INDUSTRIAL BUILDING

ndustrial Building: An industrial building is a structure with a self supporting steel frame with a light weight covering (usually fire resistant). The framework of a steel frame industrial building consist of series of transverse bents, which carry the purlins on the tops of the trusses, and girt on the sides of the column to carry the covering. The framework is braced by diagonal bracing in the planes of the roof and the sides of the building and in the plane of lower chords.

ction of Industrial Building:

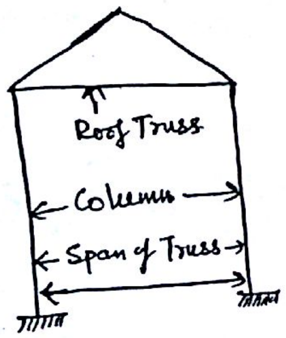
<1> To store the raw Material or manufactured products of the industry.
<2> To support and house a manufacturing process for the industry.

t: The roof truss together with the supporting columns constitute a bent.

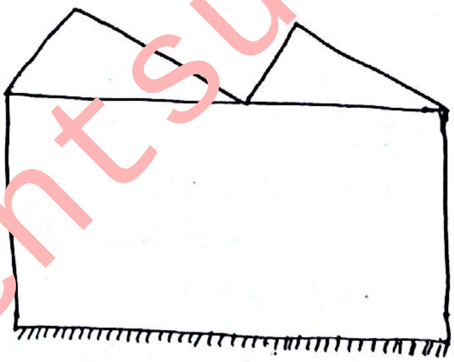
s: The space b/w two adjacent bents. Usually bay lengths are kept b/w 4-8 m.

n of truss: Span truss may range from 10-25 m or even

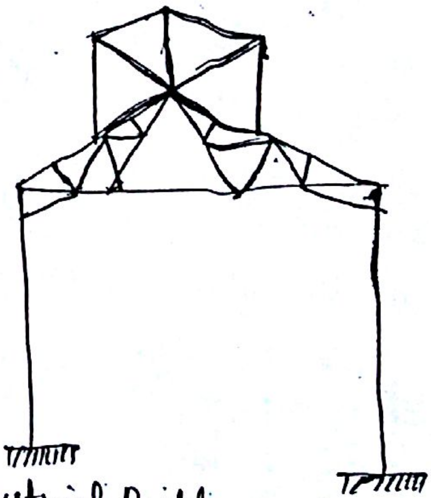
isle: ~~The width of an industrial building may consist of one or more enclosure called Aisles. or~~ Distance b/w two column lines, is known as Aisle



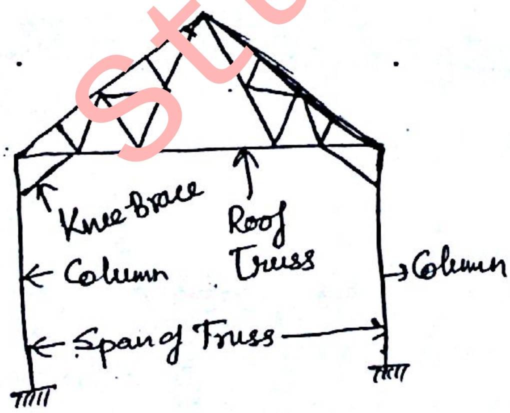
Single Aisle



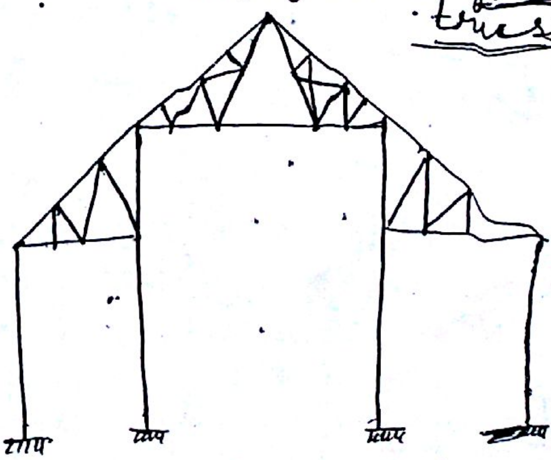
Double Aisle



Industrial Building with Sky light with fink type truss.



Industrial Building With Fink Type Truss



Industrial Building with

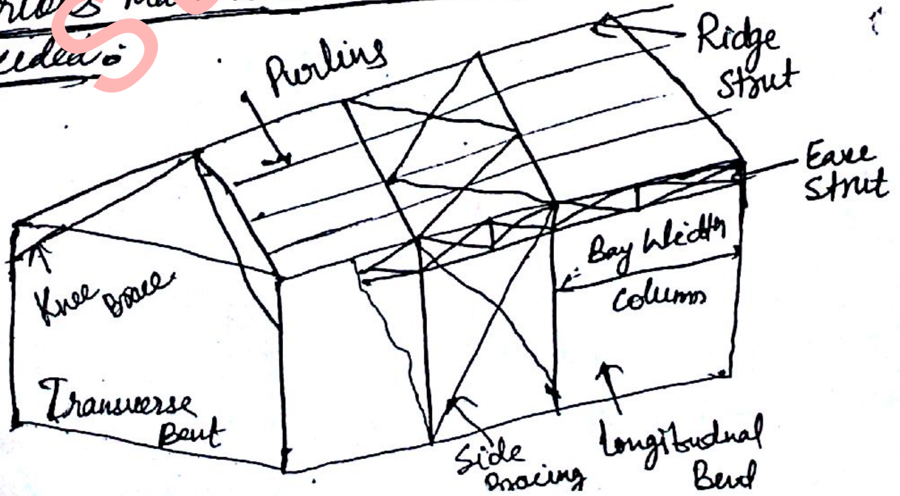
Bent (Transverse Bent): The roof truss together with supporting column constitute a bent. A transverse bent consist of a roof truss supported at the ends of column and it is braced against endwise movement by means of knee brace. Knee brace are used against the longitudinal movement parellel to span of truss.

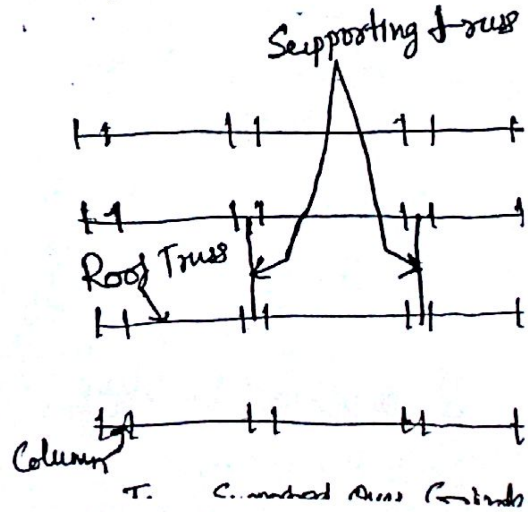
Longitudinal Bents: the transverse bent and longitudinal bent make industrial building resitant against horizontal wind forces.

Structual Framing of Industrial Building:

A structual framework consist of steel trusses supported over column making a transverse bent, where as a longitudinal bent is formed by joining transverse bent. structual framing consist following steps.

- Once the production layout is decided the column free area requirement is known. The column rows can be located according to the clearance requirements. Column rows at wide distances and with large trusses are economical as compared to closely spaced more number of rows of column with short span trusses. Also if the aisle is wide, modification can be easily accomodated in future.
- The column in each row are fixed (so as not to interfere with the mechanical layout) Generally, a column spacing of 4m to 8m is provided. If larger column spacing is required in some portion (a multi-bay system industrial building, the truss may be supported over girder or supporting truss) and the column at 'a' and 'b' can be omitted.
- A sketch of members, opening, lintels, doors, window, girts (required to support the wall surface) and end wall column is made.
- As the column spacing is fixed by this time, the pitch of the truss is selected and type of truss to be provided is decided. The panel length are worked out and purlin location are marked.
- A plan is prepared to show the lateral bracing system. It may be done either in the plane of the bottom chord or in the plane of the top chord and sometime in both the planes.
- Various Material to be used for floor, roof wall, and partition wall are decided.





COMPONENTS OF INDUSTRIAL BUILDING :-

1>. Purlin <2> Sag Rod <3> Principal Rafter <4> Roof Truss <5> Gantry girder <6> Bracket <7> Column and Column Base <8> Girt <9> Bracing

Purlin: Purlins are beams which are provided over roof truss to support the roof covering. Purlin span b/w top chords of two adjacent roof truss and transmit the load from roof covering to the trusses. Purlin are usually placed over the panel point of roof truss. However, structurally purlin should be placed slightly away from panel point so as to keep the centroid of purlin section ~~over~~ vertically over panel point.

Design of Purlin:

<i> Purlin should be placed slightly away from panel point so as to keep the centroid of purlin section vertically over panel point. When sheeting is directly placed over the purlin, these can be placed at intermediate points along the top chord of truss.

<ii> Purlin should be designed as continuous beam, but it is difficult because purlin may have to be spliced and continuity can not be assured through splices. Therefore, purlin section provided should be as long in length as possible.

<iii> The exterior bay width is kept at about 80% of interior bay width to reduce maximum moment in the end span of the purlin. It makes the moment in the end span equal to those in interior span.

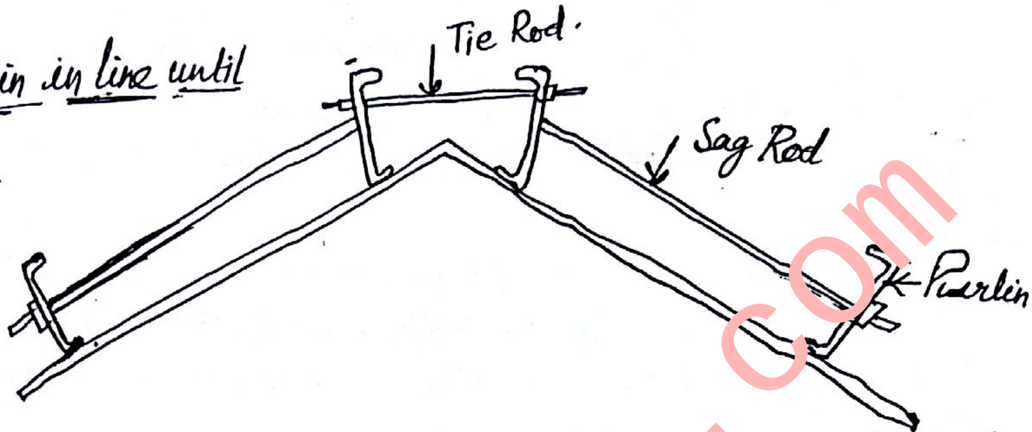
<iv> Purlin are often designed only for normal component of force since purlin with roof covering act like a deep plate girder and due to this stress from parallel component can be neglected.

Sag Rods: When the slope of the roof is appreciable, the component of the vertical load acting in the weak plane of the purlin may demand consideration. In such a situation, sag rods are provided b/w adjacent purlin to extend lateral support for purline in their weaker direction and enhance the rigidity of purlin section about their weak axis. These are round section rods and are fastened to the web of the purlin.

Design <i> A sag rod is designed as a tension member to resist the tangential component of the resultant of roof load and purlin ~~dead~~ dead load. The tangential component of the roof load is considered to be acting at the top flange of purlin, whereas normal component and purlin's dead load is assumed to act at its centroid. Therefore, sag rod should be theoretically placed at point where the resultant of these force act. But this is not ~~possible~~ practicable, and sag rod is placed at minimum gauge distance below the top.

Sag rod po... the ... as ... the ...
component from two sides of the roof truss.
The no. of sag rods to support each purlin depend on length of purlin and load to be supported.
The sag rod should not be terminated at the ridge as the ridge purlin in such a case is subjected to excessive pull, therefore the sag rod are extended over the ridge forming a continuous line b/w eaves.

Sag rod help to hold the purlin in line until the roof covering is provided.



> **Principal Rafter:** → The principal rafter of a roof truss is designed as a continuous strut. Generally, a double unequal angle section with long legs back to back is most suited for an industrial building structure because of following reason

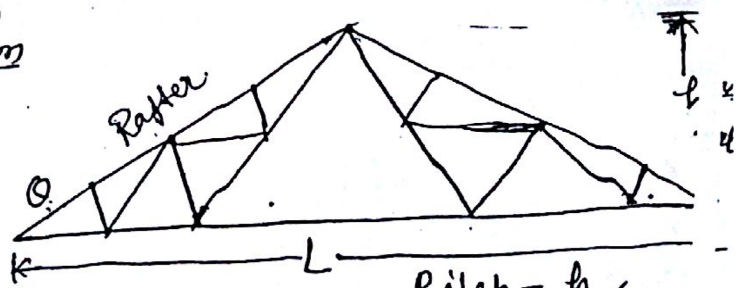
(i) A rafter section should have the same radius of gyration about main axis ($r_{xx} = r_{yy}$) so as to acheive the same bending strength about the axes and to have the value of least radius of gyration as large as possible.

least radius of gyration as large as possible

(ii) to have the value of least radius of gyration as large as possible

> **Roof Truss:** Roof truss are elements of the structure composed of members subjected to direct stresses. Sometimes the truss is also called an open web beam.

It consist of a triangular network of compression and tension member. Theoretically, truss member are subjected only to direct tension and direct compression. But in reality some shear and moment is always there at joint which is neglected except for large bridge truss.



Pitch = h/L

Slope = tanθ = 2 pitch

Roof truss may be
(i) Simple roof truss supported over masonry wall
(ii) Roof supported over column and connected to it with ~~masonry wall~~ knee braces.

Load On Roof Truss: Roof truss are subjected to

(1) Dead Loads
(2) Live Load
(3) Snow Load
(4) Wind Load.

Dead Load: Dead load of truss include dead load of roofing [illegible], purlins, trusses, and bracing system. The weight of purlins is known in advance as these are designed prior to the trusses.
a> Dead weight of truss may be assumed to be equal to 10% of the loads on the truss.
b> The dead load of the truss after the design should not vary by more than 10%.
> A rough estimate of the dead weight of the roof truss can be 60% of dead wt. of a girder subjected to same design loads, but distributed uniformly.
> Weight of bracing may be assumed to be 12 – 15 N/m² of plan area.
> Dead wt. of truss can be estimated in N/m² as.

$$= \left[\frac{\text{Span}}{3} + 5\right] \times 10$$

Live Loads: IS-875 specifies following live loads to be assumed in the analysis of industrial building

Roof Slope	Access	Live load
≤ 10°	Provided	1.5 kN/m² of plan area.
~~≥ 10°~~	Not provided	0.75 kN/m² of plan area.

≥ 10° ⟶ for roof membrane sheets or purlins 0.75 kN/m² less 0.02 kN/m² for every degree increased in slope over 10 degrees & 400 N/m²

Snow Loads: If the structure is situated in an area where the roof is subjected to snow, the load considered for design should be maximum of the live load or snow load. The load due to snow depends upon the pitch of the roof, shape of the roof, and of roofing material. Snow load may be assumed to be 2.5 N/m² per mm depth of snow. When roof slope is greater than 50°, the snow load may be neglected.

Wind Load: The most critical load on an industrial building is the wind load. However, for the roofs and walls of an industrial building, consideration must be made for pressure difference b/w opposite faces of such elements to account for external and internal air pressure exerted by the wind blowing against building. The internal air pressure may be positive or negative depending upon direction of flow of air with respect to opening in the building. When negative air pressure is less than the atmospheric pressure, it is known as suction. Positive wind load indicates that the force acting towards the structual element and negative away from it.

Wind force (F) is given by

$$F = (C_{pe} - C_{pi}) A P_d$$

C_{pe} = External Pressure Coefficient
C_{pi} = Internal Pressure Coefficient
A = Surface area of element under consideration
P_d = design Wind Pressure

...ad combination. (i) Dead load + Snow load
(ii) Dead load + Live load
(iii) Dead load + Partial or full live load (whichever causes the max stress in member)
(iv) Dead load + Wind load + Internal Positive air pressure
(v) Dead load + Wind load + Internal Suction air pressure

...alysis of Roof Truss: The analysis of roof truss consist in determining the ...ds at the panel points and then analysis the internal forces in various ...embers of the roof truss. ① Algebric method of joint ② Graphic Method of joint ③ Method of section

Design of Roof Truss: Design of roof truss consist in selecting suitable type of truss, estimation of loads and design of purlin, members roof truss and their connection. Design steps are.

> Depending upon span, lighting, roofing material, etc. available, the type of truss is decided and a line diagram of the truss is prepared.

> Various loads ~~are~~ acting over roof truss are estimated.

> Purlins are designed and loads acting on panel points of truss are computed.

> Roof truss is analysed by suitable method from following (a) Algebric method of joints (b) Graphic Method of joints (c) Method of section

> The compression member are designed. The principal rafter is designed as a continuous strut and other compression member are designed as discontinuous strut.

> The tension member are designed. Single angle tension member have twisting tendency and produce eccentric forces at joints. Therefore, double angle section are preffered. A minimum of 50 X 50 X 6 mm angle section is provided.

> The width of truss member should be kept minimum as ~~much~~ far as possible because wide members have greater secondry stress.

> If purlin are placed at intermediate points i.e. b/w the joints of the top chord, the top chord will be subjected to moments. The member in such a case, is designed for direct stress and moments.

> The member meeting at a ~~point~~ joint are so proportioned that their centroidal axes intersect at one point (to avoid eccentric condition)

> the joints of the truss are designed.

Gantry Girder: These are laterally unsupported beam and are provided in industrial building to carry cranes.

Brackets: Brackets are used to support gantry girder.

Crane Column: The column which supports the gantry girder in general, called crane column. Column are devided in to three categories

<i> Column with Bracket <ii> stepped (notched) column <iii> Double Column.

Column with Bracket: It is the simplest arrangement which is provided to support a crane girder.

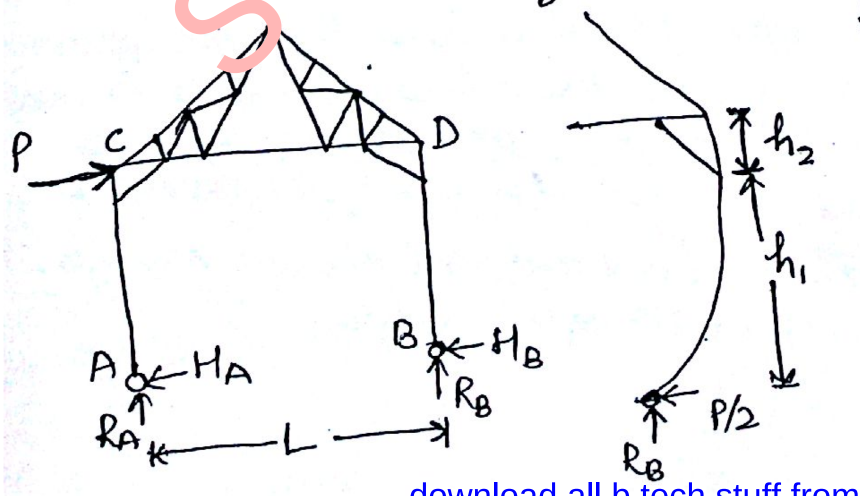
Stepped Column: A stepped column is made by steping the column at crane level. This step, on the inner flange of I-section column, is then enlarged to form a seat for gantry girder. the outer flange of I section supports the truss. The two column support is provided to support heavy crane. the two columns are designed seprately and connected by diaphragm. the inner column section is designed for loads transmitted from gantry girder and outer column is designed for gravity and wind loads transmitted from ~~gantry girder~~ industrial building and lateral thrust from crane. In stepped columns double angle strut are provided on column. these strut resist longitudinal forces at the gantry level and also act as bracing. Diagonal bracing of outer flange is also done by a single angle section above gantry level.

Column Loads: An industrial building column is subjected to following loads

<i> Dead load from roof truss <ii> live load on roof truss <iii> Crane load which consist of dead weight of gantry girder, rail, brackets wheel load and impact load.

<iv> Load due to wind (i.e horizontal and vertical component of wind reaction) and knee brace load.

Analysis: (A) Column Hinged At Base



Horizontal Reaction, at supports A & B

$$H_A = H_B = P/2$$

Vertical Reaction

$$R_A = R_B = \frac{P(h_1 + h_2)}{L}$$

P = lateral load

L = span of bent

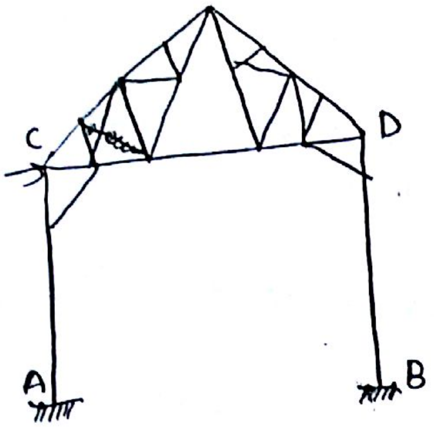
Max B.M at Knee Brace,

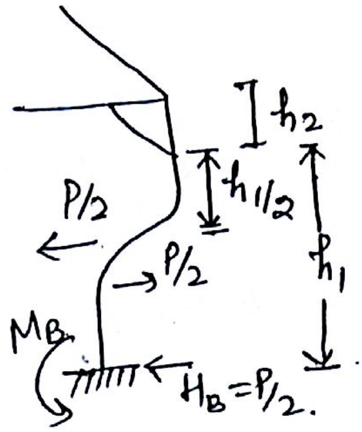
$$M = \frac{P}{2} h_1$$

$$H_A = H_B = \frac{P}{2}$$

Vertical Reaction, $R_A = R_B$

$$R_A = R_B = \frac{P\left(\frac{h_1}{2} + h_2\right)}{L}$$

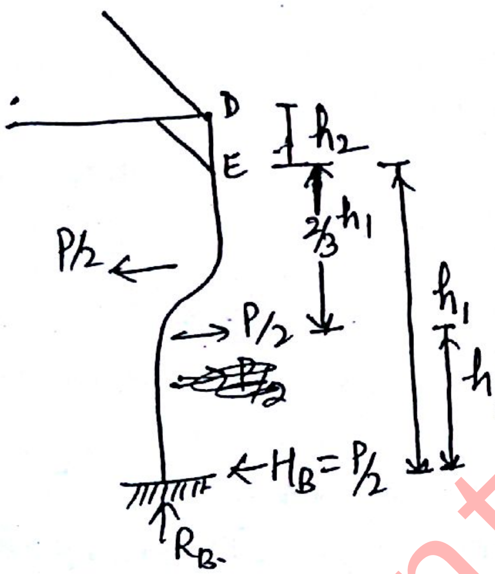




Moments,

$$M_B = M_E = \frac{P}{2} \times \frac{h_1}{2}$$

ii) Column Partially Fixed at Base



Horizontal Reaction H_A, H_B.

$$H_A = H_B = P/2$$

Vertical Reaction, ~~VA & VB~~. R_A, R_B.

$$R_A = R_B = \frac{P \times \left(\frac{2}{3}h_1 + h_2\right)}{L}$$

B.M at foot of knee,

$$M_E = \frac{Ph_1}{3}$$

B.m at foot of column.

$$M_B = \frac{P}{2} \times \frac{h_1}{3} = \frac{Ph_1}{6}$$

3) **Girt:** These are beams subjected to unsymmetrical bending. These support vertical dead loads from the siding (Sheeting or covering) and horizontal wind loads. Usually these are unequal angle section with the longer leg as the outstanding (horizontal) leg to withstand the effect of wind. Sometimes a light channel or a zee section is also provided. Girts are assumed to be ~~bending~~ continuous. Sometimes arrangement are done to support the weight of the siding by sag rods suspended from the eaves strut. The girt in such cases are subjected to wind only. The girt are bolted to the bent column and vertical. The sheeting is fixed to them in an identical manner as in case of roofing.

BRACING:

The bracing of Industrial building are so planned and provided that lateral forces due to wind, earthquake and crange surge etc are transmitted efficiently to the foundation. An individual bent may be stable against lateral loads in its own plane. However, it has little resistence to forces acting normal to its plane. Also, a series of bent constituting industrial building should be stable. therefore a system of lateral or diagonal bracing is provided to prevent the building from twisting under action of wind.

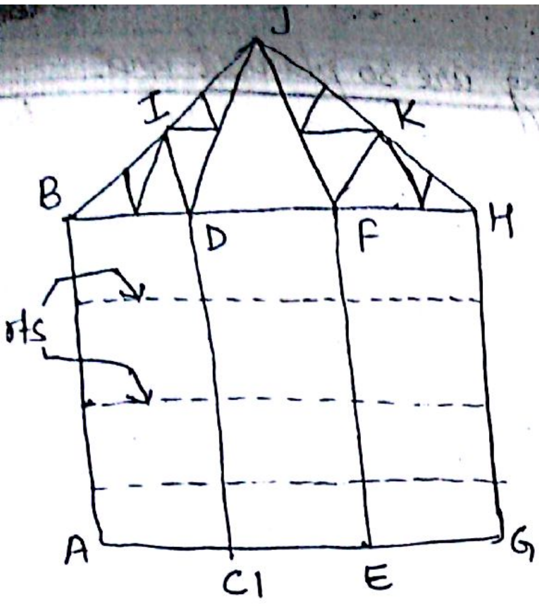
⟨i⟩ Transverse Bracing
⟨ii⟩ Longitudnal Bracing

> **Transverse Bracing:** ↳ A bent should be braced transversely to preclude collapse even during erection. Each bent after erection should be stable in the transverse direction. The end condition of column have large bearing over the stability of bent. The ultimate aim of the bracing in the transverse direction is to reduce the end moments of column. this is acheived either by providing knee braces or by rigid frame portal. ~~The knee braced bents, through popular, have a disadvantage where travelling cranes are to be used.~~

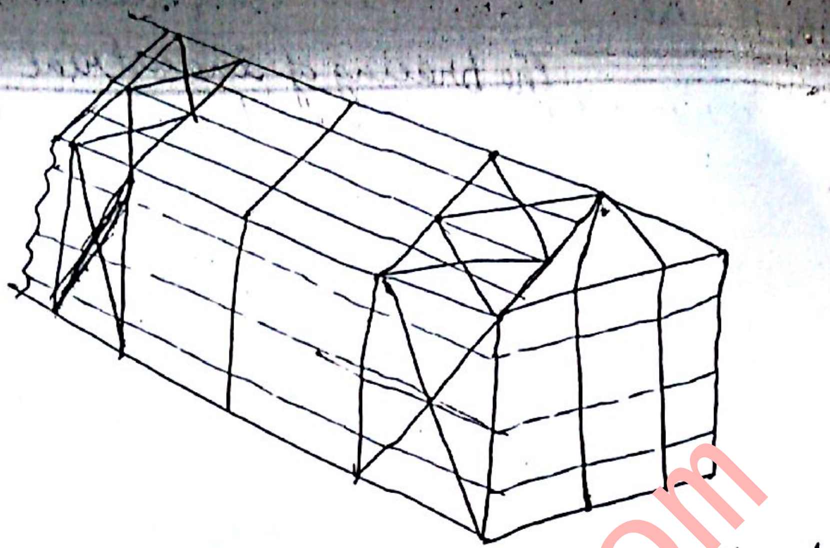
Longitudnal Bracing: ↳ The wind may be normal to the transverse bent. Therefore it becomes essential to brace the industrial building in the longitudnal direction. The truss bracing system tranffers the longitudnal loads to the column and the vertical column bracing transfers them to foundation.

Diagonal Cross Bracing: ↳ Diagonal cross bracing is used in the planes of the upper chord member. These braces together with purlins (acting as a strut to the wind) make a complete upper chord bracing system. In addition to the top chord bracing the bottom chord of truss may be tied together at the column by longitudnal strut. these strut can be provided at panel points. The ridge strut and eaves strut also form part of the bracing system.

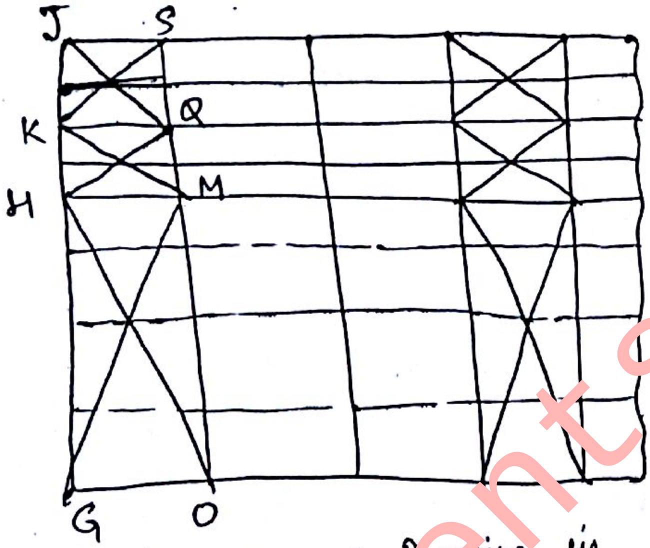
Diagonal cross bracing is used in the planes of the lower chord member only when heavy vibrating loads are anticipated in the industrial building. The diagonal bracing in either the upper or lower chord must form a horizontal or inclined truss, whose reaction are furnished by end frames.



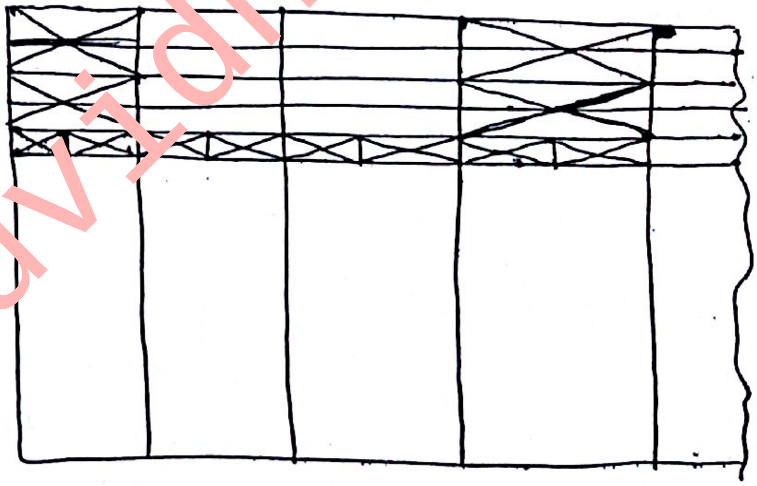
(a) End Bracing



(b) Bracing in plane of Upper Chord

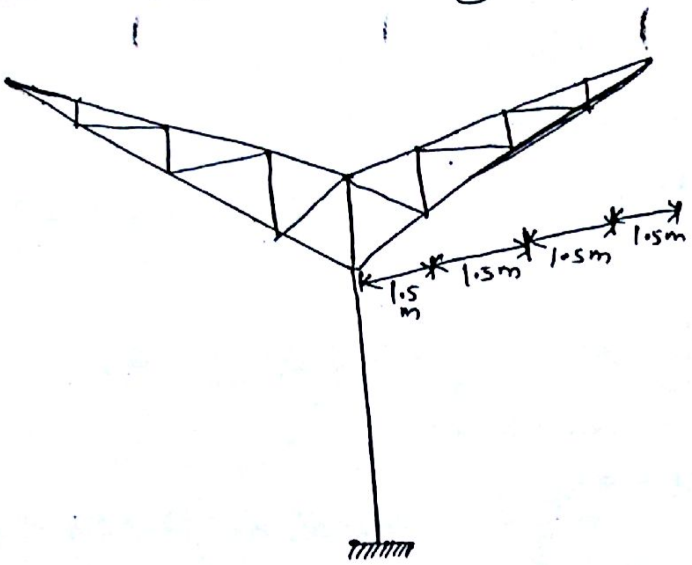


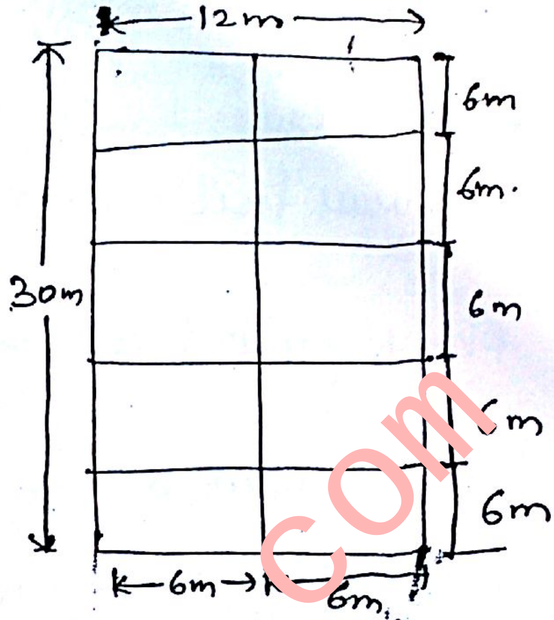
Longitudinal Bracing in plane of upper Chord.



Bracing of Industrial Building

Q) Design a roof truss for a railway platform ... 12m wide. The type of roof truss to be provided is shown. The roofing is to be done with asbestos cement sheet. Assume necessary relevant data.





Sol: As the truss is symmetrical about column, only half the truss is analysed.

<1> Dead Load:

Weight of Asbestos cement sheets = 171 N/m²

Weight of Purlins = 200 N/m²

Weight of Bracing = 12 N/m²

Self wt of roof truss $= \left[\frac{Span}{3} + 5\right] \times 10 = \left[\frac{12}{3} + 5\right] \times 10$

Self wt. of roof truss $= 90\,N/m^2$

Total dead load $= 171 + 200 + 12 + 90 = 473\,N/m^2 \simeq 500\,N/m^2$

Spacing of truss = 6m.

Length of each panel = 1.5m.

Load on each intermediate panel $= 500 \times 6 \times 1.5 = 4500\,N/m^2$
$= 4.5\,kN/m^2$

Load on end panels $= \frac{4.5}{2} = 2.25\,kN$

2> Live Loads: It is assumed that platform truss are not subjected to live loads. Therefore

Live load = 0

> Wind Load:

Let design wind pressure $= 1.05\,kN/m^2$

From IS code, Angle of inclination, $\alpha = 7.125°$

For $\alpha = 7.125°$, $C_{pe} = +0.3425$

Solidity ratio, ϕ = ... gross area, under canopy

$\alpha = 7.125$ | $\phi = 0$, $C_{pe} = -0.5425$
| $\phi = 1$, $C_{pe} = -0.8$

The butterfly truss has large opening (>20%). Hence $C_{pi} = \pm 0.7$

Maximum Positive wind load $= (+0.3425 \pm 0.7) \times 6 \times 6 \times 1.05$

$= \pm 39.4\ kN$

Max. Negative Wind load $= (-0.8 \pm 0.7) \times (6 \times 6) \times 1.05$

$= -56.7\ kN$

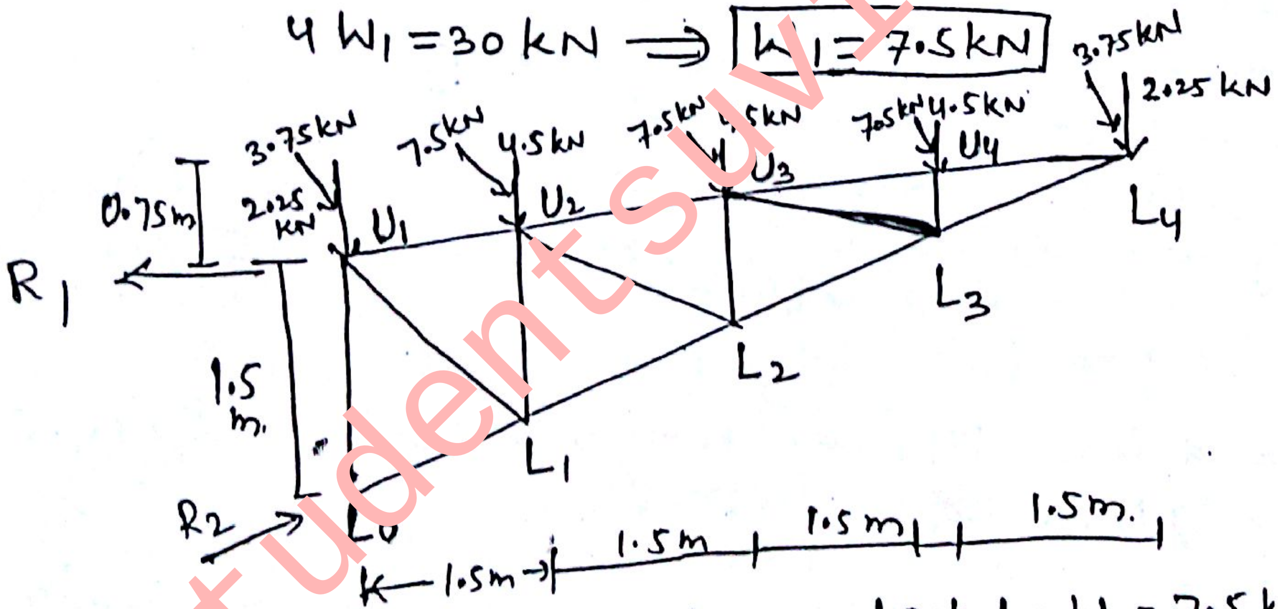
Wind load on half truss $= \frac{56.7}{2} = 28.35\ kN \simeq 30\ kN$

let wind load on intermediate panel point $= W_1$

Wind load at end panel point $= W_1/2$

$\frac{W_1}{2} + W_1 + W_1 + W_1 + \frac{W_1}{2} = 30\ kN$

$4W_1 = 30\ kN \Rightarrow \boxed{W_1 = 7.5\ kN}$

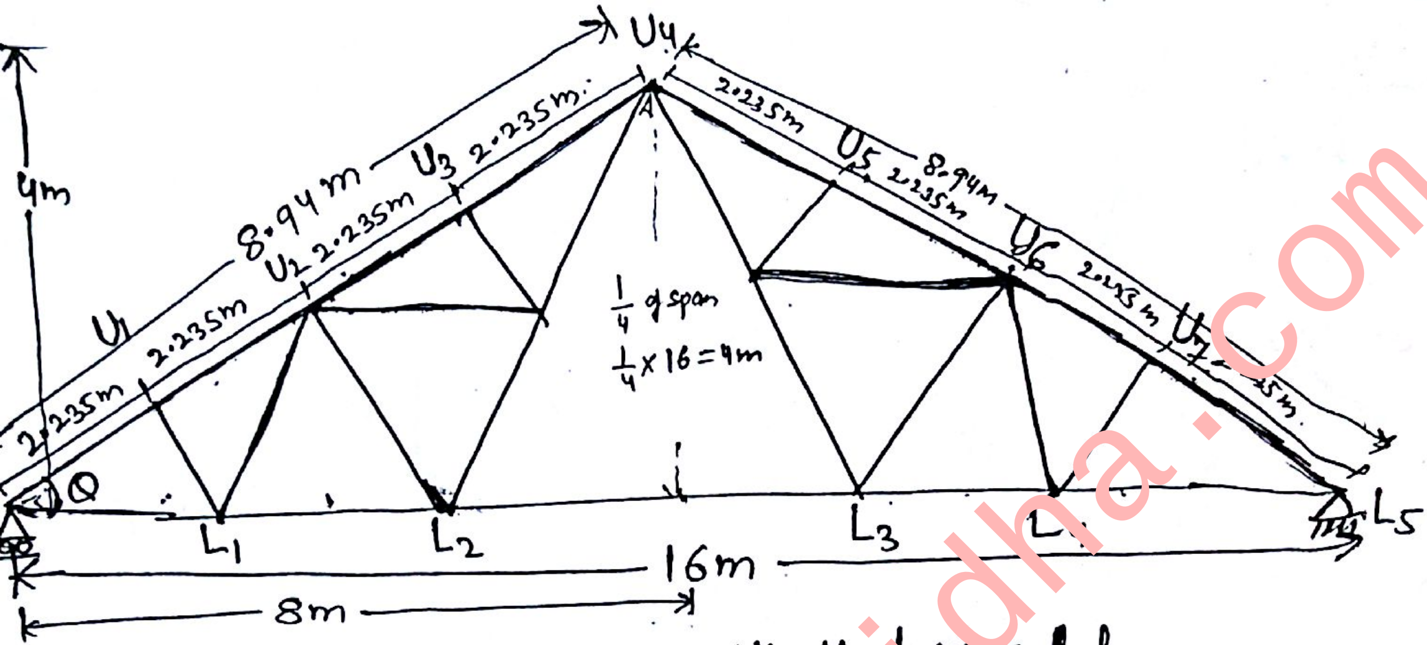


Wind load at intermediate panel point $= W_1 = 7.5\ kN$

Wind load at end panel point $= \frac{7.5}{2} = 3.75\ kN$

Wind load acts normal to principal rafter U_1L_4.

...termine the design forces in the member of steel roof truss ... span and resting on brick masonry wall. The truss are placed ... The rise of the truss is $\frac{1}{4}$ of span. Roofing is of asbestos ...ent sheets of dead wt 171 N/m². The wind load normal to roof ...uss is 940 N/m². One end of truss is hinged and other is ~~fixed~~ supported on rollers.



Sol: Let 'θ' be inclination of roof with the horizontal.

$$\tan\theta = \frac{4}{8} = \frac{1}{2} \Rightarrow \boxed{\theta = 26^\circ 34' = 26.566^\circ}$$

Length of rafter $= \sqrt{(8)^2 + (4)^2} = \sqrt{64 + 16} = \sqrt{80} = 8.94m$

Distance b/w panel points $= \frac{8.94}{4} = 2.235m$

LOAD CALCULATION

(1) Dead Load:

Wt of A.C sheet $= 171 \, N/m^2$

Wt. of Purlins $= 318 \, N/m^2$

Wt. of Bracing $= 12 \, N/m^2$

Self wt. of roof truss $= \left(\frac{Span}{3} + 5\right) \times 10 = \left[\frac{16}{3} + 5\right] \times 10 = 103.3 \, N/m^2$
$= 110 \, N/m^2$

Total Dead load $= 171 + 12 + 10 = 293 \, N/m^2$

Dead load of Purlin $= 318 \times 8 = 2544 \, N$

The panel length $= L_0U_1 = U_1U_2 = U_2U_3 = U_3U_4 = 2.235 \, m$

Panel length in Plan $\simeq 2.235 \cos 26^\circ 34' \simeq 2m$

Spacing of truss $\simeq 8m$

Load on each intermediate ...

$= 293 \times 8 \times 2 + 2544 = 7232\,N$

$= 7.4\,kN$

Load on end panel point $= \frac{7.4}{2} = 3.7\,kN$

...tion due to Dead Load: Taking moment about L_0,

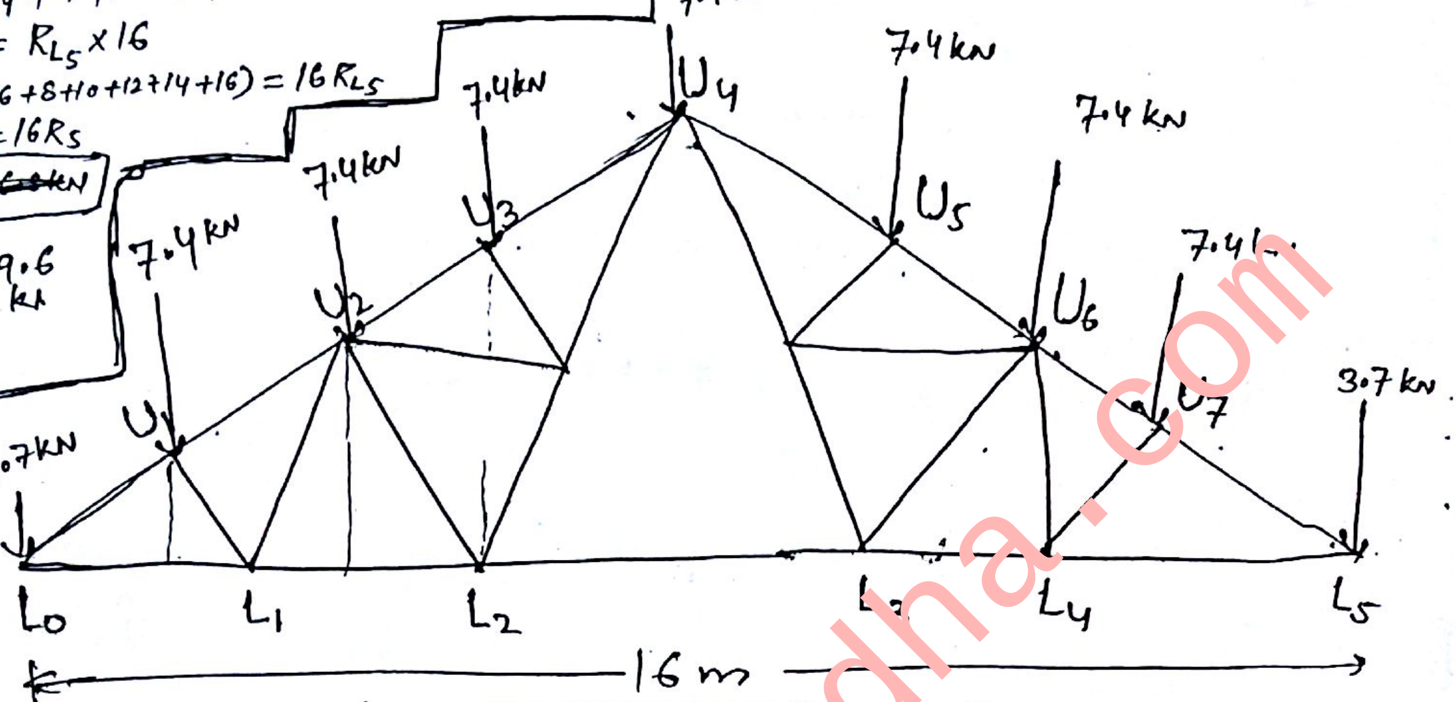
$\ldots 2 + 7.4\times4 + 7.4\times6 + 7.4\times8 + 7.4\times10 + 7.4\times12 + 7.4\times14$

$\ldots \times 16 = R_{L_5} \times 16$

$\ldots (2+4+6+8+10+12+14+16) = 16 R_{L_5}$

$\ldots \times 62 = 16 R_5$

$\ldots_{L_5} = 29.6\,kN$



Dead load on Panel Points

2> Live load:

$\theta = 26^\circ 34' = 26.566^\circ$

Let us assume no access is provided to the roof. The live load is reduced by $20\,N/m^2$ for each one degree above 10° slope.

Live load $= [750 - 20 \times (26.566 - 10)] = 418.68\,N/m^2$

The load on each intermediate Panel $= 418.68 \times 2 \times 8$

$= 6698.88\,N \simeq 6700\,N$

$= 6.7\,kN$

The load on each end panel point $= \frac{6.7}{2} = 3.35\,kN$

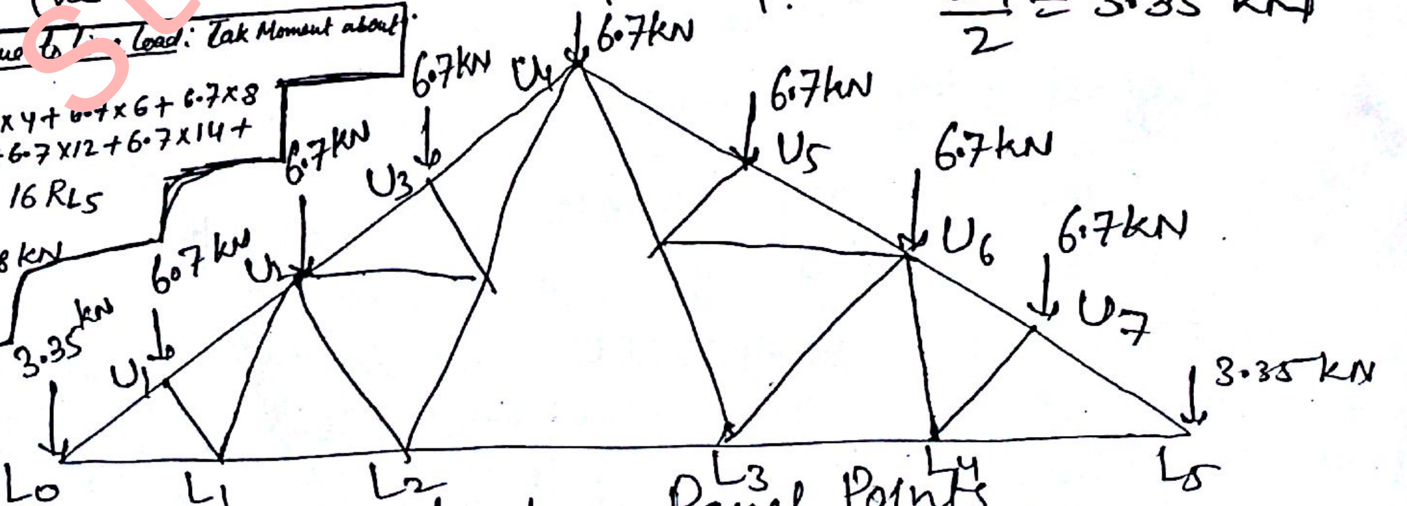
...ction due to Live Load: Take Moment about ...

$\ldots \times 2 + 6.7\times4 + 6.7\times6 + 6.7\times8$

$\ldots 6.7\times10 + 6.7\times12 + 6.7\times14 +$

$\ldots 5\times16 = 16 R_{L_5}$

$\ldots = 26.8\,kN$



Live load on Panel Points

Wind Load :- Length of Rafter = 8.94m.

Spacing of trusses = 8 m.

Total Wind load = 8.94 × 8 × 940 = 67,228 N

[Wind load normal to roof truss = 940 N/m²]

Let wind load on intermediate Panel = W_1,

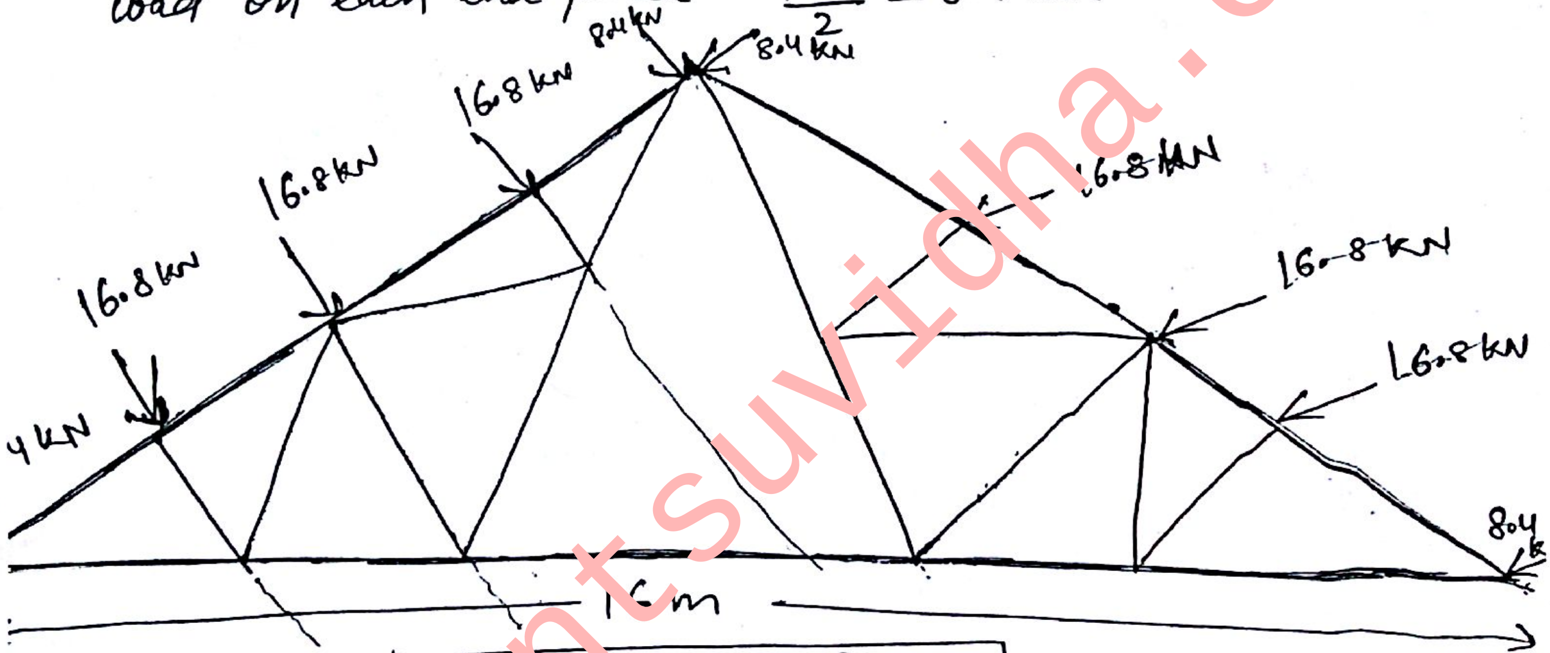
then Wind load on each end point = $\frac{W_1}{2}$

$\frac{W_1}{2} + W_1 + W_1 + W_1 + \frac{W_1}{2} = 67228$ N.

$4W_1 = 67228$ N ⇒ $W_1 = 16807$ N = 16.8 kN

load on each intermediate Panel = 16.8 kN

load on each end panel = $\frac{16.8}{2}$ = 8.4 kN



Wind load on Panels

Reaction due to wind load:

Take moment about L_0,

16.8 × 2.235 + 16.8 × 4.47 + 16.8 × 6.705 + 8.94 × 8.94 = 16 R_{L5}

R_{L5} = 18.774.

Take moment about L_5,

R_{L0} × 16 = 8.4 × 14.311 + 16.8 × 12.076 + 16.8 × 9.84 + 16.8 × 7.606 + 8.4 × 5.371

R_{L0} = 41.33 kN