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# ANALYSIS & DESIGN OF INNOVATIVE INDUSTRIAL ROOF

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## ABSTRACT

*Any building structure used by the industry to store raw materials or for manufacturing the products like machine/s is known as an industrial building. Industrial buildings may be categorized as Normal type industrial buildings and Special type industrial buildings. Normal types of industrial buildings are shed type buildings with simple roof structures on open frames. These buildings are used for workshop, warehouses etc. These building require large and clear areas un-obstructed by the columns. The large floor area provides sufficient flexibility and facilitates the later change/s in the production layout without major building alterations. The industrial buildings are constructed with adequate headroom for the use of an overhead traveling crane. Special types of industrial buildings are steel mill buildings used for manufacture of heavy machines, production of power etc. The function of the industrial building dictates the degree of sophistication.*

## I. INTRODUCTION

A structure may be defined as 'any assemblage of materials which is intended to sustain loads'. Since the gravity, wind and temperature effects are loads, the living creations and plants are also structures in the broad sense though they may not always intentionally sustain loads. The wings of bat and a spider's web are the typical tension structures, while the increasing thickness of trunk and branches of tree toward their supports can be explained by the fact that they are subject to bending and compression caused by the self weight and wind force. Any structure across this world needs a roof, because roof is one of the most important elements of a building structure to provide protection to the inmates from the sun, rain, wind, etc. The roof also protects the interior of a building from direct exposure to the weather. Roof is provided to structures depending upon their purpose and use is providing with different types of roof.

## II. LITERATURE SURVEY

As above, types of roof are discussed. Importance of truss less roof is discussed. The utility of different roof systems for different purposes use and type different authors/ industrialist is reviewed with the help of webography, research papers, books etc. Research papers on various types of roofing systems were studied. Following research papers are discussed.

### 2.1 "Development Of An Advanced Panelized Residential Roof System" by J. C. Carmody, G.E. Mosiman, J.H. Davidson, S.C. Mantell, G. Mittelman

The author in this paper described about the building envelope challenges and solutions for a self supporting and insulated panelized residential roof/attic system. Panels are designed to be self-supporting over relatively long spans without intermediate support except for a ridge beam. The structural component of the panel, referred to as the truss core, is comprised of two thin metal face sheets and an internal metal web. The web extends the entire length of the panel from soffit to ridge. The truss core concept has separate structural and insulating components integrated into a single panel at an offsite manufacturing facility. The insulation is placed either on the interior or exterior of the structural member as appropriate for the climate. A panelized roof system using a metal structure presents several challenges. The joints at the panel edges, ridges, and soffits must be designed to avoid thermal bridging and eliminate moisture transmission as much as possible. This must be done while maintaining a relatively simple construction process and an acceptable aesthetic appearance. The paper will describe approaches that address these construction assembly issues for prototypical designs in both heating- and cooling-dominated U.S.climates.

### 2.2 "A system that eliminates structural support systems in roofing" B Ravinder and K Srinivas Assistant Professor NICMAR Hyderabad.

A unique concept of self-supporting roofing technology, which offers up to 24-m clear span roofs completely eliminating structural support systems, is making an impact in the roofing industry. The technology, when combined with superior quality steel, offers time and cost benefits. This technology, with an installation capacity of 1,000 sq m per day, makes it an ideal choice for large warehouses. A planar truss is one where all members and nodes lie within a two-dimensional plane, while a space truss has members and nodes extending into three dimensions. The manifold advantages gained by adopting the concept of trussless roofing warrant its use on a large scale in civil engineering and industrial projects in coming decades.

## III. OBJECTIVES

It is proposed to study the innovative truss less roofing system for industrial buildings. The structural response parameters selected for the study are reactions for loading, horizontal thrust, construction time, water proofing, head room, cost, area utilization, etc.

Following are the objectives of this study.

i. To understand the industrial roof
ii. To study the innovative truss less roofing system for industrial buildings.
iii. To find the parameters like vertical reaction, horizontal thrust, water proofing, head room, cost, area utilization, cost, construction time, etc.
iv. To compare the conventional type of industrial roofing system with innovative roofing system in order to decide the betterness between two sheds.

## IV. PROPOSED WORK

- **Analysis of Industrial Building Roof with Truss:-**

As per the Is codes mentioned below the Analysis of roof with truss involves the following steps:-

1 IS:875(Part 3)-1987, Code of Practice for Design Loads for buildings and Structures for Wind Loads

2 IS:875(Part 2)-1987 Code of Practice for Design Loads for buildings and Structures for Imposed Loads

Load Combinations:-

1. Dead Load (D.L.) + Live Load (L.L.) + Wind Load (W.L.)
2. Dead Load (D.L.) + Live Load (L.L.)
3. Dead Load (D.L.) + Wind Load (W.L.)

Load Calculations on Roof Truss:-

1. Pitch of Truss

   Pitch = Rise / Full Span

2. Dead Load on Roof Truss

   a. Self Weight of truss = 1/100 [(l/3) + 5] KN/$m^2$

      L = Span of Truss. It is acting on plan area.

   b. Weight of Purlin = Assumed as 0.07 to 0.15 KN/$m^2$

      It is acting on plan area.

   c. Weight of bracings = Assumed as 0.015 KN/$m^2$

      It is acting on plan area.

   d. Weight of Roofing Sheet

      Asbestos Cement (A.C.) Sheets = 0.156 KN/$m^2$

      It is acting on inclined area.

3. Live Load on Roof Truss:-

   Live Load = [750 - 20 (θ - 10)] < 400 N/$m^2$

   Where θ = Angle of Truss.

4. Wind Load on Roof Truss:-

a. Internal wind Pressure:- It depends on permeability of building(Openings provided in building)

1. No permeability
2. Medium permeability / Normal permeability (+- 0.2$P_z$)
3. High permeability((+- 0.5$P_z$)

   (+ sign for suction and - sign for lifting)

   Where $P_z$ = Design wind pressure in N/$m^2$

   It is calculated using formula $P_z = 0.6\ V_z^2$ IS:875(Part 3)-1987, Pg. No. 12

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

**Design of Members of Truss:-**

**3.5.1 Design of Tension Member:-**

1.Calculate $A_{net}$ required

$A_{net}$ = Given Axial load / $\sigma_{at}$

Where $\sigma_{at}$ = 150MPa

2. Select a suitable section from steel table considering following conditions

a. If the end connections are bolted. $A_{gross}$ is taken 10% to 40% more than required

b. In case of welded end connections there is no hole so $A_{gross} = A_{net}$ required

3. Select a section from steel table and arrange it as per the requirement. Then calculate capacity.

Capacity = $A_{net}$ x $\sigma_{at}$

4. Compare the proposed load and calculated capacity. If the capacity is within 5% to 10% of proposed load our selected section is economical.

**Design of Compression Member:-**

1. Assume slenderness ratio λ

Single angle strut λ = 120 to 150

Double angle strut λ = 100 to 120

Channel Section λ = 80 to 100

I section λ = 30 to 50

Heavy load column = 40

2. Calculate value of $\sigma_{ac}$ using above assumed value of λ.

3. Calculate $A_{gross}$ = Axial Compression Load / $\sigma_{ac}$

4. Select a section from steel table and arrange it as per the requirement. Than calculate capacity.

5. Calculate the $I_{xx}$, $I_{yy}$, $r_{min}$ and λ.

6. Calculate capacity

Capacity = $A_{gross}$ x $\sigma_{ac\ calculated}$

Compare the proposed load and calculated capacity. If the capacity is within 5% to 10% of proposed load our selected section is economical.

**Steps for Analysis of Industrial Roof using Truss-less Roofing:-**

As per the Is codes mentioned below the Analysis of roof with truss involves the following steps:-

IS:875(Part 2)-1987 Code of Practice for Design Loads for buildings and Structures for Imposed Loads

1. Load Combinations:-

1 Dead Load (D.L.) + Live Load (L.L.) + Wind Load (W.L.)

2 Dead Load (D.L.) + Live Load (L.L.)

3 Dead Load (D.L.) + Wind Load (W.L.)

Load Calculations on Roof Truss:-

Dead load = The self weight of sheets/m

It varies depending upon thickness of sheet being used for the respective span.

Live load = 0.75 $y^2$KN/ m

where y = rise/span (H/L)

H - the height of the highest point of structure from its springing.

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L - chord width of the roof.

Referring IS:875(Part2)-1987Table No. 5, Page No. 16 the calculations has to be done.

Wind Load:-

Wind load depends on following wind pressure

b. Internal wind pressure

c. External wind pressure

a. Internal wind Pressure:- It depends on permeability of building(Openings provided in building)

1. No permeability
2. Medium permeability / Normal permeability (+- $0.2P_z$)
3. High permeability((+- $0.5P_z$)

(+ sign for suction and - sign for lifting)

Where $P_z$ = Design wind pressure in $N/m^2$

It is calculated using formula $P_z = 0.6\ V_z^2$ IS:875(Part 3)-1987, Pg. No. 12

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

Refering IS-875-1987(Part III) Pg No. 8 , $V_b$ ,$k_1$, $k_2$, $k_3$ are as below

$V_b$ = Design Wind Speed

$k_1$ = Probability Factor or Risk Factor

$k_2$ = Terrain , Height and Stucture size Factor

$k_3$ = Topography Factor

b. External Wind Pressure:-

External Wind Pressure depends on direction of wind

2. When wind blows parallel to ridge
3. When wind blows perpendicular to ridge

The coefficients required are referred from IS:875(Part 3)-1987, Table No. 5 ,Pg No. 16 and also from Table No. 15, Pg No. 28.

Horizontal Thrust:-

$$H = (wl^2) / 8h$$

Where w = Uniformly Distributed Load in KN/m

l = Span in m

h = the height of the highest point of structure from its springing in m.

Analysis & Design

**Common Data**

1. Span = 25 m
2. wind speed = 39 m/s
3. Location= Kolhapur
4. Column Spacing – 5 m
5. area covered – 25 x 60 $m^2$

**Analysis and Design of Roof with Truss:**

Following is used for roof with truss.

1. Type of Truss : Pratt
2. Pitch of Truss : 1/6
3. Height of Truss bottom : 8m

Pitch = Rise / Span
Rise = Span x Pitch
= 25 x 1/6
= 4.2m

Angle of Truss , tanθ = Rise / span = 4.2 / 12 = 18.40°

Inclined Length = $[(12.5)^2 + (4.2)^2]^{1/2}$ = 13.17m

Number of Nodes = 9

Nodal Spacing = 13.17/9 = 1.46m

Plan Area = 12.5 x 5 = 62.5m$^2$

Inclined Area = 13.17 x 5 = 65.85 m$^2$

**Dead Load Calculations :-**

1. Self Wt. of Truss = 1/100 [L/3 + 5 ] KN/m$^2$
   = 1/100 [ 25/3 +5]
   = 0.13 KN/m$^2$

Self Wt acting on Plan Area = 0.13 x 62.5 = 8.33 KN

1. Weight of Purlins:-
   Permissible Limit is 0.07 KN/m$^2$ to 0.015 KN/m$^2$
   So assume 0.015 KN/m$^2$
   Weight of Purlin acting on Plan area = 0.015 x 62.5 = 9.375 KN
2. Weight of Bracings = 0.015 KN/m$^2$
   Weight of Bracing acting on Plan area = 0.015 x 62.5 = 0.94KN
3. Weight of A.C. Sheets = 0.156 KN/m$^2$
   Weight of A.C. Sheets acting on Inclined area = 0.156 x 65.85 = 10.27 KN

Total Dead Load = 8.33 + 9.375 + 0.94 +10.27 = 28.92

Dead Load on per nodal point = 28.92/ 9 = 3.22 KN

Dead Load on end nodal point = 3.21/2 =1.61 KN

**Live Load Calculations :**

Live load = 750 - 20 (θ - 10) N/m$^2$
= 750 - 20 (18.40 - 10) N/m$^2$
= 582 N/m$^2$

Live Load acting on plan area = 582 x 62.5 = 36.375 KN

Live load per nodal point = 36.375/9= 4.04KN

Live load on end nodal point = 4.04/2= 2.02 KN

**Wind Load Calculations:-**

1. Internal Wind Pressure

Assuming normal permeability of building.

Take internal pressure = +- 0.2 $P_z$

Where,

+ sign is for Suction and - sign for Lifting

2. External Wind Pressure

Referring IS-875-1987(Part III), Table No. 5, Page No. 16, the calculations have been done.

h/w = 8/25 = 0.32 < 1/2 and thus, the calculations are as below

a. When wind blowing parallel to ridge for θ = 18.40°

For Windward Side

| | | |
|---|---|---|
| 10 | - | -0.80 |
| 20 | - | -0.70 |
| 18.40 | - | -0.716 |

External wind Pressure = -0.716 $P_z$

For Leeward Side

| | | |
|---|---|---|
| 10 | - | -0.60 |
| 20 | - | -0.60 |
| 18.40 | - | -0.60 |

External wind Pressure = -0.60 $P_z$

b. When wind blowing perpendicular to ridge for θ = 18.40°

For Windward Side

| | | |
|---|---|---|
| 10 | - | -1.2 |
| 20 | - | -0.4 |
| 18.40 | - | -0.528 |

External wind Pressure = -0.528 $P_z$

For Leeward Side

| | | |
|---|---|---|
| 10 | - | -0.40 |
| 20 | - | -0.40 |
| 18.40 | - | -0.40 |

External wind Pressure = -0.40 $P_z$

Combination of External and Internal Wind Pressure

a. When wind blowing parallel to ridge for θ = 18.40°

1. When Internal Wind Pressure = -0.2 $P_z$

Windward Side Pressure = -0.2-0.714 = -0.914$P_z$

Leeward Side Pressure = -0.2 -0.6 = -0.8 $P_z$

2. When Internal Wind Pressure = +0.2 $P_z$

Windward Side Pressure = +0.2-0.714 = -0.514$P_z$

Leeward Side Pressure = +0.2-0.6 = -0.4 $P_z$

1. When wind blowing perpendicular to ridge for θ = 18.40°

1.When Internal Wind Pressure = -0.2 $P_z$

Windward Side Pressure = -0.2-0.514 = -0.714$P_z$

Leeward Side Pressure = -0.2-0.4 = -0.6 $P_z$

2. When Internal Wind Pressure = +0.2 $P_z$

Windward Side Pressure = +0.2-0.514 = -0.314$P_z$

Leeward Side Pressure = +0.2-0.4 = -0.2 $P_z$

By considering all possible conditions maximum or worst condition for wind load is **-0.914$P_z$**

Calculation of $P_z$

$P_z = 0.6\ V_z^2$

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

Refering IS-875-1987(Part III) the Values of $V_b$ ,$k_1$, $k_2$, $k_3$ are as below

$V_b$ = 39 m/s

$k_1$ = 1.0

$k_2$ = 0.93

$k_3$ = 1.0

$V_z$ = 39 x 1 x 0.93 x 1.0

= 36.27 m/s

$P_z = 0.6\ V_z^2 = 0.6\ (36.27)^2 = 789.30\ N/m^2$

Our Maximum Condition = -0.914$P_z$ = -0.914 x 789.30 = - 721.42 N/$m^2$

Wind load Acting on Inclined Area = -721.42 x 65.85 = -47.54 KN

Wind load per nodal point = -47.54/9= -5.28 KN

Wind load on end nodal point = -5.28/2= -2.64 KN

**Analysis & Design of Trussless Roofing**

Dead Load = Self weight of sheet/m

= 0.175 KN/ m

Live load = 0.75 $y^2$KN/ m

where y = rise/span (H/L)

H - the height of the highest point of structure from its springing.

L - chord width of the roof.

Live load = 0.75 $(5/25)^2$ KN/ m= 0.2 KN/m

Wind Load – as above calculated.

**Computed Design Roof Loads:**

Wind Pressure : 86.82 N/$m^2$

Snow/Live Pressure : 00 kg/$m^2$

Maximum Stress Ratio:

Shear : 0.221 0.000 0.158

Shear & Bending : 2.081 0.000 0.043

Axial & Bending : 1.642 0.000 0.133

After calculating the reactions and stress it is required to use sheet of 1.20mm thickness

## V. CONCLUSION

- A continuous roof up to 25 m at a stretch can be used very effectively covered with our systems. Further this system can be used for span upto 35m.
- Estimated Fabrication and installation speed of covering over 1000 sqm. of area in just 24 hours.
- A full proofing against water seepage and extreme weather conditions given enhanced protection to goods, store in the facility thus reducing the cost related to product failure or rejection.
- No ancillary support required in the absence of any support structures in the
- system result in larger enclosed volume which offer optimum space utilization.
- The advantages are more safety, high durability, resistance to decay and increased design flexibility.

The Innovative roofing system is moderately economical.

## REFERENCES

[1] IS:875(Part 3)-1987, Code of Practice for Design Loads for buildings and Structures for Wind Loads

[2] IS:875(Part 2)-1987, Code of Practice for Design Loads for buildings and Structures for Imposed Loads

[3] IS:800-1984, Code of Practice for General Construction in Steel

**[4]** J. C. Carmody, G. E. Mosiman, J. H. Davidson, S. C. Mantell, G. Mittelman , 2008, "The Development of an Advanced Panelized Residential Roof System", Meeting of The Building Enclosure Technology and Environment Council.

[5] B Ravinder and K Srinivas , Assistant Professor NICMAR Hyderabad , Jun 2013, "A system that eliminates structural support systems in roofing".