OPSC-AEE 2020

Odisha Public Service Commission

Assistant Executive Engineer

Civil Engineering

Design of Steel Structures

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

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Publications

Design of Steel Structures

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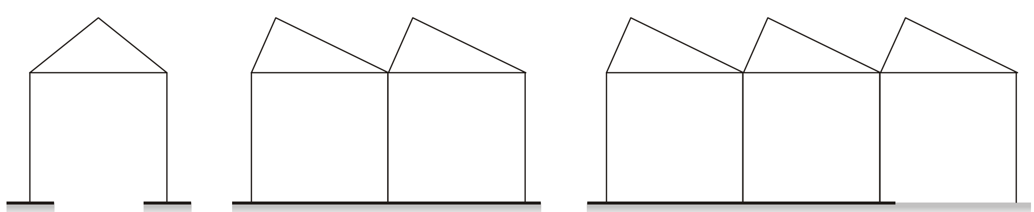
CHAPTER 8

Industrial Roof Truss

8.1 Introduction

Steel building structures can be classified into shell structures and framed structures. A framed structure can further be classified as a single storey structure (e.g. low rise steel structure) and a multi-storey (high rise) steel structure. Industrial buildings are low rise steel structures characterized by their comparatively low height and lack of interior floors, walls and partitions. Invariably, the roofing system for such buildings is truss with roof coverings. The enclosure of an industrial building may be brick masonry, concrete wall or GI sheet coverings. The walls are usually non-bearing but these must be adequately strong to resist lateral forces due to the wind or an earthquake. Some examples of such buildings are workshop, steel mills, machine plants, warehouses, hangers, etc.

The width of an industrial building may consist of one or more enclosure called aisles. Single aisle, double aisle and triple aisle bents have been shown in figure respectively. The length of an industrial building is divided into bays. A bay is defined as the space between two adjacent bents. Overall economy in the design of an industrial building is achieved when bay lengths are much smaller than the span of the truss. Usually bay lengths are kept between 4-8 m, whereas a truss span may range from 10-25 m or even more if required.



(a) Single Aisle (b) Double Aisle (c) AisleTriple

Fig. *Industrial Building Bent*

8.2 Planning

The planning of an industrial building is based on functional requirements, i.e., on the operations to be performed inside the building. In the planning of a particular type of industrial building, due consideration should be given to factors such as wide area free of columns, large heights, large doors and openings, large span of trusses, consistent with the operations to be performed, a compromise with all the listed factors to give minimum weight of trusses, purlins, columns, etc. and lightening and sanitary arrangement.

The site for a proposed plant is in general, pre-selected before it comes for design. But it is better to discuss with the designer the preliminary plans in advance. This gives the designer an opportunity to choose a suitable site giving due consideration to future developments.

Some of the factors governing the site selection are as listed below:

1. The site should be located on an arterial road
2. Local availability of raw materials
3. Facilities like water, electricity, telephone, etc.
4. Topography and water drainage
5. Soil condition with reference to foundation design
6. Sufficient space should be available for storage of raw materials and finished products
7. Sufficient space should be available for transportation facilities to deliver raw materials and collect the finished products
8. Waste disposal facilities. A schematic layout of an industrial building is shown in figure.

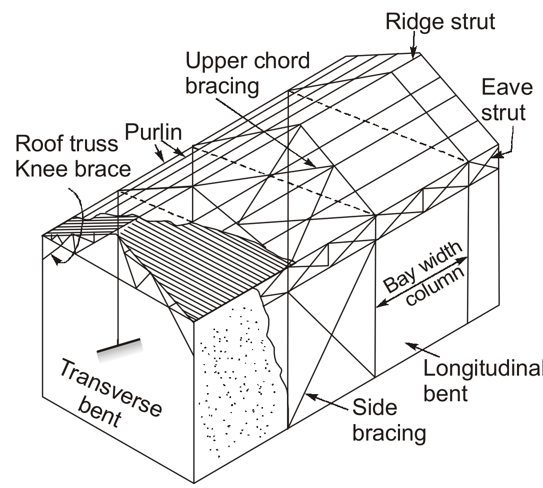


Fig. Structural Frame of an Industrial Building

8.3 Components of an Industrial Shed

Figure shows the various components of an industrial shed. It mainly consists of:

1. Roof trusses
2. Purlins - Side Purlins or Side Rail
3. Bracing
4. Columns and their bases
5. Gable End Columns
6. Gantry Girders
7. Cladding, Sag rods, Flooring etc.

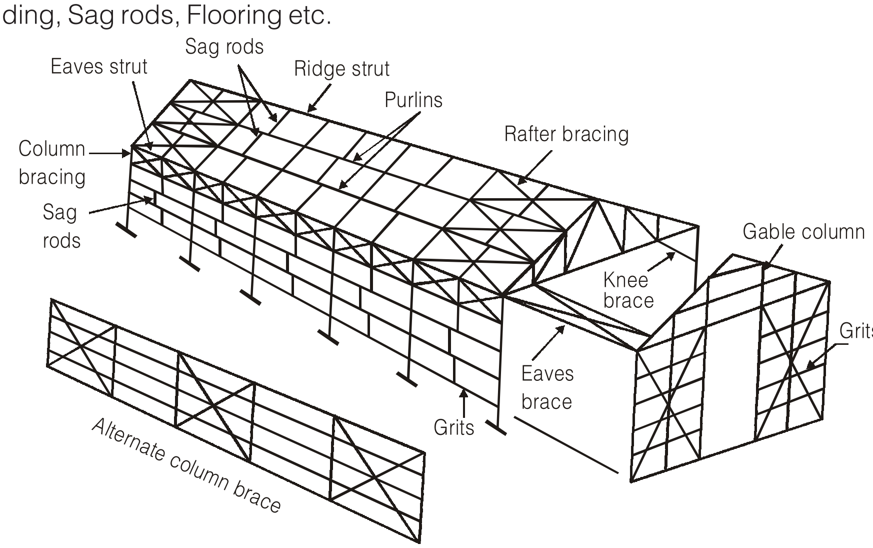


Fig. Various components of industrial shed

8.4 Roof Trusses

- They are economical for spans more than 6 m. Pratt, Howe and Compound Fink trusses are used upto maximum span of 30 m.
- The pitch of a roof truss (= rise/span) should be 1/4 to 1/6 for proper drainage.
- Spacing of roof trusses is kept 1/3 to 1/5 of the span.
- Roof trusses usually require very light members.
- A minimum angle section ISA 50 × 50 × 6 mm should be provided to avoid damage during transportation, erection etc.
- Double angle sections are usually used for main rafter and ties.
- The gusset plate should be at least 6 mm thick and at least 2 rivets should be used to connect any member to it.

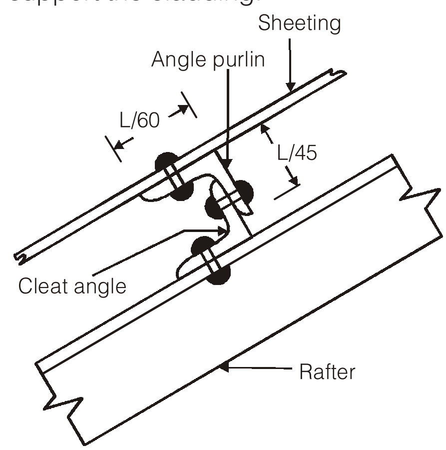
NOTE

Members of roof trusses are designed as axially loaded tension or compression members if they are slender and their resistance to bending is neglected. However, if loads from purlins, false ceiling etc. are applied in between the nodes then principal rafters or main ties are designed for combined stresses from bending and axial load.

8.4.1 Purlins and Grits

Angle, channel, I and Z sections are used for purlins and grits to support the cladding.

IS 800 : 2007 provides general design procedure for angle purlins conforming to steel grades Fe 410-O, Fe 410-S, Fe 410 -W and roof slopes not exceeding 30° based on a minimum live load of 750 N/m^2 if the following requirements are fulfilled:



(i) Width of angle leg in the plane perpendicular to the roof covering $\geq \frac{L}{45}$

(ii) Width of angle leg in the plane parallel to the roof covering $\geq \frac{L}{60}$

(iii) Maximum bending moment in the purlin, $M = \frac{w \times L^2}{10}$

Where w = uniformly distributed load per unit length on purlin including wind load

L = span of purlin

(iv) The bending moment about minor axis may be neglected and the angle purlin may be designed for the above moment.

$$\therefore \quad Z_x \text{ required} = \frac{M}{\sigma_{bc}} = \frac{w \times L^2}{10 \times 165} \text{mm}^3$$

8.4.2 Bracings

In steel buildings, if the joints are assumed as hinged, then bending of the building due to wind perpendicular and parallel to ridge is resisted mainly by the eaves/knee bracing, column and rafter bracing, and gable end bracing.

The snow load may be taken as 2.5 kN/m^2 per mm of snow, where it is applicable.

8.4.3 Loads on Trusses

1. **Dead load:** If the spacing of truss is 4 m and pitch of truss is 1 : 4 then self weight of the truss is taken as

$$w = \left(\frac{l}{3} + 6\right) \text{kg/m}^3 \text{ of plan area}$$

2. **Live load:** If slope of truss is more than 10°, live load is taken as

L.L. = 0.75 kN/m – 0.02 kN/m^2 (for every degree increase in slope over 10°)

L.L. $\nless$ 0.4 kN/m^2

3. **Snow load :** Snow load is taken as 2.5 N/m^2 for every 1 mm depth of snow. If slope of truss is more than 50°, snow load need not be considered.

Economic spacing of truss

It is given as $t = 2p + r$

where, t = cost of trusses; p = cost of purlins; r = cost of roof covering

Example - 8.1 In a roof truss if pitch is $\frac{2}{\sqrt{3}}$ and slope is $\frac{1}{\sqrt{3}}$, the angle of inclination with horizontal would be

(a) 30° (b) 45°
(c) 60° (d) 75° (KPSC)

Solution: (a)

Slope of roof truss

$$\tan\theta = \frac{\text{Rise of truss}}{\text{Half span}} = \frac{1}{\sqrt{3}}$$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30^\circ$$

Example - 8.2 The slope of a roof truss is 30°, (access is not provided except maintenance), the imposed load on the roof truss taken as

(a) 350 N/m² (b) 400 N/m²
(c) 750 N/m² (d) 1500 N/m² (OPSC)

Solution: (b)

$$\text{Slope of roof, } \theta = 30^\circ$$

Imposed load on roof (when access is not provided and slope of roof > 10°)

$$\text{Imposed load} = (750 - 20(\theta - 10))\,\text{N/m}^2$$
$$= (750 - 20(30 - 10))\,\text{N/m}^2 = 350\,\text{N/m}^2 \not< 400\,\text{N/m}^2$$

Minimum imposed load on roof is 400 N/m².

Student's Assignment

Q.1 Generally the purlins are placed at the panel points so as to avoid
(a) axial force in rafter
(b) shear force in rafter
(c) deflection of rafter
(d) bending moment in rafter

Q.2 As per IS : 800. The maximum bending moment for design of purlins can be taken as
(a) $\frac{WL}{6}$ (b) $\frac{WL}{8}$
(c) $\frac{WL}{10}$ (d) $\frac{WL}{12}$ (KPSC)

Q.3 In a gabled industrial building in order to minimize the wind forces on the roof, the roof slope should be kept close to
(a) 5° (b) 15°
(c) 30° (d) 45° (UPPSC)

Q.4 Purlins are provided, in industrial buildings, over roof trusses to carry dead loads, live loads and wind loads. As per IS code, what are they assumed to be?
(a) Simply supported
(b) Cantilever
(c) Continuous
(d) Fixed (OPSC)

Q.5 The live load for a sloping roof with slope 15°, where access is not provided to the roof, is taken as
(a) 0.65 kN/m² (b) 0.75 kN/m²
(c) 1.35 kN/m² (d) 1.50 kN/m²

Q.6 Purlins can be designed economically
(a) By assuming all the loads normal to the roof truss
(b) By fixing them with rafters
(c) By providing sag rods
(d) All the above **(MPSC)**

Q.7 The wind load on a steel truss for an industrial building will depend upon
(a) location of structure
(b) shape of structure
(c) location, shape and height of structure
(d) shape and height of structure

Q.8 The self weight of roof truss in (N/m^2) may be obtained by
(a) $\left(\frac{l}{3}+5\right)$ (b) $\left(\frac{l}{3}+5\right)\times 10$
(c) $\left(\frac{l}{3}-5\right)$ (d) $\left(\frac{l}{3}-5\right)\times 10$

Q.9 In a truss design, snow load need not be considered when roof is steeper than
(a) 10° (b) 15°
(c) 30° (d) 45° **(TNPSC)**

Q.10 The range of economical spacing of trusses varies from
(a) $L/3$ to $L/5$ (b) $L/4$ to $2L/5$
(c) $L/2$ to $L/3$ (d) $2L/5$ to $3L/5$

ANSWER KEY // STUDENT'S ASSIGNMENT

1. (d)	**2.** (c)	**3.** (c)	**4.** (c)	**5.** (a)
6. (d)	**7.** (c)	**8.** (b)	**9.** (d)	**10.** (a)

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENT

1. (d)

Purlins have a tendency to sag in the direction of sloping roof and sag rods are sometimes provided midway or at third points, between roof trusses, as desirable to take up the sag. These rods reduce the moment M_{vv} and result in a smaller purlin section.

4. (c)

Purlins are assumed to be continuous beams.

10. (a)

The economic spacing of the truss is the spacing that makes the overall cost of trusses, purlins, roof coverings columns, etc. the minimum.
The spacing of the roof trusses can be kept 1/4 of the span for up to 15 m, and 1/5 of span from 15-30 m spans of roof trusses.

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