IS 3201 (1988): Criteria for design and construction of precast-trusses and purlins [CED 51: Planning, Housing and pre-fabricated construction]

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(Reaffirmed 2005)

Indian Standard

CRITERIA FOR DESIGN AND CONSTRUCTION OF PRECAST CONCRETE TRUSSES AND PURLINS

(First Revision)

UDC 692·421·2 : 691·327 : 624·04

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

Gr 5

October **1988**

Indian Standard

CRITERIA FOR DESIGN AND CONSTRUCTION OF PRECAST CONCRETE TRUSSES AND PURLINS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards on 29 February 1988, after the draft finalized by the Prefabricated Construction Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Modern developments in concrete precasting and prestressing techniques indicate that precast reinforced concrete and prestressed concrete trusses can be very suitably and economically employed for roofing industrial buildings. Concrete trusses are more fire resistant than steel trusses and require little periodic maintenance. This standard was first published in 1965. This revision has been taken up with a view to keeping abreast with the rapid development in the field of concrete technology. The important changes made in the revision are given below:

i) Trusses up to 75 m spans have been covered,

ii) Guidance for dead load for initial design has been given,

iii) Preferred spacing and spans of trusses have been modified, and

iv) Provisions for handling and erection loads have been covered in detail.

0.3 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 or analysis, 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.

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

1. SCOPE

1.1 This standard lays down the criteria for design and construction of precast reinforced and prestressed concrete trusses. It is intended to apply to trusses spanning up to 60 m. When rigorous structural analysis is applied, spans up to 75 m are covered in this code.

2. TERMINOLOGY

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

2.1 Precast Reinforced Concrete Truss — Reinforced concrete truss having all the members in reinforced concrete only.

2.2 Precast Prestressed Concrete Truss — Reinforced concrete truss having some of its principal members prestressed.

2.3 Solid Purlin — Purlin having its tensile and compression zones connected by concrete along its length such as purlin with T, L, trapezoidal, or rectangular cross-section.

2.4 Thickness of Member — The dimension in the plane of the truss perpendicular to the axis of the truss.

2.5 Trussed Purlin — Purlin having members in triangulated or virendeel shapes.

2.6 Width of the Truss — The dimension in the plane perpendicular to the plane of the truss.

3. SYMBOLS

3.1 For the purpose of this standard and unless otherwise defined in the text, the following letter symbols shall have the meaning indicated against each:

E_c = modulus of elasticity of concrete,

E_s = modulus of elasticity of steel,

σ_{cu} = ultimate cube strength of concrete in compression at 28 days,

I_{AB} = moment of inertia of member AB,

l_{AB} = length of member AB,

M_{FAB} = fixed end moment at the end A of the member AB, and

δ_{AB} = relative deflection of the member in a direction perpendicular to its axis.

4. MATERIALS

4.1 The materials for precast concrete trusse shall conform to the requirements of 4 of IS : 456-1978* and 4 of IS : 1343-1980† for reinforced concrete and prestressed concrete members, respectively.

4.2 Concrete

4.2.1 Concrete for truss members shall be controlled concrete conforming to IS : 456-1978* and of grade not weaker than M 20 in case of reinforced concrete trusses and M 35 in case of prestressed concrete trusses.

NOTE — Where portland pozzolana cement is used, delayed strength development at the early ages shall be considered.

4.3 Steel

4.3.1 For reinforced concrete members, the steel reinforcement shall be the following:

a) Mild steel and medium tensile steel bars conforming to IS : 432 (Part 1)-1982‡.

b) High strength deformed bars conforming to IS : 1786-1985§.

4.3.2 For prestressed concrete trusses, the prestressing steel shall be the following:

a) Plain hard-drawn steel wire conforming to IS : 1785 (Part 1)-1983‖ and IS : 1785 (Part 2)-1983¶.

b) Cold-drawn indented wire conforming to IS : 6003-1983**.

c) High tensile steel bar conforming to IS : 2090-1983††.

d) Uncoated stress relieved strand conforming to IS : 6006-1983‡‡.

5. ANALYSIS

5.1 In case of triangulated trusses where statical indeterminacy is due only to rigidity of '*n*' joints, the truss may be treated as pin-jointed for the purpose of finding forces in various members for preliminary design. All loads may be assumed as acting at the nodes. In large span trusses (span exceeding 30 m), the secondary moments due to relative deflection of the joints in the end members near the support should be considered even in preliminary design.

5.2 The secondary moment and the secondary forces in various members may be arrived at by using the preliminary sections assumed as indicated under **5.1**.

5.3 The secondary moments may be computed by finding the relative displacement of each member with the help of a Williot Mohr diagram or by any other method, including computer.

5.3.1 The fixed end moment produced at each end of the member due to deflection is given as:

$$M_{FAB} = + \frac{6\, E_t .\, I_{AB}\, \delta_{AB}}{(l_{AB})^2}$$

The next moment for preliminary design may be taken as 0·7 times the fixed end moment, computed as above for preliminary design. Flatter diagonals are preferable to steep diagonals to steep diagonals to reduce the net moments in the truss members.

5.3.2 The moment due to self-weight of each member or any other superimposed load shall also be taken into account while calculating the secondary moments due to relative deflection and the rigidity of the joints.

5.4 The equilibrium of joints is obtained by further distribution of unbalanced moment at each joint by any of the method, such as the moment distribution method, or the Kani's interation method of frame analysis.

5.5 The analysis may also be made by treating the whole truss as rigid jointed without making any simplifying assumptions described in **5.1** to **5.4**. However, for the usual triangulated trusses up to a span of 30 m, the secondary stresses due to loads and those due to prestress, resulting from rigidity of joints, compensate each other at most of the joints and so it is accurate enough to find the forces in the members assuming the truss to be pin-jointed.

6. DESIGN

6.1 Loading — For the purpose of design of precast reinforced concrete and prestressed concrete trusses, the following loads shall be considered:

a) Dead load,

b) Live load,

c) Wind load,

d) Seismic load, and

e) Handling and erection loads.

The effect of shrinkage and temperature variation shall also be taken into account in the design of the truss seatings.

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*Code of practice for plain and reinforced concrete (*third revision*).

†Code of practice for prestressed concrete (*first revision*).

‡Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*).

§Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*).

‖Specification for plain hard-drawn steel wire for prestressed concrete: Part 1 Cold drawn stress-relieved wire (*second revision*).

¶Specification for plain hard-drawn steel wire for prestressed concrete: Part 2 As-drawn wire (*first revision*).

**Specification for indented wire for prestressed concrete (*first revision*).

††Specification for high tensile steel bars used in prestressed concrete (*first revision*).

‡‡Specification for uncoated stress relieved strand for prestressed concrete (*first revision*).

6.1.1 *Dead Load* — For trusses supporting asbestos cement/galvanized iron/aluminium or such light roofing material transmitted through precast concrete purlins, the following intensity of loading from self-weight of truss for preliminary design may generally be assumed in absence of more specific data:

a) Truss supporting area up to 100 sq m = 700 N/m²

b) Truss supporting area above 100 sq m and up to 200 sq m = 1 000 N/m²

c) Truss supporting area above 200 sq m to 400 sq m = 150 N/m²

For trusses supporting ribbed concrete roof panels, the average dead load per square metre of the plan area will be approximately 1 000 N/m² more than the above values.

6.1.1.1 For the dead weight of the roofing sheets and ceiling, if any, actual ascertained weights shall be used; but if these are not available, unit weights given in IS : 875 (Part 1)-1987* may be used.

6.1.1.2 For dead load initially assumed shall be checked after the design is completed and the design shall be revised if the actual calculated dead load exceeds the assumed dead load.

6.1.2 *Live Load* — Live load on the pitched roofing with precast reinforced concrete and prestressed concrete trusses shall be in accordance with the relevant provisions of IS : 875 (Part 2)-1987†. The other superimposed loads from the services on bottom chord or other members of the truss should be considered.

6.1.3 *Wind Load* — Wind load shall be considered in accordance with the relevant provisions of IS : 875 (Part 3)-1988‡.

6.1.4 *Seismic Load* — The seismic load shall be considered in accordance with the relevant provisions of IS : 1893-1984§.

6.1.5 *Handling and Erection Load* — Trusses are normally cast in simple moulds on the floor in flat position and have to be tilted to vertical position at the time of demoulding. The demoulding is normally done in 2 to 3 days after casting. The concrete stress induced during this stage should be limited to one half the concrete strength attained in the period before tilting the truss.

Trusses are normally erected only after 75 percent of the 28-day strength is obtained. The handling of the trusses should be done carefully with slings around node points and should be accomplished in such a way that no adverse stresses are induced during this phase. The stresses induced should be limited to 50 percent of the strength of concrete during the handling phase.

Similarly prestressing by post-tensioning should be normally done only after 75 percent of the 28-day strength of concrete is achieved. Special care shall be taken in having higher strength concrete and closely spaced reinforcement in anchorage zone.

For very long and high trusses, special steel supports or frames should be used during demoulding and handling to avoid the danger of buckling/bending of long booms which are not internally prestressed.

6.2 Stresses

6.2.1 *Permissible Stress in Concrete and Steel* — Design criteria shall be in accordance with IS : 456-1978* for reinforced concrete members and IS : 1343-1980† for prestressed concrete members.

The permissible final stresses after losses in high tensile steel shall not exceed 60 percent of the ultimate strength (or 80 percent of the proof stresses in case of steels with guaranteed yield points) of high tensile steel wire or bar.

6.2.2 Truss members subjected to a total direct tensile force more than 500 kN should normally be prestressed to avoid cracks. Crack width analysis should be made in accordance with the accepted methods in case of reinforced concrete members subjected to predominantly direct tension or direct tension and bending.

6.3 Modulus of Elasticity

6.3.1 *Modulus of Elasticity of Concrete* — Unless otherwise determined by tests, the modulus of concrete E_c shall be as indicated in IS : 1343-1980† for prestressed concrete trusses and as indicated in IS : 456-1978* for reinforced concrete trusses.

6.3.2 *Modulus of Elasticity of Steel* — Unless otherwise specified, the modulus of elasticity E_s for mild steel and high tensile steel shall be in accordance with IS : 456-1978* and IS : 1343-1980† respectively.

6.4 Dimensions — The principal dimensions of precast reinforced and prestressed concrete trusses shall be as given in **6.4.1** to **6.4.4**. The gravity axis of different members of the truss shall meet.

*Code of practice for design loads (other than earthquake) for buildings and structures: Part 1 Dead loads.

†Code of practice for design of loads (other than earthquake) for buildings and structures: Part 2 Imposed loads.

‡Code of practice for design of loads (other than earthquake) for buildings and structures: Part 3 Wind loads.

§Criteria for earthquake resistant design of structures (*fourth revision*).

*Code of practice for plain and reinforced concrete (*third revision*).

†Code of practice for prestressed concrete (*first revision*).

6.4.1 *Span* — The span of precast reinforced and prestressed concrete trusses shall preferably be in increments of 3 m ranging between 9 to 30 m and 6 m for spans in the range of 30 to 60 m.

6.4.2 *Rise of the Truss* — The central rise of the truss may preferably be not less than one-sixth of the span for straight chord trusses and between one-eighth and one-tenth of the span for curved chord trusses.

6.4.3 *Spacing of Trusses* — The spacing of trusses shall be decided on economical grounds. The spacing of trusses should usually be 6 m. Other preferred dimensions are 4·8,7·5, 9·0 and 12·0 m.

6.4.4 *Spacing of Purlins* — The sapcing of purlins shall be governed by the standard widths of roofing sheets or pretensioned planks or other roofing materials available which shall conform to the requirements of relevant Indian Standards.

6.5 Shape of the Truss — Shapes commonly used in steel trusses are possible for concrete trusses as well as portal frames in trussed form. For trusses carying concrete roofing panels, bow trusses with curved chords are economical and induce constant tension in the bottom chord and reduced secondary moments in the top chord due to load transfer being uniformly distributed along the top chord.

6.5.1 For precast reinforced concrete trusses, a camber at least equal to the calculated deflection of the truss dead and applied loads may be provided. In prestressed precast trusses, however, camber is not essential.

6.6 Design of Members

6.6.1 *Thickness*

6.6.1.1 The thickness of all the members, that is, truss thicknesses shall preferably be uniform except at the bearing surface of the truss where the section may be widened to provide adequate seating.

6.6.1.2 To reduce the effect of secondary stresses, the thickness of the members shall preferably be less than the width of the members.

6.6.2 *Reinforced Concrete Compression Members* — The reinforced concrete compression members of the trusses shall be designed in accordance with the requirements for compression members specified in IS : 456-1978*. For the purpose of taking the effective length of the members, the ends may be assumed as pin-jointed. The stresses in members due to combination of direct load and bending moment shall not exceed the permissible stresses for bending multiplied by the appropriate reduction coefficient treating the member as a long column in the appropriate direction taking due effect of ties provided by purlins or any other lateral stiffeners.

*Code of practice for plain and reinforced concrete (*third revision*).

6.6.3 *Reinforced Concrete Tension Members* — Members subjected to tension shall be designed conforming to the following requirements:

a) There should be sufficient reinforcement to resist all the tension at the permissible tensile stress of steel,

b) The calculated tensile stress on the effective section shall not be greater than the value specified in **4.4.1.1** of IS : 456-1978*, and

c) Local bending should be checked in case of suspension or transfer of loads away from node points of loads eccentric to the axis of the truss.

6.6.4 *Minimum Reinforcement* — Notwithstanding the provisions in **6.6.2** and **6.6.3**, a minimum reinforcement of four 6 mm diameter corner bars for thick members and two 6 mm diameter bars for members less than 75 mm thick shall be provided irrespective of the nature and magnitude of the forces in the member.

6.6.5 *Design of Prestressed Concrete Tie Members*

6.6.5.1 The effective prestress in tie member after losses shall be in accordance with **19.3.2** of IS : 1343-1980†.

6.6.5.2 Axial prestressing shall preferably be provided.

6.6.5.3 Longitudinal mild steel reinforcement in the prestressed tie member shall be designed, treating the member as a short column with the effective prestress as an axial compressive load.

6.6.5.4 All other requirements specified in IS : 1343-1980† shall be complied with.

6.6.6 *Joints* — The design of joints shall conform to the appropriate requirements of the joints in prefabricated construction.

6.7 *Design of Purlins*

6.7.1 Purlins are usually subjected to bending in two planes resulting from the wind load acting normal to the sheeting and the dead acting vertically downwards.

6.7.2 Where solid reinforced or prestressed concrete purlins are proposed the section shall be adequate to resist moments in both the planes and the resulting stresses shall be within permissible limits as specified in IS : 456-1978* and IS : 1343-1980†.

6.7.3 Alternatively where trussed purlins are proposed, they shall primarily be designed to carry the component of the load in its own plane and the load component normal to the plane of the truss shall be resisted entirely by the top member

*Code of practice for plain and reinforced concrete (*third revision*).

†Code of practice for prestressed concrete (*first revision*).

of the trussed purlin. The combined stressed shall be within the permissible limits specified in the relevant Indian Standards.

6.8 Transverse Reinforcement

6.8.1 The diameter of the transverse reinforcement shall be not less than 4 mm.

6.8.2 Transeverse reinforcement either in the form of helicals or stirrups shall be provided in all members irrespective of whether they are in tension or compression or carrying no load.

6.8.3 The pitch of the reinforcement shall conform to the requirement of IS : 456-1978*.

6.9 Cover — Reinforcement shall have a concrete cover and the thickness of such cover (exclusive of plaster or other decorative finish) shall be in accordance with the provisions of IS : 456-1978* for reinforced concrete members and with IS : 1343-1980† for prestressed concrete members.

6.10 Laps, welds, sleeves, nuts, etc, adopted shall be properly designed and detailed, specially in the case of tension members.

7. CONSTRUCTION

7.1 Casting of Trusses

7.1.1 Trusses may be cast in factory or at site depending upon the requirements of the job and the transportation and other facilities available.

7.1.2 Trusses may be cast in one piece or in several pieces depending on transport and handling facilities available. Where it may be necessary to cast the truss in pieces, it may be divided into convenient number of segments. For very large trusses, all the members of the truss may be cast individually. These may be assembled and prestressed or jointed and grouted before hoisting.

7.1.3 *Placing and Compacting of Concrete* — All precautions in handling and placing of high strength concrete mixes shall apply. The concrete placed shall be compacted thoroughly by using pin vibrators or other suitable means. Electrical percussion hammer with suitable attachments, such as the kango hammer may be used for vibrating the concrete.

7.1.4 Depending on the number of trusses of same size to be cast, timber or steel casting moulds may be used. Where timber moulds are used, the constituent walling planks shall be adequately stiffened to withstand the vibration. The mould planks may be interconnected by precast mortar spacer blocks and L-bolt.

7.1.5 *Joints* — Typical details of joints are shown in Fig. 1.

7.2 *Handling and Hoisting of Trusses*

7.2.1 Trusses cast in horizontal position on ground shall be lifted off the casting mouls or bed by means of stiffening frames.

7.2.2 Each member of the truss shall be checked for bending in transverse direction due to self-weight and any handling stresses likely to occur.

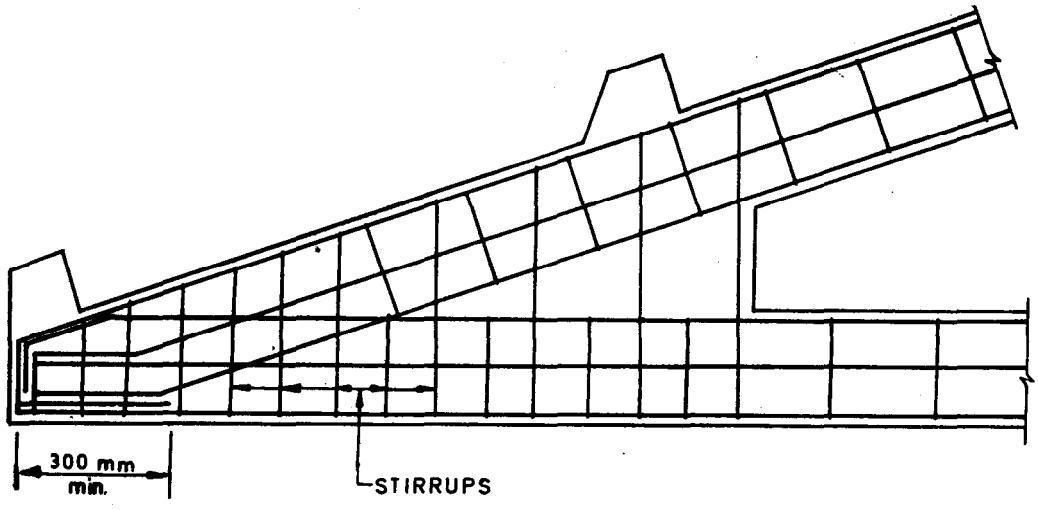
7.2.3 The trusses should be temporarily braced after hoisting till permanent bracings are provided by purlins or other stiffeners so that the lateral stability of the trusses is ensured.

7.2.4 The precast reinforced and prestressed trusses may be hoisted by the use of a simple derrickpole and winch. Proper care shall be taken during hoisting operation so that the trusses do not become twisted.

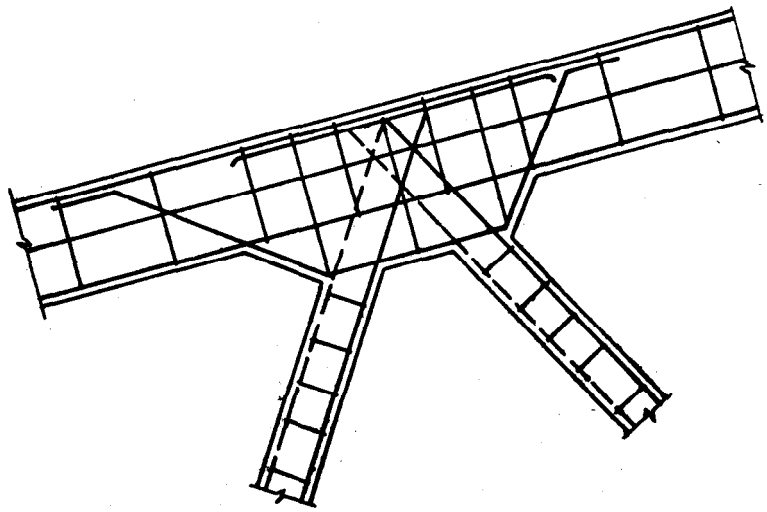
7.3 Bracing — The top and bottom chord of the trusses should be adequately braced for transfer of horizontal forces perpendicular to the plane of the truss in order to transfer in longitudinal direction as well as taking possible buckling of compression members. Typical details of bracing are shown in Fig. 2.

*Code of practice for plain and reinforced concrete (*third revision*).

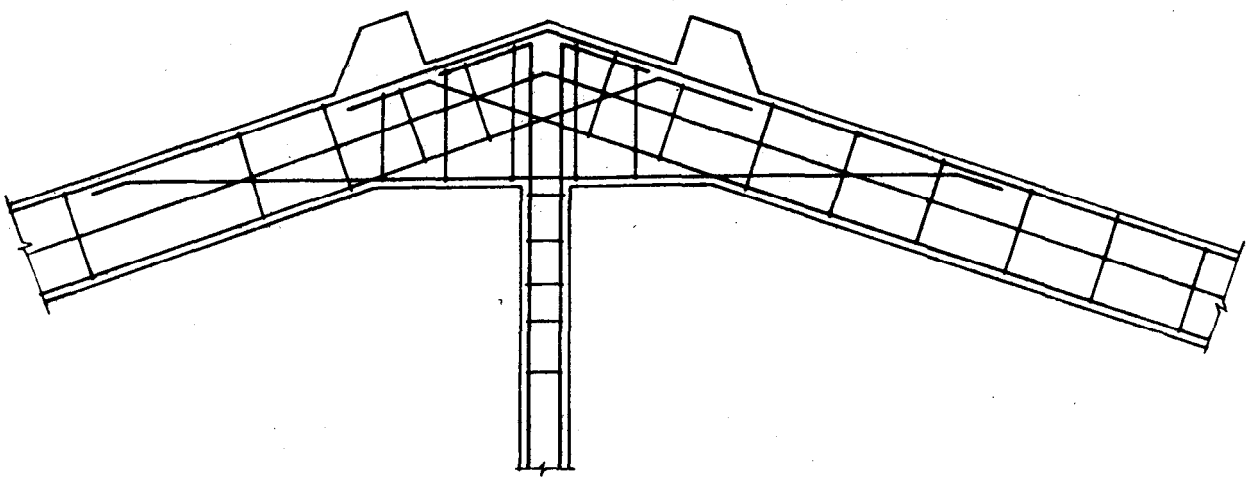
†Code of practice for prestressed concrete (*first revision*).



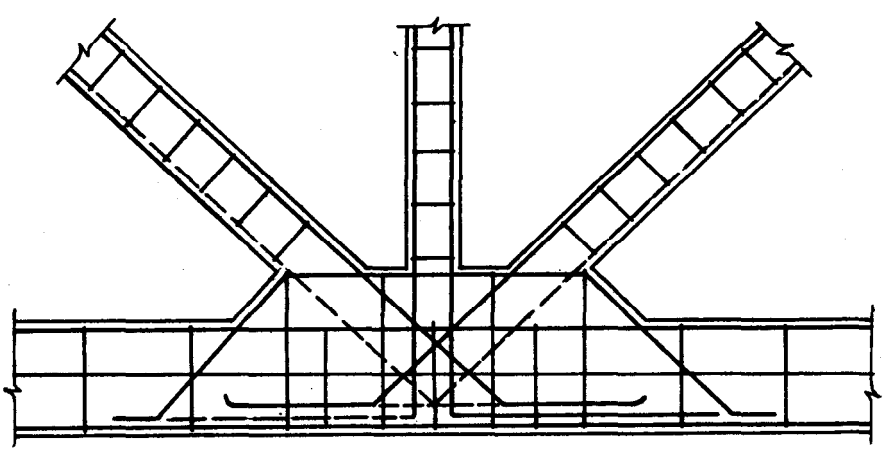
1A End Joint Detail



1B Top Chord Joint Detail

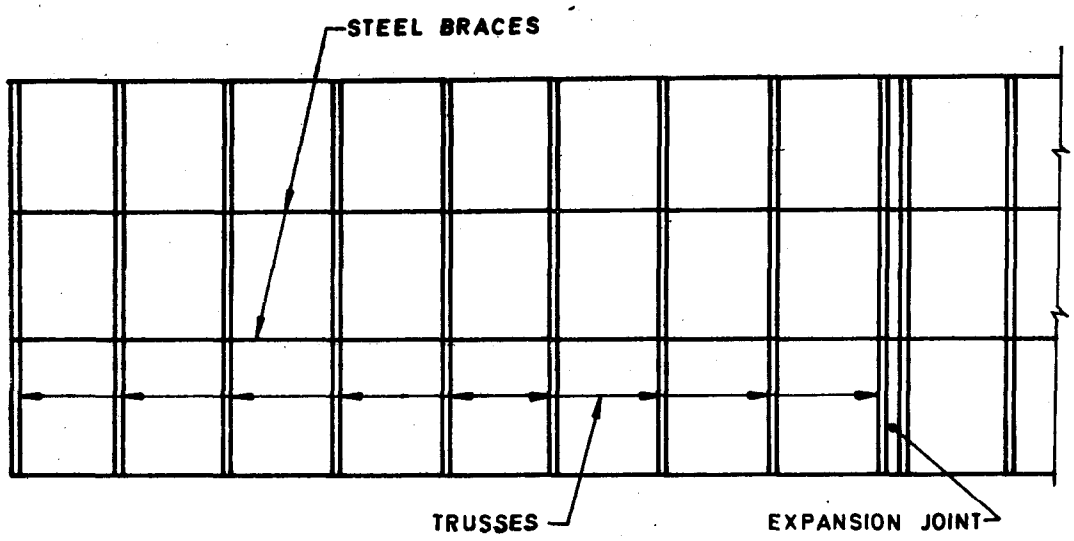


1C Crown Joint Detail

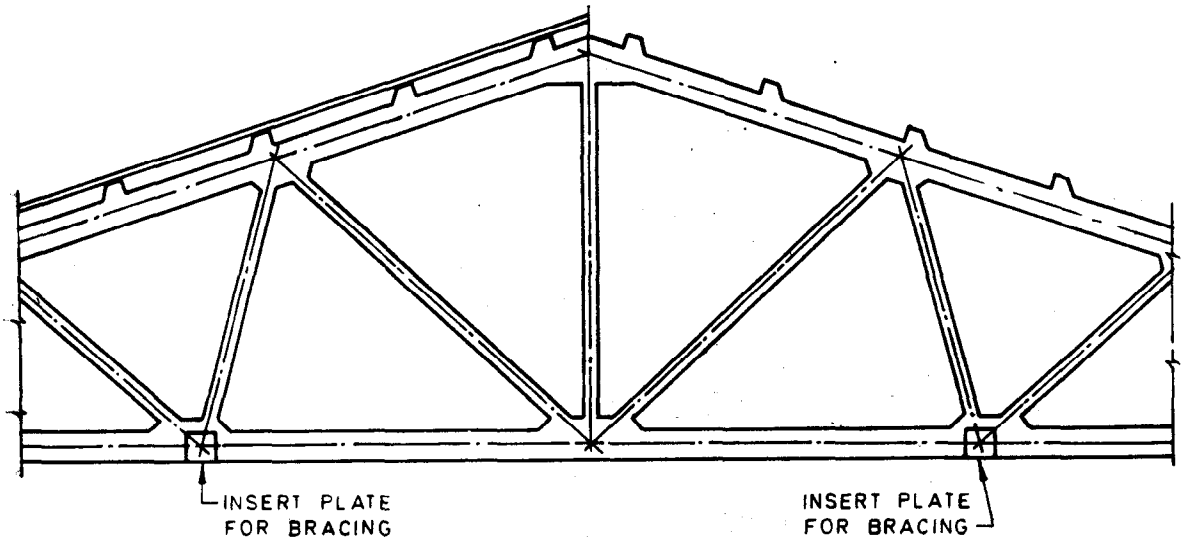


1D Bottom Tie Joint

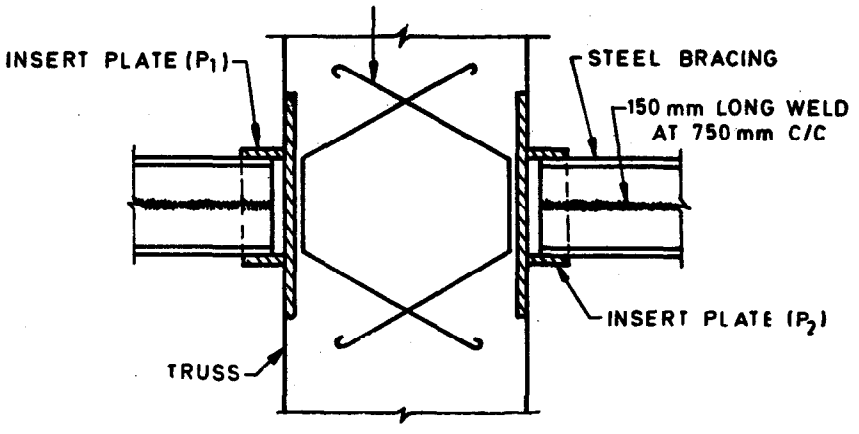
FIG. 1 TYPICAL DETAILS OF TRUSS JOINTS



2A Key Plan of Trusses and Braces



2B Precast Truss with Insert Plates for Fixing Braces



2C Typical Details of Steel Bracing

FIG. 2 TYPICAL DETAILS OF BRACING

7.4 Purlins — Purlins may be structural steel sections [*see* SP 6 (1)-1964*], cold formed steel section (*see* IS : 811-1965†), reinforced concrete (solid, angle, channel or trussed) and prestressed concrete. Typical details of fixing of purlins with the truss are shown in Fig. 3. Typical details of ribbed slab purlin are shown in Fig. 4.

7.4.1 To reduce the self-weight of solid purlins, balanced cantilever and/or pretensioned purlins may be used with advantage. In case of pretensioned purlins, all relevant provisions of IS : 1343-1980* for prestressed work shall apply. Typical cross-section of purlin is shown in Fig. 5.

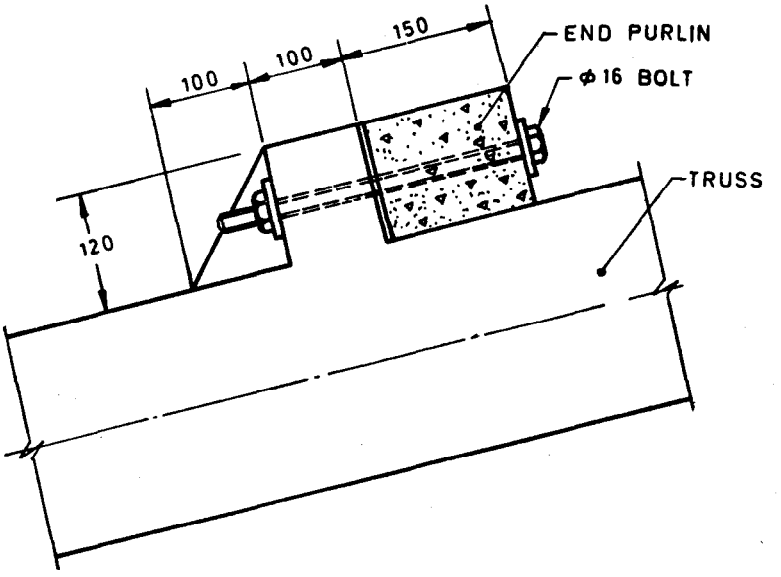
7.5 Prestressing — Prestressing of trusses of more than 20 m span shall preferably be carried out from both ends to reduce any prestressing losses due to friction.

7.6 Grouting — All post-tensioned members of the precast prestressed trusses shall be grouted. The specification for grout shall be as indicated by the designer.

*Handbook of structural engineers: Part 1 Structural steel section.

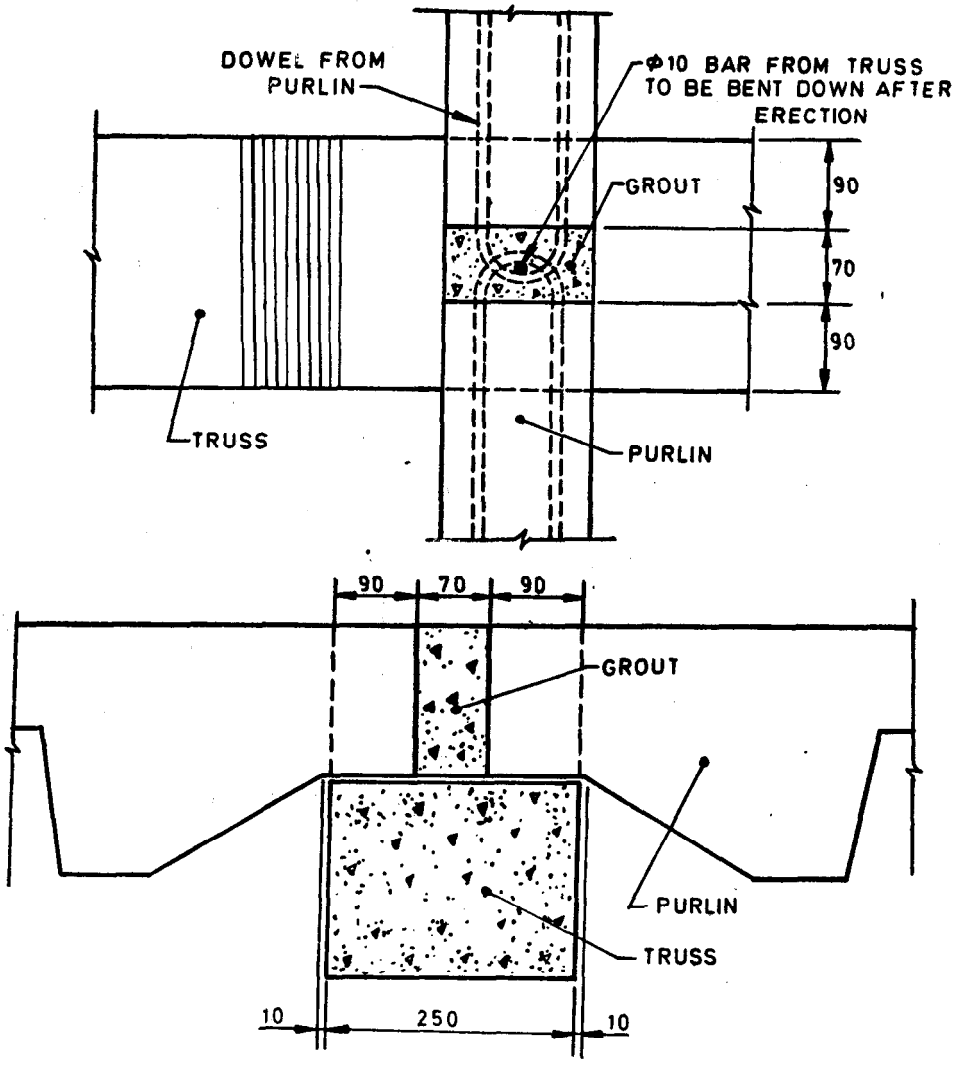
†Specification for cold formed light gauge structural steel sections (*first revision*).

*Code of practice for prestressed concrete (*first revision*).



All dimensions in millimetres.

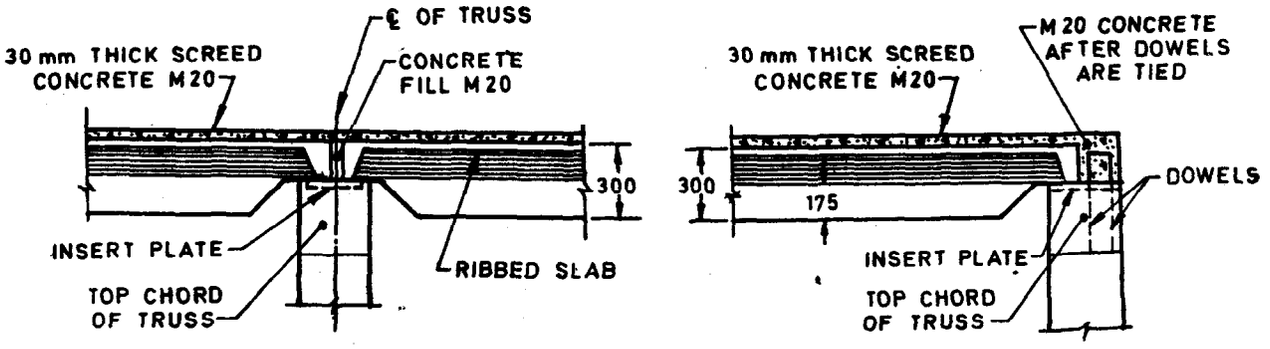
3A Fixing Details of Purlin with End and Expansion Joint Truss



All dimensions in millimetres.

3B Fixing Details of Purlin with Middle Truss

FIG. 3 TYPICAL DETAILS OF FIXING OF PURLINS WITH THE TRUSS



4A Ribbed Slab Purlin Details on Top Chord of Truss

4B Ribbed Slab Purlin Details on End Truss Joint

All dimensions in millimetres.

FIG. 4 TYPICAL DETAILS OF TRUSS WITH RIBBED SLAB PURLIN

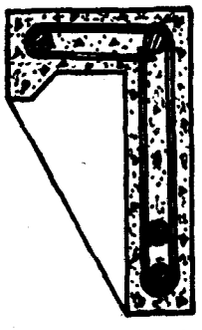


FIG. 5 TYPICAL CROSS-SECTION OF 'L' PURLIN

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