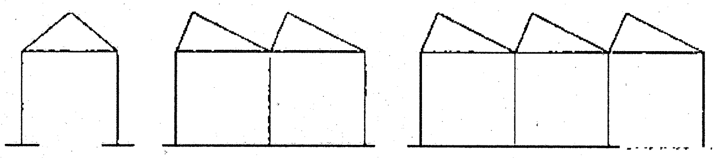
CHAPTER 13

Industrial Roof Truss

13.1 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. 13.1 Industrial Building Bent

13.2 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.

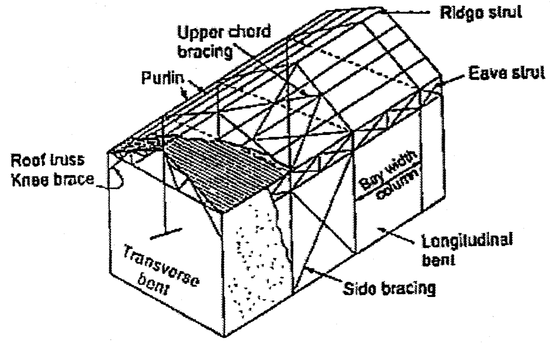


Fig. 13.2 Structural Frame of an Industrial Building

13.3 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.

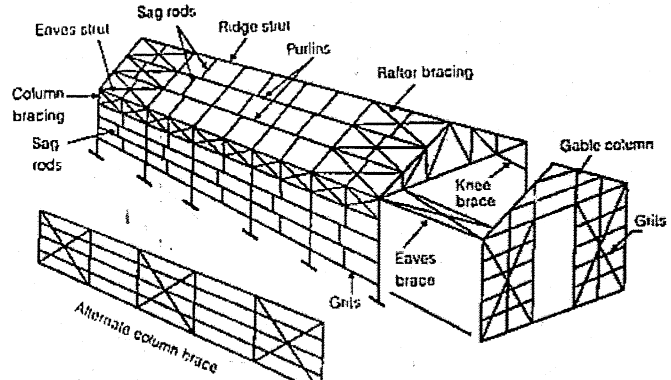


Fig. 13.3 Various components of industrial shed

13.5 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.

13.5.1 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/m² 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.

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

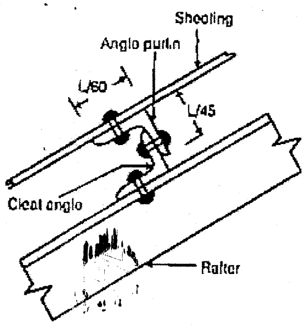


Fig. 13.4

13.5.2 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/m² per mm of snow, where it is applicable.

13.5.3 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/m² (for every degree increase in slope over 10°)
   L.L. ≮ 0.4 kN/m²

3. **Snow load**
   Snow load is taken as 2.5 N/m² 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 13.1 Find the wind pressure for design of a sloping roof of span 10 m and pitch 1/4. The height of eaves is 5 m above ground. The building is situated in Madras and its permeability is normal.

Assume, Probability factor, $k_1 = 1.0$
Terrain/height/structure size factor, $k_2 = 0.8$
Topography factor, $k_3 = 1.0$

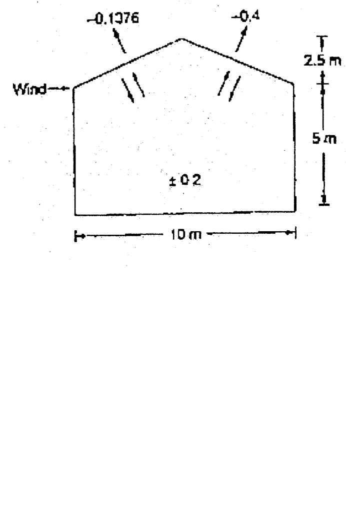
Solution:

Basic wind speed at Madras, $V_b = 50$ m/sec

Design wind speed, $V_z = k_1 k_2 k_3 V_b = 0.8 \times 50 = 40$ m/sec

Design wind pressure, $p_d = 0.6 \times V_z^2 = 0.6 \times 1600 = 960$ N/m²

(i) Wind normal to ridge:
External wind pressure coefficient C_{pe}



$$\text{On wind-ward slope} = -\left(0.4 - 0.4\times\frac{6.56}{10}\right) = -0.1376$$

$$\text{On lee-ward slope} = -0.4$$

Internal air pressure coefficient for normal permeability,

$$C_{pi} = \pm 0.2$$

Combined external + Internal wind pressure

Wind-ward slope,

$(-0.1376 + 0.2)\times 960 = 59.9\ \text{N/m}^2$ (downward)

$(-0.1376 - 0.2)\times 960 = -324.1\ \text{N/m}^2$ (uplift)

Lee-ward slope

$(-0.4 + 0.2)\times 960 = -192\ \text{N/m}^2$ (uplift)

$(-0.4 - 0.2)\times 960 = 576\ \text{N/m}^2$ (uplift)

(ii) **Wind parallel to ridge:**

External pressure coefficient C_{pe},

On both slopes for 1/4th length of building = −0.7

On both slopes for mid 1/2 length of building = −0.6

Internal air pressure coefficient for normal permeability, $C_{pi} = \pm 0.2$

Combined external + Internal wind pressure

On both slopes for 1/4th length of building

$(-0.7 + 0.2)\times 960 = 480\ \text{N/m}^2$ (uplift)

$(-0.7 - 0.2)\times 960 = -864\ \text{N/m}^2$ (uplift)

On both slopes for mid 1/2 length of building

$(-0.6 + 0.2)\times 960 = -384\ \text{N/m}^2$ (uplift)

$(-0.6 - 0.2)\times 960 = -768\ \text{N/m}^2$ (uplift)

Thus maximum wind pressure for design is 59.9 N/m² (downward) and 864 N/m² (uplift).

Example 13.2 **Design an I-section purling for a trussed roof from the following data.**

Span of roof = 12 m

Spacing of truss = 5 m

Spacing of purlins along slope of roof truss = 2 m

Slope of roof truss = 1 vertical, 2 horizontal

Wind load on roof surface normal to roof = 1000 N/m²

Vertical load from roof sheets, etc. = 200 N/m²

Solution:

$$\text{Slope of roof} = \tan^{-1}\left(\frac{1}{2}\right) = 26.6°$$

Assuming an ISLB 125@11.9 kgf/m is to be used as purlin

Dead load on purlin/per metre length:

(i) Weight of roof sheeting = 200 × 2 = 400 N/m

(ii) Self weight = 119 N/m (Approx)

Total vertical load, W_2 = 519 N/m

Wind load per metre length,

$$W_1 = 1000\times 2 = 2000\ \text{N/m}$$

$$M_x = (W_1 + W_2\cos\theta)\frac{l^2}{10} = 516\sin 26.6°\times\frac{5^2}{10}$$

$$= 6160\ \text{Nm} = 6160\times 10^3\ \text{Nmm}$$

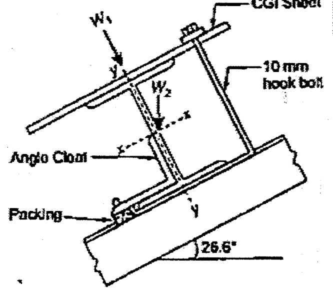
$$M_y = (W_2\sin\theta)\frac{l^2}{10} = 519\sin 26.6°\times\frac{5^2}{10}$$

$$= 581\ \text{Nm} = 581\times 10^3\ \text{Nmm}$$

$$\text{Maximum fibre stress} = \frac{M_x}{Z_x} + \frac{M_y}{Z_y}$$

$$= \frac{6160\times 10^3}{65.1\times 10^3} + \frac{581\times 10^3}{11.6\times 10^3}$$

$$= 144.7\ \text{MPa} \ngtr 165\ \text{MPa}$$

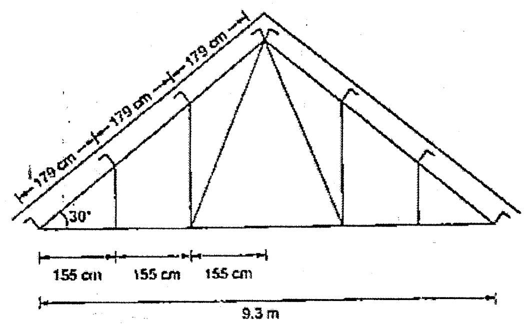


Which is all right.

Provide ISLB 125@11.9 kgf/m for purlins, as shown in figure.

Example 13.3 **Design a roof truss of span 9.3 m at a spacing of 4 m for an industrial shed. The height of eaves is 6.5 m and it is situated near Delhi. The roof truss is supported on 40 cm thick brick masonry.**

Solution:



Use Pratt truss of pitch 30° as shown in figure.

Load

(i) Imposed loads

Imposed load $= 0.75 - 20 \times 0.02 = 0.35\ \text{kN/m}^2$

Take minimum load 0.4 kN/m² (horizontal) for purlin and (2/3) × 0.4 N = 0.267 kN/m (horizontal) for trusses.

(ii) Wind load

For Delhi,

Basic wind speed, $V_b = 47$ m/sec

Taking, risk factor, $k_1 = 1.0$

Height and size factor, $k_2 = 0.88$

and, topography factor, $k_3 = 1.0$

Design wind speed,

$$V_z = V_b \times k_1 \times k_2 \times k_3$$

$$= 47 \times 1.0 \times 0.88 \times 1.0$$

$$= 41.36\ \text{m/sec}$$

Design wind pressure, $p_z = 0.6 \times V_z^2 = 1026.4\ \text{N/m}^2$

From table B-7 and B-9, wind load is evaluated assuming normal permeability as follow:

$$\frac{1}{2} < \frac{h}{w} = \frac{650}{930} < \frac{3}{2}$$

Wind normal to ridge	Total pressure = $(C_{pe} - C_{pi})p_z$	
	$C_{pi} = +0.2$	$C_{pi} = -0.2$
Windward, $C_{pe} = -0.2$	$-410.6\ \text{N/m}^2$	0
Leeward, $C_{pe} = -0.5$	$-718.5\ \text{N/m}^2$	$-308\ \text{N/m}^2$
Wind parallel to ridge on both slopes, $C_{pe} = -0.8$	$-1026.4\ \text{N/m}^2$	$-616\ \text{N/m}^2$

Maximum wind load $= -1026.4\ \text{N/m}^2$ uplift on both slopes.

Design of purlins

Spacing of purlins = 1.79 m

Weight of 20 gauge CGI sheet = 112.7 N/m²

Loads on purlins per metre length:

(i) Weight of sheeting $= 112.7 \times 1.79 = 201.7$ N/m

(ii) Weight of purlin (assuming) = 100 N/m

Total dead load = 301.7 N/m

Imposed load $= 400 \times 1.79 = -1837.3$ N/m

(uplift)

Dead + Imposed load $= 301.7 + 620 = 921.7$ N/m

Dead + wind load $= 301.7 - 1837.3 = -1535.6$ N/m

Since increase in permissible stresses is 33.33% when wind load is considered, dead + wind load may be considered 33.33% less effective.

$$\frac{1535.6}{1.33} = 1154.6\ \text{N/m} > 921.7\ \text{N/m}$$

Therefore, the combination of dead and wind loads in critical.

$$\text{Maximum bending moment} = \frac{1154.6 \times 4^2}{10} = 1847.3\ \text{Nm}$$

$$= 1847.3 \times 10^3\ \text{Nmm}$$

For an angle purlin,

$$Z_x = \frac{1847.3 \times 10^3}{165} = 11.2 \times 10^3\ \text{N.mm}$$

$$\text{Minimum depth} = \frac{L}{45} = \frac{4000}{45} = 88.88\ \text{mm}$$

$$\text{Minimum width} = \frac{L}{60} = \frac{4000}{60} = 66.66\ \text{mm}$$

Provide ISA 90 × 90, 6 mm @ 8.2 kgf/m having $Z_x = 12.2\ \text{cm}^3$.

Objective Brain Teasers

Q.1 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) $\frac{WL}{12}$

Q.2 The sway bracing is designed to transfer

(a) $2\frac{1}{2}$% of the top panel wind load to bottom bracing

(b) 10% of the top panel wind load to bottom bracing

(c) 25% of the top panel wind load to bottom bracing

(d) 50% of the top panel wind load to bottom bracing

Q.3 The bracing provided in the plane of end posts is called

(a) sway bracing

(b) portal bracing

(c) top lateral bracing

(d) bottom lateral bracing

Q.4 The maximum permissible span of asbestos cement sheets is

(a) 650 mm (b) 810 mm

(c) 1250 mm (d) 1680 mm

Q.5 To minimize the total cost of a roof truss, the ratio of the cost of truss to the cost of purlins shall be

(a) 1 (b) 2

(c) 3 (d) 4

Answers

1. (c) 2. (d) 3. (b) 4. (d) 5. (b)

Conventional Practice Questions

Q.1 Discuss the various loads or roof trusses for design.

Q.2 Determine live load and wind load for a steel roof truss of a cinema hall at Bangalore. The span of truss is 24 m and its pitch is 1/5. Height of eaves above ground level is 7.5 m. Take permeability of the building as zero.

Q.3 Design and detail the members meeting at joint X of the roof truss shown in figure. Also design welded connections for the same