*, may be selected keeping in view the total load to be lifted, height and working space available in the structure. Erection may be started from the end truss in a structure. Temporary bracing is necessary particularly for compression members such as top chord during erection to keep the trusses vertical until the rest of the roof structure is complete.

*Code of practice for finishing of wood and wood based materials: Part 1 Operations and workmanship.

†Code of practice for finishing of wood and wood based materials: Part 2 Schedules.

8.2 While roof trusses up to 7 m span, owing to their being light weight could be lifted manually and fixed in position with the help of common ladders, larger units may require use of cham-pulley or the like.

Following steps in sequence would be helpful during erection:

a) Roof trusses may be kept near the site,

b) Wooden pole (*ballie*) is erected in the middle of span (slightly off truss line) with the help of ropes tied at the top, anchored with pegs in the ground. Pulley is to be fixed on the pole, well above the expected height of apex of the truss.

c) Truss is suitably lashed with ropes at the panel points, at one-third span of bottom chord or preferably equidistant joints formed by web members from apex to the bottom chord and with loose rope sling formed at apex for tying with lifting pulley or the like.

d) Truss to be erected should be vertically placed by the side of the wooden *ballie.*

e) Rope pulley should be suitably attached to the sling at the apex.

NOTE — Members should be protected from injury at sling points by suitable cushioning.

f) Truss is now lifted and placed in position. Alignment of truss is checked.

g) Apex of end truss is then temporarily braced on both sides at ground for stability with the help of ropes.

h) Ballie is then shifted near to the line of second truss and process of lifting repeated. Two trusses are then temporarily braced together with battens on the top or the like.

j) The sequence of operation from (a) to (h) may be repeated till the last truss is erected in structure taking care that all trusses previously erected have been temporarily braced with each other.

k) Fixing of purlins and roof coverings are then completed.

9. MAINTENANCE

9.1 Nail-jointed timber frames, if not much exposed, shall be maintained by painting with one or more coats of paint at least once in five years. For exposed structures the painting shall be done at least once in two years.

9.2 Normally very little maintenance is required for properly designed, fabricated and erected nail-jointed timber structural units as design recommendations contain a safety factor that normally includes the need for such maintenance.

9.3 A general inspection is recommended within the first year of service as timber gets gradually seasoned after assembly, particularly if well seasoned timber is not used initially. General inspection of the joints and members is usually desirable. General loosening of joints, excessive deflection, twisting or bowing of members or misaligned sections are to be periodically inspected for improving the durability of a structure.

9.4 Nail-jointed timber structures are very easy to repair. The repairs involve only reinforcement of joints weakened by inadequate fastenings, replacement or repair of damaged or decayed wood and reinforcement or repairs of splitted or twisted members.

9.5 Testing of nail-jointed timber trusses may be done in accordance with IS : 4925 (Part 1)-1968* and IS : 4925 (Part 2)-1968†.

APPENDIX A

(*Clause* 5.6.3.1)

METHOD OF TESTING NAIL JOINTS

A-1. TEST SPECIMENS

A-1.1 The test specimen shall conform to the requirements given in **A-1.2** or **A-1.3** as appropriate to the test. The ends of the specimen shall be planed accurately so as to have the end section truly perpendicular to the longitudinal edges.

A-1.2 Specimens for Compression Parallel to Grain — Each specimen shall consist of three pieces, each of $35d \times 25d \times \frac{l}{3}$ mm size where 'd' is the shank diameter and 'l' is the length of the nail in the joint. Out of these three pieces, the central pieces project $10d$ from the other two and all the three pieces shall jointed with 8 number, 3·55 mm diameter nails 75 mm long in four rows, driven two in a row each at a distance of $10d$ from the upper end of the side members and the lower end of middle member respectively. Intermediate distance between the two lines (horizontal) of nails is kept as $5d$. The adjacent nails shall be driven from alternate sides at a distance of $5d$ from any edge (*see* Fig. 10 A).

*Method of test for nail-jointed timber trusses: Part 1 Destructive test.

†Method of test for nail-jointed timber trusses: Part 2 Prooftest.

A-1.3 Specimens for Compression Perpendicular to Grain — Each specimen shall consist of three members out of which two side members shall each be of length 450 mm, width 20*d* and thickness *l*/3 mm and the central member of length 200 mm, width 25*d* and thickness *l*/3 mm. The grains of the two side members shall be perpendicular to the direction of the load while those of the central member shall be parallel to the direction of the load. The three members shall be jointed with eight nails in four rows, two in a row. The first line (horizontal) of nails shall be at a distance of 10*d* from the loaded end of the central member, the other line at 5*d* from the upper unloaded edge of the side members. The distance between the two horizontal lines of nails shall be 5*d*. Any two adjacent nails in a row shall be driven from alternate sides at a distance of 5*d* from each edge (*see* Fig. 10 B).

NOTE — Sizes of timber members shall be applicable to nails of size 3·55 mm × 75 mm. For nails of other sizes the timber members shall be different dimensions.

A-2. PROCEDURE

A-2.1 The specimen shall be so placed that the centre of the cross section of the specimen is vertically in line with the centres of the moving heads of the machine. A load of not more than 50 kgf (500 N) shall be applied for initial set of the joint.

A-2.2 The rate of loading shall be constant throughout a test and shall be calculated by the following formula:

$$R = 0{\cdot}33\ d$$

where

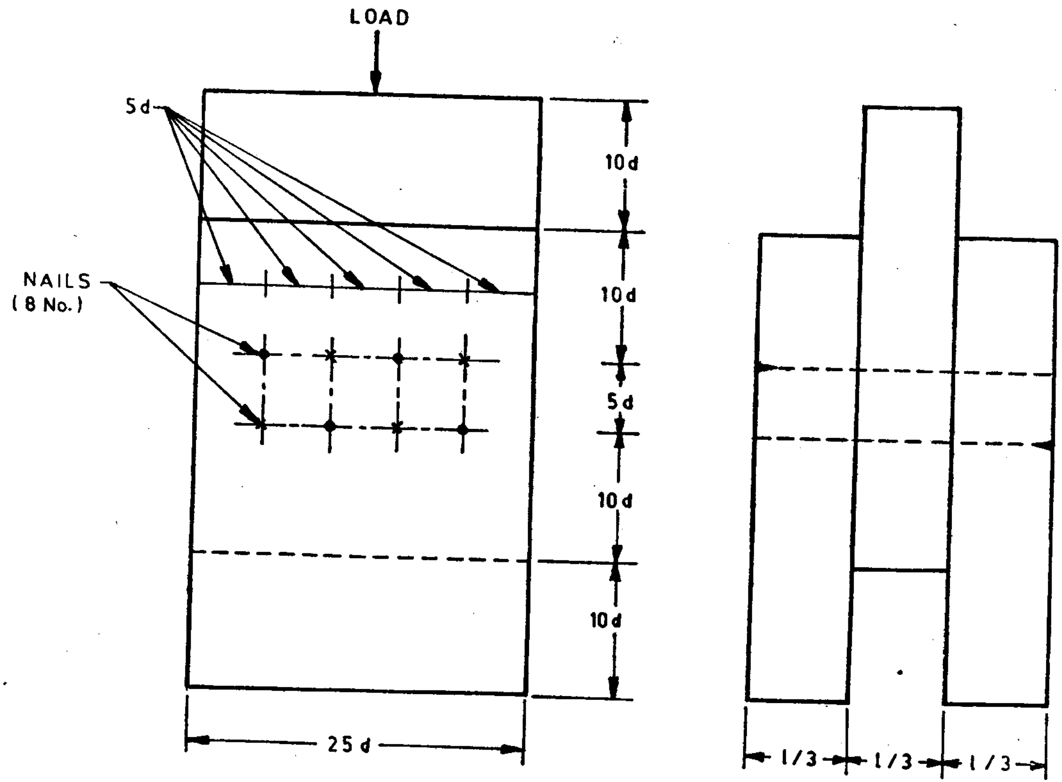
R = machine cross-head speed in mm/min, and
d = diameter of nail in mm.

A-2.2.1 The above rate of loading may be increased or decreased by 25 percent of calculated value depending upon the feasibility of taking the slip readings.

A-2.3 Moisture Determination — The moisture content of the joint shall be noted with the help of Hydromat (moisture meter). It shall be 15 to 16 percent of the oven-dry weight.

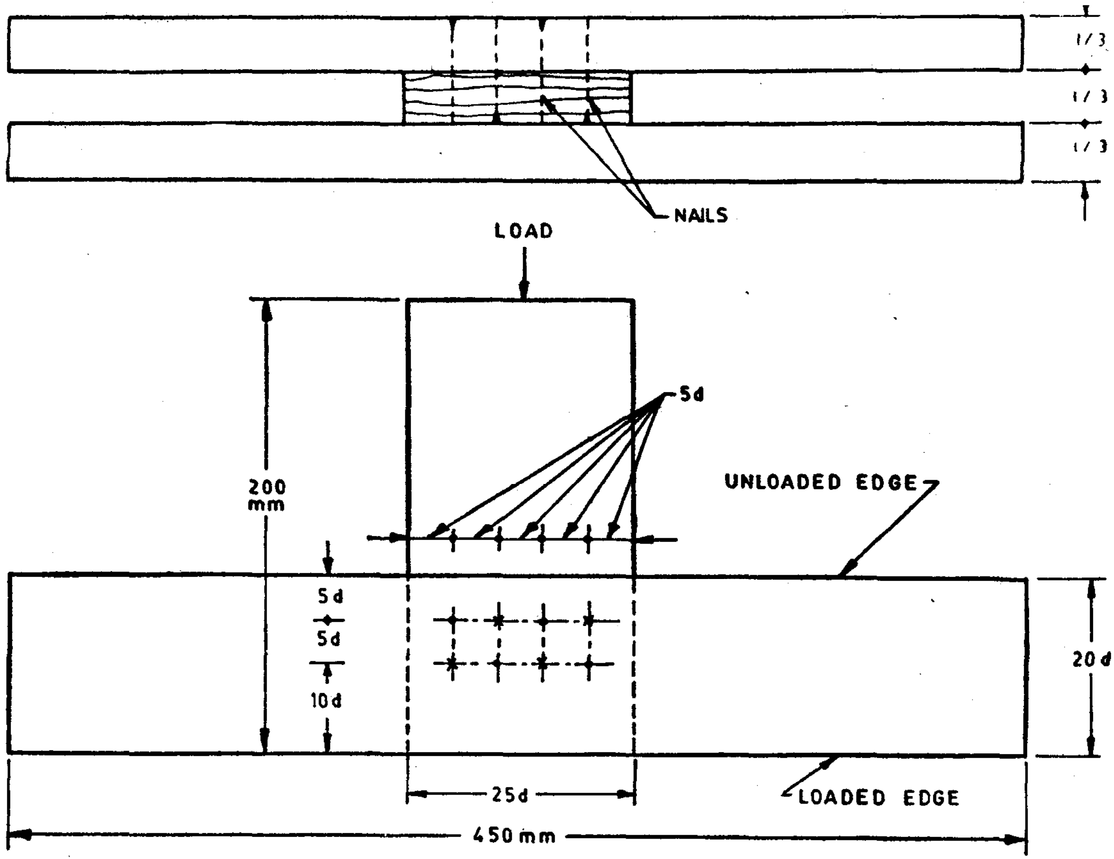
A-3. MEASUREMENT AND OBSERVATIONS

A-3.1 The slip of the central member with respect to the side members shall be measured with the help of dial gauges having a least count of 0·01 mm. In order to ensure the working of dial gauge additional check may be provided with the use of scale. It is always preferable to use both dial gauge and the scale so as to correlate both while taking a reading and thus avoiding any discrepancy. The readings shall be noted at every increase of load of 100 kgf (1 000 N) till the ultimate load is reached. This load-interval can be suitably changed subject to feasibility of taking readings with different kinds of species. Residual loading is also applied and readings taken.



d = Shank diameter of nails

10A Specimen of Nail Joint for Load Test Parallel to Grain



10B Specimen of Nail Joint for Load Test Perpendicular to Grain

d = Shank diameter of nails

FIG. 10 SPECIMEN OF NAIL JOINT FOR LOAD TEST

A-3.2 All types of failures in the joint shall be noted preferably with illustrative sketches, and any special point noticed during the test shall be recorded.

A-4. RECORDING OF DATA AND COMPILATION

A-4.1 The data shall be recorded and load-slip graphs drawn (*see* Fig. 11). The elastic limit shall be computed from the graphs. The safe load per nail shall be calculated. A method for calculating safe loads is given in **A-5**.

A-5. METHOD OF CALCULATING SAFE LOAD

A-5.1 Observations from Load-Slip Graph — There is no well defined proportional limit on the curves.

Joints obey Hooke's law to a certain extent as is evident from straight line or nearly straight line portion of the graph.

It is not possible to fix the exact point where proportionality between slip and load ceases with the present methods of testing. It may be possible to have a properly defined elastic limit if readings are taken with the help of an instrument of high precision in the early stages of the curve.

The ultimate loads are not very uniform and are not to be very much relied upon. Sometimes the breakdowns are sudden and it is not possible to get points on the curve to represent the non-load carrying region of the joint.

A-5.2 Assumptions made for Arriving at Safe Loads for Nail Joints

a) Maximum slip of the joint, beyond which the nail-joint may not be expected to be serviceable, is taken as 10 mm.

b) Load at 10 mm slip is termed as 'yield load'.

c) Slip at its safe load for permanent constructions is restricted to 0·4 mm.

d) Allowable slip at safe load for temporary construction is 1·5 mm.

A-5.3 Criteria

a) For permanent constructions, lesser of the following two loads is the safe load:

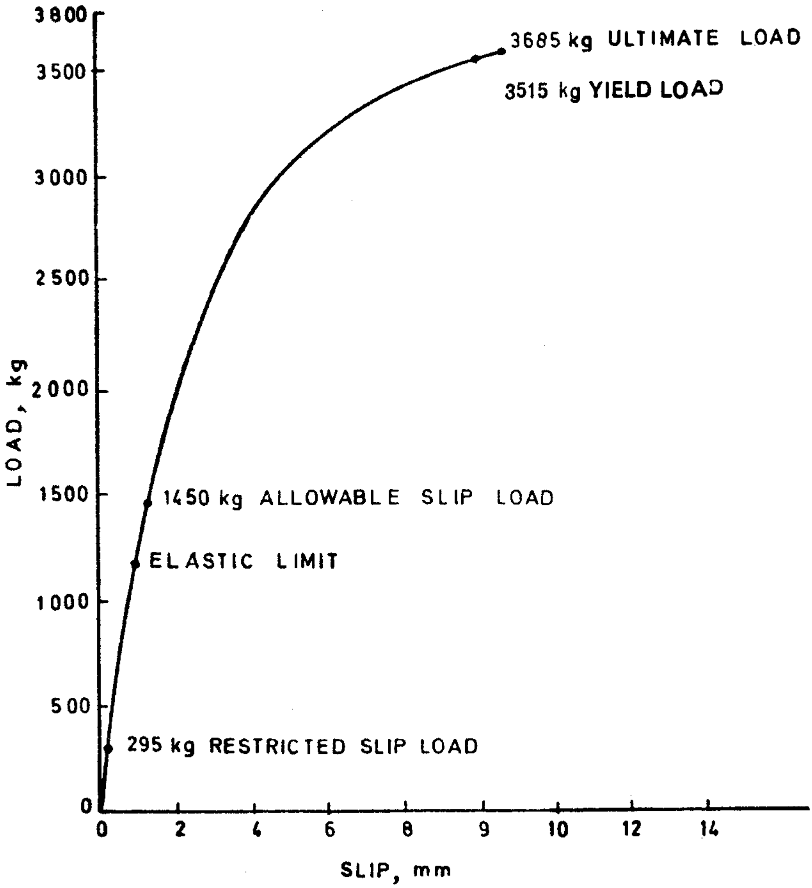
  i) Load after applying a factor of safety 3 to the yield load.

  ii) Load at restricted slip of 0·4 mm.

b) For temporary construction, lesser of the following two loads is the safe load:

  i) Load after applying a factor of safety 3 to the breaking load.

  ii) Load at allowable slip of 1·5 mm.



For Temporary Construction		For Permanent Construction	
Ultimate Load	= 3 685 kg	Yield Load	= 3 515 kg
Load with FS 3 to Ultimate Load	= 1 228 kg	Load with FS 3 to Yield Load	= 1 172 kg
Allowable Slip Load	= 1 450 kg	Restricted Slip Load	= 295 kg
Acceptable Safe Load for Nailed Joint	= 1 228 kg	Acceptable Safe Load for Nailed Joints	= 295 kg
Safe Load/Nail	= 153 kg	Safe Load/Nail	= 37 kg
		No. of Nails Used	= 8 kg

Fig. 11 Nail Strength Determination

APPENDIX B

(*Clause* 5.9)

EXAMPLE OF THE DESIGN OF A NAIL-JOINTED TIMBER TRUSS

B-1. DESIGN DATA

a) Effective span of truss	12 metres
b) Spacings of trusses	2·5 metres
c) Species of timber	bijasal (*Pterocarpus mersupium*) Group B
d) Slope of roof	26·5°
e) End conditions of truss	Both ends fixed to the supporting walls or columns
f) Roofing materials	Corrugated galvanized sheets
g) Conditions of openings of the building	Large openings of doors and windows, as in industrial sheds
h) Height of the building	Between 5 to 10 metres
j) Strength characteristics of bijasal timber	

i) *Mechanical Properties* (Refer Table 2 of IS : 883-1970*)

1) Average unit mass at 12% moisture content	800 kg/m^3
2) Bending and tension along grain for inside location	148 kgf/cm^2
3) Compression parallel to grain for inside location	92 kgf/cm^2
4) Compression perpendicular to grain for inside location	41 kgf/cm^2
5) Modulus of elasticity	103 000 kgf/cm^2

*Code of practice for design of structural timber in buildings (*third revision*).

ii) *Nail Strength* (Refer Tables 1 and 2)

1) For 5·00 mm ϕ and 150 mm long nails

a) Double shear = 205 kgf multiple shear = 1·5 × 205 = 308 kgf parallel to grain

b) Double shear = 150 kgf multiple shear = 1·5 × 150 = 225 kgf perpendicular to grain

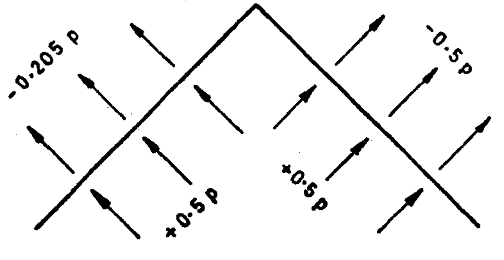
2) For 4·00 mm ϕ and 100 mm long nails

Double shear = 150 kgf parallel to grain

k) *Loads*

i) Dead loads	30 kgf/m²
ii) Imposed loads	40 kgf/m² (Refer Table 2 of IS : 875-1964*)
iii) Basic wind pressure p for heights up to 30 metres	150 kgf/m² (Refer IS: 875-1964*)
1) External wind pressure:	
Windward slope	0·205 p } Refer Table 4 of IS : 875-1964*
Leeward slope	0·50 p }
2) Internal wind pressure:	
For buildings with large openings (more than 20 percent of wall area)	= ± 0·50 p acting normal to the wall of the roof surface

Case I : Considering internal wind pressure of + 0·5 p

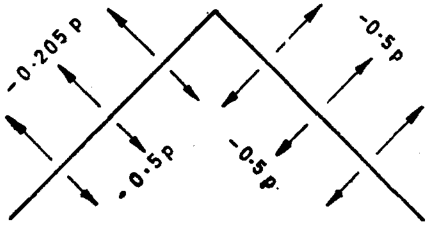


Pressure windward side = 0·705 p

Pressure leeward side = 1·0 p

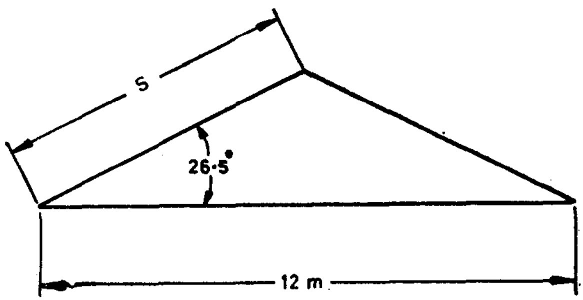
*Code of practice for structural safety of buildings: Loading standards.

Case II : Considering internal wind pressure of $-0.5\ p$



Pressure windward side	$= +0.295\ p$
Pressure leeward side	= zero

B-2. TRUSS PATTERN



Slanting length S of the truss $= \sec. 26.5° \times \frac{1\ \text{Span}}{2}$

$\therefore S = 1.117\ 40 \times \frac{12}{2} = 6.70$

Each panel length is $= \frac{6.70}{5} = 1.34$ m (The maximum allowed length of each panel is 1·4 m) for galvanized steel sheeting.

B-2.1 Loads on the Truss

a) Dead loads at the intermediate node points of top chord (refer Fig. 12)

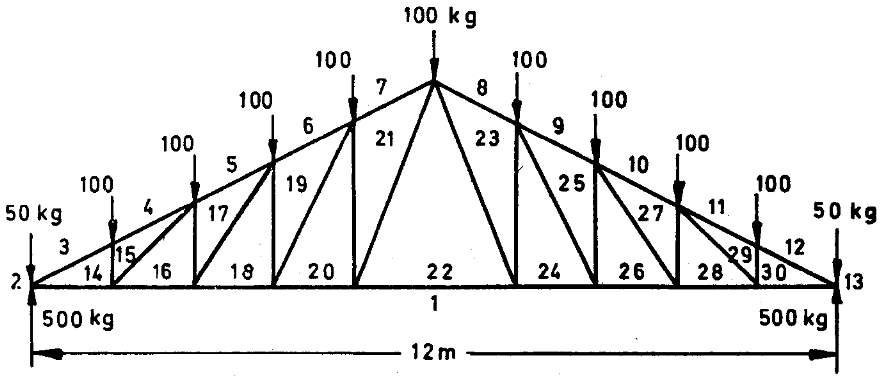
$= 30 \times 2.5 \times 1.34 =$ say 100 kgf

Load at heel node point $= \frac{100}{2} = 50$ kgf

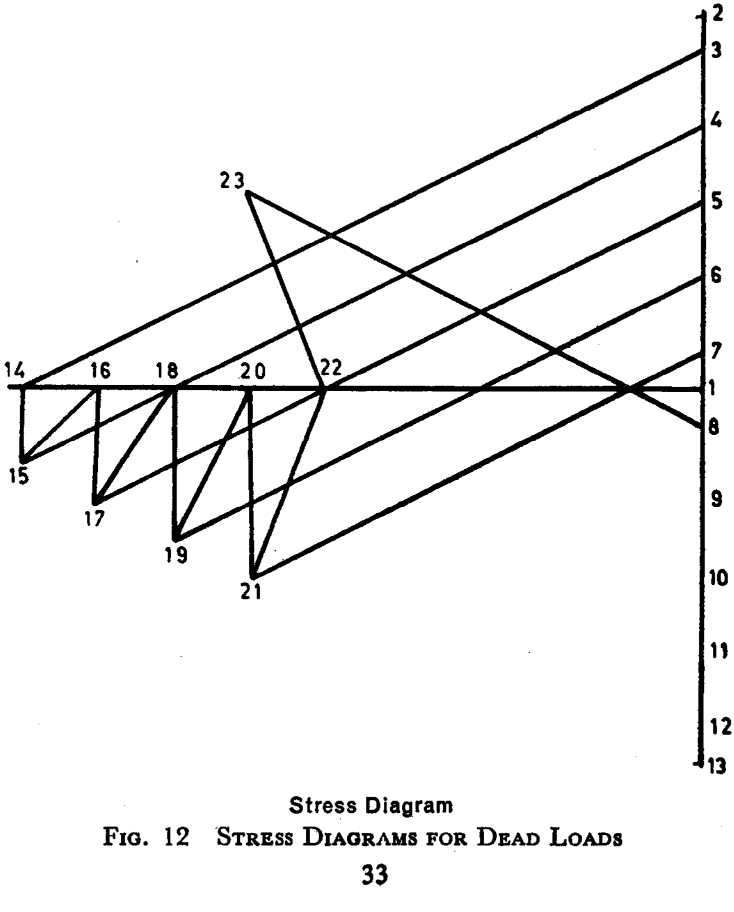
b) Imposed loads at the intermediate node points of top chord (refer Fig. 13)

$= 40 \times 2.5 \times 1.34 =$ say 130 kgf

Load at heel node point = 65 kgf

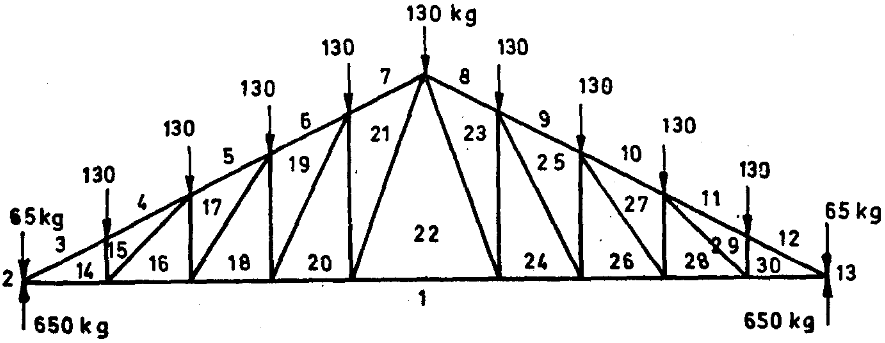


TRUSS DIAGRAM

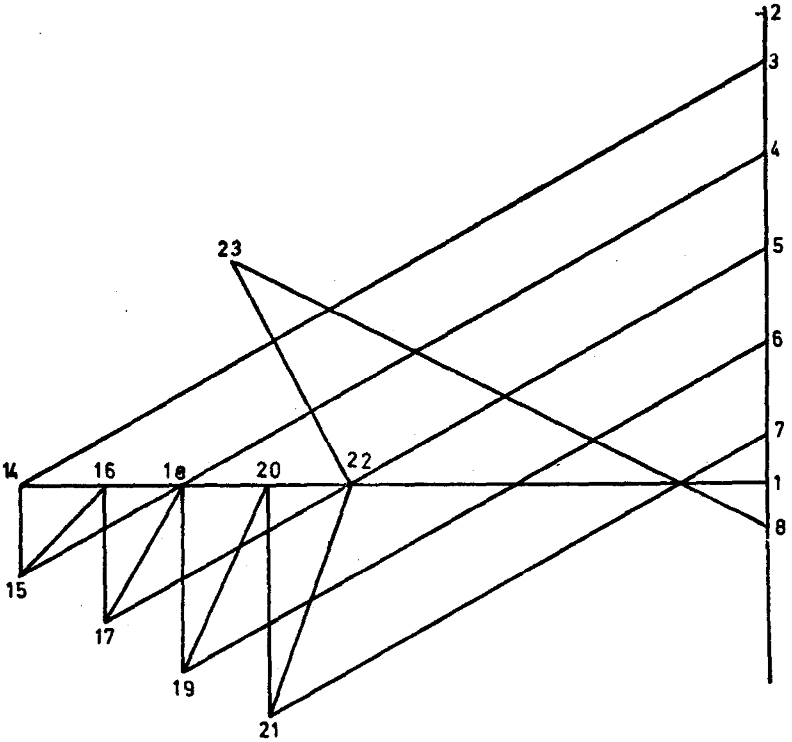


Stress Diagram

FIG. 12 STRESS DIAGRAMS FOR DEAD LOADS



TRUSS DIAGRAM



Stress Diagram

FIG. 13 STRESS DIAGRAMS FOR IMPOSED LOADS

c) Wind loads (refer Fig. 14)

i) *Case I* : At the intermediate node points of top chord windward side $= (-0{\cdot}705 \times 150) \times 2{\cdot}5 \times 1{\cdot}34 =$ say 360 kgf

$\therefore$ Load at heel node point = 180 kgf.

ii) *Case I*: At the intermediate node points of top chord, leeward side $= (-1 \times 150) \times 2{\cdot}5 \times 1{\cdot}34 =$ 500 kgf

$\therefore$ Load at heel node point = 250 kgf.

iii) *Case II*: At the intermediate node points of top chord windward side $= (0{\cdot}295 \times 150) \times 2{\cdot}5 \times 1{\cdot}34$ = say 150 kgf

$\therefore$ Load at heel node point = 75 kgf.

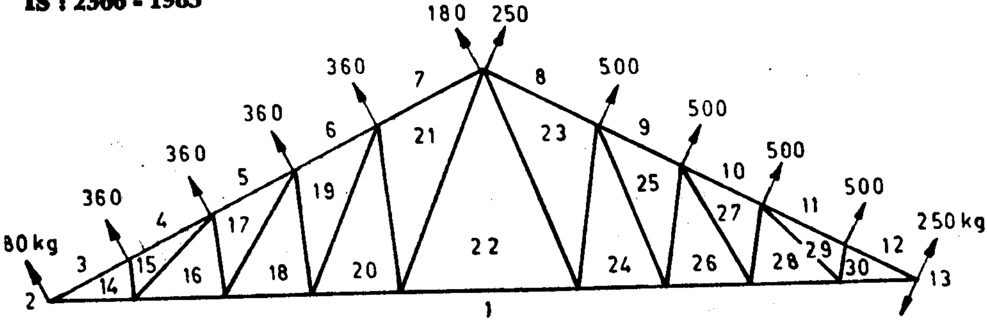
iv) *Case II* : At the intermediate node points of top chord, leeward side = Nil.

B-3. DESIGN OF TRUSS MEMBERS

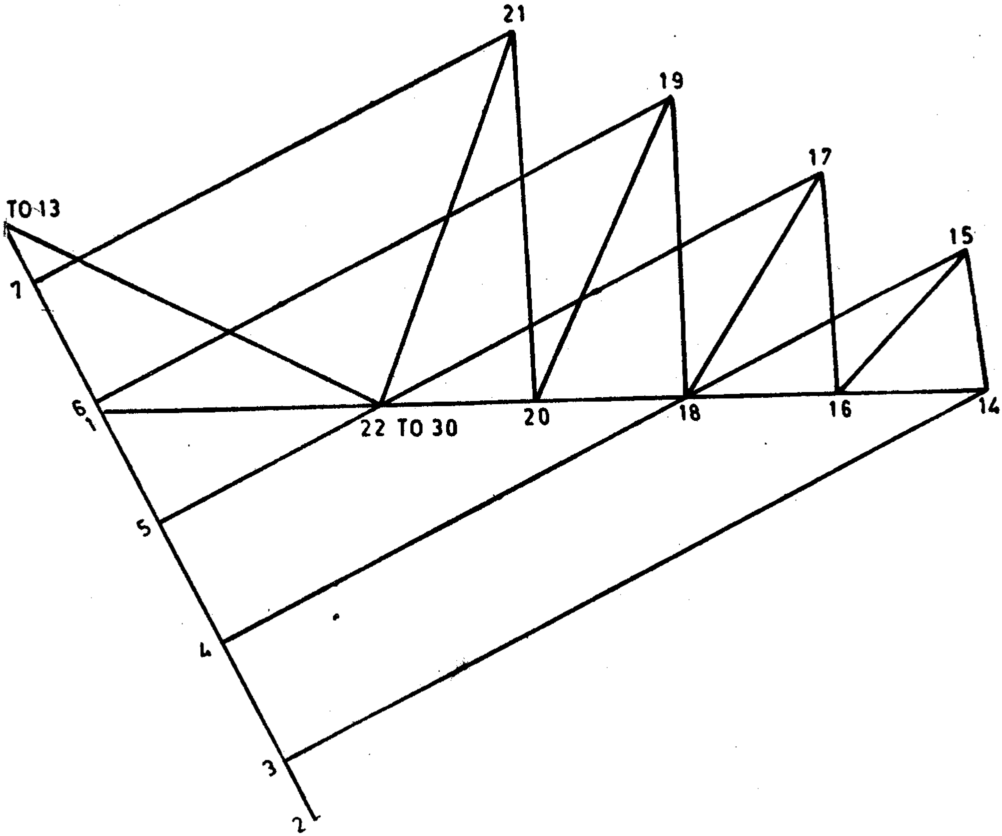
B-3.0 To provide the minimum spacing of nails at the node joints, the depth of the top chord should at least be 20 *d*, where *d* is the diameter of the nails.

Using 5·00 mm dia, 150 mm long nails

Minimum depth of top chord $= 20 \times d = 20 \times 5 = 100$ mm = 10 cm



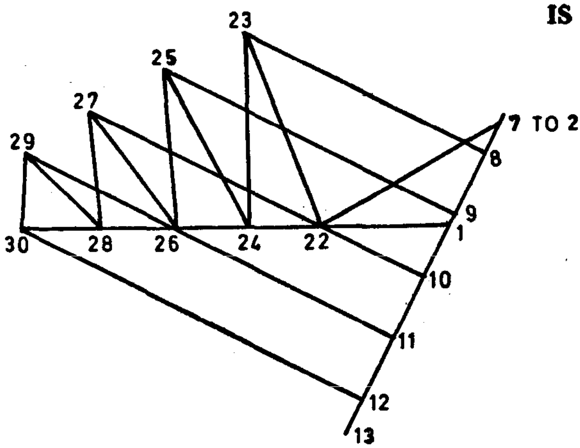
CASE-I TRUSS DIAGRAM FOR WIND LOADS (SUCTION)



CASE-I WINDWARD SIDE

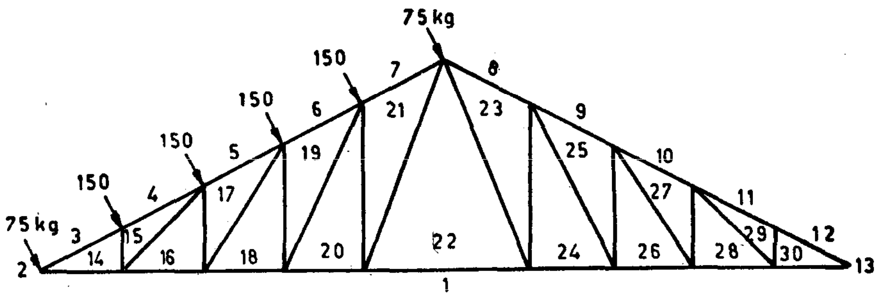
Stress Diagram for Wind Loads (Suction)

FIG. 14 STRESS DIAGRAMS FOR WIND LOADS — *Contd*

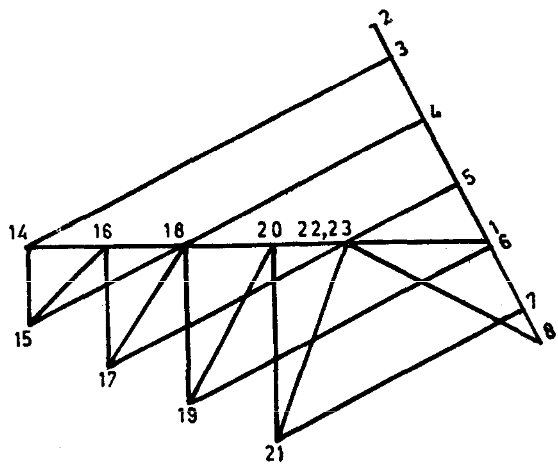


CASE-I LEE WARD SIDE

Stress Diagram for wind load (suction)



CASE-II TRUSS DIAGRAM FOR WIND LOADS (PRESSURE)



CASE-II WINDWARD SIDE

Stress Diagram for Wind Loads (Pressure)

FIG. 14 STRESS DIAGRAMS FOR WIND LOADS

B-3.1 General Arrangement of Members — For efficient functioning of joints and economy in fabrication of trusses, it is proposed to have co-planer twin sections for top and bottom chord members with a space equal to the proposed thickness of tension members. The compression web members shall also be twin sections, attached to the top and bottom chord members on their outer faces.

Modification factor $k_2 = 1{\cdot}33$ (refer Table 6 of IS : 883-1970*)

B-3.1.1 *Design of Top Chord Members*

Maximum length of top chord $L = 134$ cm, and assuming $d = 3$ cm

$$L/d = 134/3 = 44{\cdot}6$$

Now, constant $K_{10} = 0{\cdot}702\sqrt{\dfrac{2{\cdot}5E}{f_{cp}}}$ (refer IS : 883-1970*)

$$= 0{\cdot}702\sqrt{\frac{2{\cdot}5 \times 103\,000}{92}}$$

$$= 37{\cdot}13$$

Since L/d is greater than K_{10}, it will be designed as long column. (refer IS : 883-1970*).

a) *Case I* : Pressure on windward side

Maximum stress in top chord due to dead load + imposed load + wind load = − 3 320 kgf (refer stress table — Table 4)

Now, permissible compressive stress

$$f_c = P/A = \frac{0{\cdot}329 \times E \times 2{\cdot}5}{(L/d)^2} \quad \text{(refer IS : 883-1970*)}$$

$$= \frac{0{\cdot}329 \times 103\,000 \times 2{\cdot}5}{(44{\cdot}6)^2}$$

$$= 42{\cdot}44 \times K_2 = 42{\cdot}44 \times 1{\cdot}33$$

$$= 56{\cdot}44 \text{ kgf/cm}^2$$

Therefore, area required $= \dfrac{3\,320}{56{\cdot}44} = 58{\cdot}8 \text{ cm}^2$

Therefore, depth of the top chord $= \dfrac{58{\cdot}8}{3 \times 2}$ = say 10 cm

*Code of practice for design of structural timber in buildings (*third revision*).

b) *Case II* : Pressure on leeward side

Maximum stress due to dead load + imposed load = — 2 330 kgf (from stress table — Table 4)

$$f_c = P/A = \frac{0{\cdot}329 \times E}{(Ld)^2} = 42{\cdot}44 \text{ kgf/cm}^2$$

$$\text{Therefore, area required} = \frac{2\,330}{42{\cdot}44} = 54{\cdot}9 \text{ cm}^2$$

$$\text{Therefore, depth of the member} = \frac{54{\cdot}9}{3 \times 2} = 9{\cdot}1 \text{ cm.}$$

NOTE — The size of the top chord as per the design comes to 3 × 10 cm, but to accommodate required numbers of nails with standard spacing, the top chord members are to be kept as 3 × 12·5 cm as explained later.

B-3.1.2 *Design of Bottom Chord Members*

Maximum stress in bottom chord = + 3 070, − 1 945 kgf

Length of the panel L = 120 cm

a) Designing it for tensile stress, $f_t = \frac{P}{A}$

Therefore, $P = f_t \times K_2 \times A$

$3\,070 = 148 \times 1{\cdot}33 \times A$

Therefore, A = 15·5 cm² which is very less.

Hence a minimum section of 3 × 12·5 cm (twin) shall be adopted as in top chord for accommodating the required number of nails.

b) Now designing for compressive stress of 1 945 kgf, and assuming d = 3 cm.

$L/d = 120/3 = 40$

Since L/d is greater than K_{10}, it will be designed as long spaced columns.

Now, maximum permissible compressive stress

$$f_c = P/A = \frac{0{\cdot}329 \times E \times 2{\cdot}5}{(L/d)^2}$$

$$= \frac{0{\cdot}329 \times 103\,000 \times 2{\cdot}5}{(40)^2}$$

$$= 52{\cdot}91 \times K_2 = 52{\cdot}91 \times 1{\cdot}33$$

$$= 70{\cdot}37 \text{ kgf/cm}^2$$

$$\text{Therefore, area required} = \frac{1\,945}{70{\cdot}37} = 27{\cdot}6 \text{ cm}^2$$

A section of 3 × 12·5 cm shall be adopted for entire bottom chord.

B-3.1.3 *Designing of Web Members* — Whether required or not at any of the node joints, a minimum of two nails shall be provided. If the depth of the upper and lower chord members are enough to accommodate nails in a vertical row, the web members shall have a minimum width of 10*d*, just enough to satisfy the minimum edge distance which is 5 cm, using nails 5·00 mm diameter, 150 mm long. Stresses in the design of web members may be increased by 33⅓ percent for any eccentricity due to shifting of web axis wherever necessary for jointing facility.

a) *Web members in compression*

i) Maximum stress in member 14 – 15 = 410, + 345 kgf (refer stress table – Table 4)

$$L = 65 \text{ cm, and assuming } d = 2 \text{ cm}$$

$$L/d = 32{\cdot}5 \text{ cm}$$

Since L/d is between 11 and K_8, it will be designed as an intermediate column.

Maximum permissible compressive stress

$$f_c = P/A = f_{cp}\left[1 - \frac{1}{3}\left(\frac{L}{dk_8}\right)^4\right] \times K_2$$

$$= 92 \times 1{\cdot}33\left[1 - \frac{1}{3}\left(\frac{32{\cdot}5}{37{\cdot}13}\right)^4\right]$$

$$= 98{\cdot}5 \text{ kgf/cm}^2$$

Therefore, area required $= \dfrac{410}{98{\cdot}5} = 4{\cdot}16 \text{ cm}^2$

Hence a minimum section of 2 × 6 cm shall be adopted.

This section is safe against tension, and also for stresses due to combination of dead load and imposed load.

ii) Web member 16 – 17

Maximum stress in the member due to dead load + imposed load + wind load.

= – 605 kgf, + 560 kgf.

$L = 120$ cm, and assuming $d = 2$ cm.

$L/d = \dfrac{120}{2} = 60$ cm, which is greater than K_8 and hence shall be designed as long spaced column.

Now, maximum permissible compressive stress

$$f_c = P/A = \frac{0{\cdot}329 \times E \times 2{\cdot}5}{(L/d)^2} \times 1{\cdot}33$$

TABLE 4 STRESS TABLE

(*Clauses* B-3.1.1 and B-3.1.3)

Sl No.	Name of the Member	Length of the Member in cm	Stresses Due to Dead Loads in kgf	Stresses Due to Imposed Loads in kgf	Stresses Due to Wind Loads in kgf			Stresses Due to Dead Load + Imposed Loads in kgf (4 + 5)	Resultant Stresses Due to Wind Suction (6 + 7)	Resultant Stresses Due to D. L. + T. L. + Wind Pressure (8 + 9)	Resultant Stresses Due to D. L. + T. L. + Wind Suction (9 + 10)	Maximum Resultant Stresses	Design Stresses
					Case I		Case II						
					Wind Ward Side	Lee Ward Side	Wind Ward Side						
					Suction		Pressure						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	3 – 14	134	– 1 000	– 1 330	+ 2 140	+ 2 100	– 900	– 2 330	+ 4 240	– 3 230	+ 1 910	– 3 230, + 1 910	– 3 230, + 2 050
2.	4 – 15	134	– 1 000	– 1 330	+ 2 280	+ 2 100	– 990	– 2 330	+ 4 380	– 3 320	+ 2 050	– 3 320, + 2 050	– 3 320, + 2 350
3.	5 – 17	134	– 900	– 1 190	+ 2 040	+ 2 100	– 870	– 2 090	+ 4 140	– 2 960	+ 2 050	– 2 960, + 2 050	– 2 960, + 2 240
4.	6 – 19	134	– 780	– 1 050	+ 1 760	+ 2 100	– 760	– 1 830	+ 3 860	– 2 590	+ 2 030	– 2 590, + 2 030	– 2 590, + 2 100
5.	7 – 21	134	– 670	– 910	+ 1 480	+ 2 100	– 650	– 1 580	+ 3 580	– 2 230	+ 2 000	– 2 230, + 2 000	– 2 230, + 2 000
6.	8 – 23	134	– 670	– 910	+ 1 480	+ 2 100	– 650	– 1 580	+ 3 580	– 2 230	+ 2 000	– 2 230, + 2 000	– 2 230, + 2 000
7.	9 – 25	134	– 780	– 1 050	+ 1 480	+ 2 450	– 650	– 1 830	+ 3 930	– 2 480	+ 2 100	– 2 480, + 2 100	– 2 590, + 2 100
8.	10 – 27	134	– 900	– 1 190	+ 1 480	+ 2 850	– 650	– 2 090	+ 4 330	– 2 740	+ 2 240	– 2 740, + 2 240	– 2 960, + 2 240
9.	11 – 29	134	– 1 000	– 1 330	+ 1 480	+ 3 200	– 650	– 2 330	+ 4 680	– 2 980	+ 2 350	– 2 980, + 2 350	– 3 320, + 2 350
10.	12 – 30	134	– 1 000	– 1 330	+ 1 480	+ 2 900	– 650	– 2 330	+ 4 380	– 2 980	+ 2 050	– 2 980, + 2 050	– 3 230, + 2 050
11.	1 – 14	120	+ 890	+ 1 190	– 2 380	– 1 050	+ 990	+ 2 080	– 3 430	+ 3 070	– 1 350	+ 3 070, – 1 350	+ 3 070, – 1 945
12.	1 – 16	120	+ 800	+ 1 055	– 1 940	– 1 050	+ 820	+ 1 855	– 2 990	+ 2 675	– 1 135	+ 2 675, – 1 135	+ 2 675, – 1 595
13.	1 – 18	120	+ 700	+ 930	– 1 560	– 1 050	+ 650	+ 1 630	– 2 610	+ 2 280	– 980	+ 2 280, – 980	+ 2 280, – 1 295
14.	1 – 20	120	+ 610	+ 805	– 1 180	– 1 050	+ 490	+ 1 415	– 2 230	+ 1 905	– 815	+ 1 905, – 815	+ 1 905, – 935
15.	1 – 22	240	+ 500	+ 680	– 750	– 1 050	+ 340	+ 1 180	– 1 800	+ 1 520	– 620	+ 1 520, – 620	+ 1 520, – 620
16.	1 – 24	120	+ 610	+ 805	– 750	– 1 600	+ 340	+ 1 415	– 2 350	+ 1 755	– 935	+ 1 755, – 935	+ 1 905, – 935
17.	1 – 26	120	+ 700	+ 930	– 750	– 2 176	+ 340	+ 1 630	– 2 925	+ 1 970	– 1 295	+ 1 970, – 1 295	+ 2 280, – 1 295
18.	1 – 28	120	+ 800	+ 1 055	– 750	– 2 700	+ 340	+ 1 855	– 3 450	+ 2 195	– 1 595	+ 2 195, – 1 595	+ 2 675, – 1 595
19.	1 – 30	120	+ 890	+ 1 190	– 750	– 3 275	+ 340	+ 2 080	– 4 025	+ 2 420	– 1 945	+ 2 420, – 1 945	+ 3 070, – 1 945
20.	14 – 15	65	– 100	– 130	+ 380	—	– 180	– 230	+ 380	– 410	+ 150	– 410, + 150	– 410, + 345
21.	15 – 16	175	+ 140	+ 190	– 560	—	+ 265	+ 330	– 560	+ 595	– 230	+ 595, – 230	+ 595, – 520
22.	16 – 17	120	– 145	– 195	+ 600	—	– 265	– 340	+ 600	– 605	+ 260	– 605, + 260	– 605, + 560
23.	17 – 18	215	+ 180	+ 240	– 730	—	+ 325	+ 420	– 730	+ 745	– 310	+ 745, – 310	+ 745, – 655
24.	18 – 19	180	– 200	– 260	+ 800	—	– 350	– 460	+ 800	– 810	+ 340	– 810, + 340	– 810, + 690
25.	19 – 20	270	+ 220	+ 300	– 890	—	+ 390	+ 520	– 890	+ 910	– 370	+ 910, – 370	+ 910, – 780
26.	20 – 21	240	– 245	– 335	+ 1 000	—	– 435	– 580	+ 1 000	– 1 015	+ 420	– 1 015, + 420	– 1 015, + 820
27.	21 – 22	325	+ 270	+ 365	– 1 090	—	+ 470	+ 635	– 1 090	+ 1 105	– 355	+ 1 105, – 355	+ 1 105, – 915
28.	22 – 23	325	+ 270	+ 365	—	– 1 550	—	+ 635	– 1 550	+ 635	– 915	+ 635, – 915	+ 1 105, – 915
29.	23 – 24	240	– 245	– 335	—	+ 1 400	—	– 580	+ 1 400	– 580	+ 820	– 580, + 820	– 1 015, + 820
30.	24 – 25	270	+ 220	+ 300	—	– 1 300	—	+ 520	– 1 300	+ 520	– 780	+ 520, – 780	+ 910, – 780
31.	25 – 26	180	– 200	– 260	—	+ 1 150	—	– 460	+ 1 150	– 460	+ 690	– 460, + 690	– 810, + 690
32.	26 – 27	215	+ 180	+ 240	—	– 1 075	—	+ 420	– 1 075	+ 420	– 665	+ 420, – 655	+ 745, – 655
33.	27 – 28	120	– 145	– 195	—	+ 900	—	– 340	+ 900	– 340	+ 560	– 340, + 560	– 605, + 560
34.	28 – 29	175	+ 140	+ 190	—	– 850	—	+ 330	– 850	+ 330	– 520	+ 330, – 520	+ 595, – 520
35.	29 – 30	65	– 100	– 130	—	+ 575	—	– 230	+ 575	– 230	+ 345	– 230, + 345	– 410, + 345

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$$= \frac{0{\cdot}329 \times 103\,000 \times 2{\cdot}5}{(60)^2} \times 1{\cdot}33$$

$$= 23{\cdot}5 \times 1{\cdot}33 \text{ kgf/cm}^2$$

Therefore, area $A = \frac{605}{23{\cdot}5 \times 1{\cdot}33} = 19{\cdot}3 \text{ cm}^2$ which is less.

Hence a minimum section of 2 × 7·5 cm (twin) shall be adopted to accommodate required number of nails.

iii) Web member 18—19

Maximum stress in the member due to dead load + imposed load + wind load.

= 810 kgf, + 690 kgf

Here, L = 180 cm, and assuming d = 2·5 cm.

$L/d = \frac{180}{2{\cdot}5} = 72$, which is greater than K_8 and hence shall be designed as long spaced columns.

$$\text{Now, } f_c = P/A = \frac{0{\cdot}329 \times E \times 2{\cdot}5}{(L/d)^2} \times 1{\cdot}33$$

$$= \frac{0{\cdot}329 \times 103\,000 \times 2{\cdot}5}{(72)^2} \times 1{\cdot}33$$

$$= 16{\cdot}33 \times 1{\cdot}33 = 21{\cdot}72 \text{ kgf/cm}^2$$

Therefore, area required $A = \frac{810}{21{\cdot}72} = 37{\cdot}3 \text{ cm}^2$

Therefore, depth of the member $= \frac{37{\cdot}3}{2{\cdot}5 \times 2}$ = say 7·5 cm

Hence adopt a twin member of 2·5 × 7·5 cm

iv) Web member 20—21

Maximum stress in the member due to dead load + imposed load + wind load.

= 1 015 kgf, + 820 kgf.

Now, L = 240 cm, and assuming d = 3 cm

$L/d = \frac{240}{3} = 80$ which is greater than K_8 and shall be designed as long spaced column.

$$\text{Now, } f_c = P/A = \frac{0{\cdot}329 \times E \times 2{\cdot}5}{(L/d)^2} \times 1{\cdot}33$$

$$= \frac{0{\cdot}329 \times 103\,000 \times 2{\cdot}5}{(80)^2} \times 1{\cdot}33$$

$$= 13{\cdot}23 \times 1{\cdot}33 = 17{\cdot}6 \text{ kgf/cm}^2$$

Therefore, area required $= \frac{1\,015}{17{\cdot}6} = 57{\cdot}6 \text{ cm}^2$

Therefore, depth of the member $= \frac{57{\cdot}6}{2 \times 3} = 10$ cm

Hence adopt a twin member of 3 × 10 cm

b) *Web members in tension*

i) Maximum stress in member 15 – 16 due to dead load + imposed load + wind load.

$= 595$ kgf, $-$ 520 kgf.

$L = 175$ cm

Maximum permissible tensile stress $f_t = P/A$

Therefore, $P = f_t \times A \times 1{\cdot}33$

$595 = 148 \times 1{\cdot}33 \times A$

Therefore, $A = \frac{595}{148 \times 1{\cdot}33} = 3 \text{ cm}^2$ which is less.

Again, maximum compressive stress = 520 kgf.

$L = 175$ cm

$\frac{175}{d} = 50$ (refer IS : 883-1970*)

Therefore, $d = 3{\cdot}5$ cm. The member may be designed as long solid column.

Maximum permissible compressive stress

$$f_c = P/A \quad = \frac{0{\cdot}329 \times E}{(L/d)^2} = 1{\cdot}33$$

$$= \frac{0{\cdot}329 \times 103\,000}{(50)^2} \times 1{\cdot}33$$

$$= 13{\cdot}55 \times 1{\cdot}33 = 18 \text{ kgf/cm}^2$$

Therefore, area required $A = \frac{520}{18}$

$= 29 \text{ cm}^2$

*Code of practice for design of structural timber in buildings (*third revision*).

Therefore, depth of the member $= \frac{29}{3 \cdot 5}$

$= 8 \cdot 5$ cm

Hence adopt a solid section of $3 \cdot 5 \times 8 \cdot 5$ cm

ii) Web member 17 – 18

Maximum stress = + 745 kgf, – 655 kgf

Since the magnitude of tensile stress is more, it may be designed as a tension member.

Maximum permissible tensile stress $f_t = \frac{P}{A}$

Therefore, $P = f_t \times A \times 1 \cdot 33$

that is, $745 = 148 \times 1 \cdot 33 \times A$

Therefore, area required $A = \frac{745}{148 \times 1 \cdot 33} = 4$ cm² which is less.

Now, Maximum permissible compressive stress $f_c = \frac{P}{A} =$
18 kgf/cm²

Assuming $\frac{L}{d} = 50$ (since understressed)

Area required $A = \frac{655}{18} = 36 \cdot 5$ cm²

Therefore, depth $= \frac{36 \cdot 5}{3 \cdot 5} = 10 \cdot 5$ cm

Hence adopt a section of $3 \cdot 5 \times 10 \cdot 5$ cm

iii) Web member 19 — 20

Maximum stresses in the member = + 910 kgf, — 780 kgf
and $L = 270$ cm

Maximum permissible tensile stress $f_t = \frac{P}{A}$

Therefore, $P = f_t \times A \times 1 \cdot 33$

$910 = 148 \times 1 \cdot 33 \times A$

$A = 5$cm² which is less.

Now, maximum permissible compressive stress $f_c = \frac{P}{A} = 18$ kgf/cm²

Assuming $L/d = 50$ (since understressed)

Area required $= \frac{780}{18} = 43{\cdot}4\ cm^2$

Assuming $d = 3{\cdot}5\ cm^2$

Therefore, depth $= \frac{43{\cdot}33}{3{\cdot}5} = 12{\cdot}5$ cm

Hence adopt a section of 3·5 × 12·5 cm

iv) Web member 21—22 — Increase the stress by $33\frac{1}{3}$ percent for eccentricity due to shifting of web axis for facilitating jointing at apex.

Maximum stress in the member = + 1 105 × 1 ·33 = + 1 470 kgf
— 915 × 1·33 = − 1 216 kgf

Maximum permissible tensile stress $f_t = \frac{P}{A}$

Therefore $P = f_t \times A \times 1{\cdot}33$

$1\ 470 = 148 \times 1{\cdot}33 \times A$

$A = \frac{1\ 470}{148 \times 1{\cdot}33} = 7{\cdot}5\ cm^2$

Again, maximum permissible compressive stress $f_c = \frac{P}{A}$
$= 18\ kgf/cm^2$

Assuming $L/d = 50$ (maximum allowed for solid column)

Therefore, area required $A = \frac{1\ 216}{18} = 68\ cm^2$

Therefore depth $= \frac{68}{4{\cdot}5}$ (assuming $d = 4{\cdot}5$ cm) = 15 say

Hence adopt a section of 4·5 × 15 cm

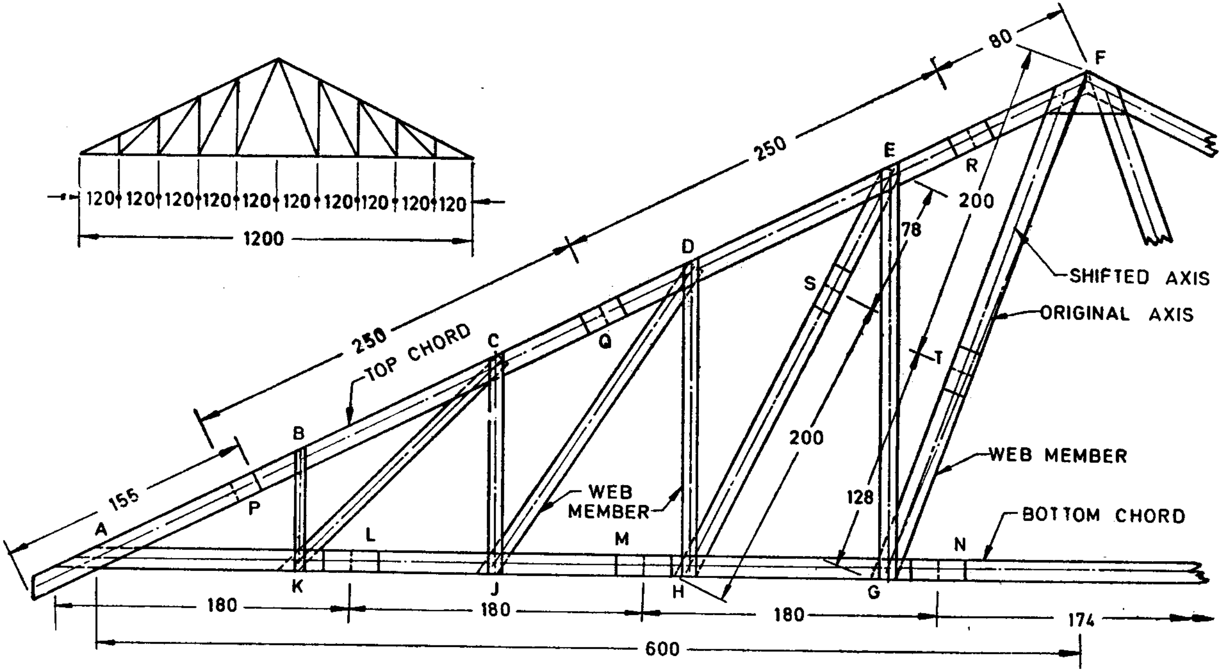
B-3.1.4 *Design of Joints* (Refer Fig. 15)

Number of nails required at joints $= \frac{\text{Max stress on the member}}{\text{Lateral strength of nail}}$

a) Heel joint A $= \frac{3\ 230}{412 \times 1{\cdot}33} = 6$ nails

b) Joint B $= \frac{410}{225 \times 1{\cdot}33} = 2$ nails

c) Joint C $= \frac{605}{225 \times 1{\cdot}33} = 2$ nails



All dimensions in centimetres.

FIG. 15 LOCATION OF JOINTS

d) Joint D $= \frac{810}{225 \times 1{\cdot}33} = 3$ nails

e) Joint E $= \frac{1\,015}{225 \times 1{\cdot}33} = 4$ nails

f) Joint F, maximum stress = 1 105 kg + 33% (due to change in axis)

$= \frac{1\,469}{225 \times 1{\cdot}33} = 5$ nails

g) Joint G $= \frac{1\,469}{225 \times 1{\cdot}33} = 5$ nails

h) Joint H $= \frac{910}{225 \times 1{\cdot}33} = 3$ nails

j) Joint J $= \frac{745}{225 \times 1{\cdot}33} = 3$ nails

k) Joint K $= \frac{595}{225 \times 1{\cdot}33} = 2$ nails

m) Joint L $= \frac{2\,675}{308 \times 1{\cdot}33} = 7$ nails

n) Joint M $= \frac{2\,280}{308 \times 1{\cdot}33} = 6$ nails

p) Joint N $= \frac{1\,520}{308 \times 1{\cdot}33} = 4$ nails

q) Joint P $= \frac{3\,230}{308 \times 1{\cdot}33} = 8$ nails

r) Joint Q $= \frac{2\,960}{308 \times 1{\cdot}33} = 8$ nails

s) Joint R $= \frac{2\,230}{308 \times 1{\cdot}33} = 6$ nails

t) Joint S $= \frac{910}{150 \times 1{\cdot}33} = 5$ nails

u) Joint T $= \frac{1\,469}{150 \times 1{\cdot}33} = 7$ nails

The number of nails so determined may also be checked for other duration of loads.

(*Continued from page* 2)

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