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# Structural Behavior of Industrial Structure Subjected to Lateral Loads

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***Abstract* - Industrial structures are low rise steel structures housing workshops or industries and characterized by their comparatively low height and absence of interior walls and partition with or without gantry girders. Since gantry girders contribute to heavy loads a typical hangar building is considered for the analysis. In the current paper, the structural behavior of hangar subjected to lateral loads i.e, both wind load and seismic loads is analyzed by equivalent static analysis using standard FEM software package ETABS. The study encloses behavior of different truss configuration and different frame sections. The member forces are considered as the main parameter.**

***Keywords* - *Hangar, truss configuration, member forces, lateral loads, frame sections, gantry girder.***

## I. INTRODUCTION

The industrial buildings are classified into two categories namely normal/simple industrial buildings and sophisticated industrial buildings. Normal industrial building consist simple single storeyed industrial sheds with or without gantry girders to house workshops, warehouses etc whereas sophisticated industrial buildings used to house big industries in which some manufacturing processes need spaces with specific and controlled environmental conditions. Hangar buildings are one such buildings which is used for aircraft manufacture, assembly, testing procedures. Since this type of building uses gantry girder facility, it makes the structure heavy. The present study aims to promote the lightest possible structure for this purpose which performs well under the heavy loading without any compromise. The different type of truss configurations are studied considering five main types of trusses with five different sectional properties. Therefore 25 truss configurations have been considered for the analysis. Also the type of frames are also important to contribute for efficient structural performance. So 3 different frames are compared; 1.Composite frame which is a combination of concrete columns and steel truss. 2. Steel frame which is a combination of steel columns and steel truss. 3. Portal frame is mostly used frames as it is suitable for large span with no intermediate supports. This is characterized by roof girder.

## II. BUILDING DESCRIPTION AND MODEL IMPLEMENTATION

A typical hangar building of size 29x56m is considered. The building has both annexe portion and hangar portion, wherein the annexe portion is a RCC building for administration purpose and hangar portion attached, is of size 15x42m which is used for aircraft assembly, manufacture, testing purposes. The height of the hangar is 13.4m. The building is a upcoming project of aircraft assembly unit in Bangalore. Hence has limitations and specifications like height limitation, seismic zone, wind speed, loads acting, material used and so on. A typical model is created using ETABS. The inputs are given according to the described data about the building specifications. The building is located in seismic zone II. Design service loads are considered with reference to source of data of hangar from the firm and values are according to relevant codes, IS: 875( part- 1,2,3) for dead loads, wind loads and IS 1893 (part 1) 2002 for seismic loads. The building description is as listed in the table.

Table 1. Building description

| | | |
|---|---|---|
| 1 | Hangar size | 15x42m |
| 2 | Height of the hangar | 13.4m |
| 3 | Material grades for RCC | M20 & Fe415 |
| 4 | Material grade of Steel | Fe250 |
| 5 | Gantry girder load | 132kN |
| 6 | Horizontal thrust on the column due to gantry girder | 6.6kN |
| 7 | Loads on purlins(Sheet load, wind load, live load ) | 1.5kN/m |
| 8 | Section property of purlin | ISMC 75 |
| 9 | Size of RCC column of hangar | 450x700 |
| 10 | Seismic analysis | Equivalent static analysis |

Fig 1. Plan of the hangar building.

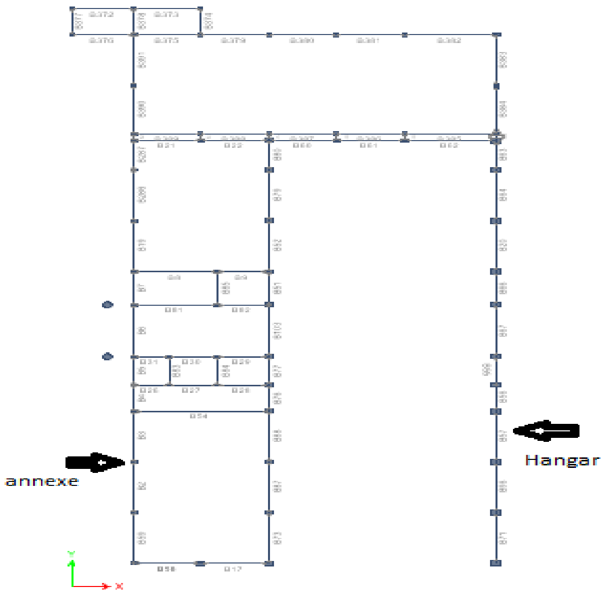
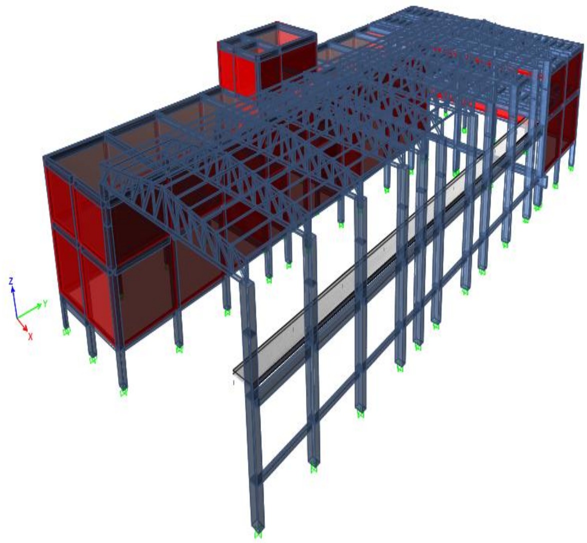



Fig 2. 3D Elevation of the hangar



The structure is subjected to lateral loads. Wind loads and seismic loads are according to IS code based on area and zone specifications. The wind and seismic data is listed below.

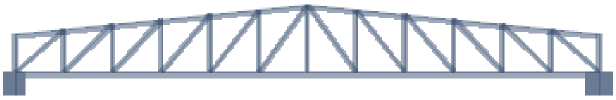
Table 2. wind and seismic data

| | | |
|---|---|---|
| 1 | Seismic zone | II |
| 2 | Zone factor | 0.10 |
| 3 | Importance factor | 1 |
| 5 | Response reduction factor | 3 |
| 4 | Site type | Type II |
| 5 | Wind speed | 33m/s |
| 6 | Terrain category | 2 |
| 7 | Structure class | B |
| 8 | Risk co efficient k1 | 1 |
| 9 | Topography K3 | 1 |

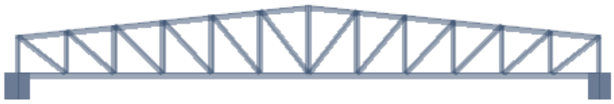
## III COMPARITIVE STUDY

The hangar building is studied for various configuration by replacing the frame elements. The behavior of roof element changes under lateral load, hence, is studied by adopting different types of trusses by changing its configurations. The main types of trusses considered are:

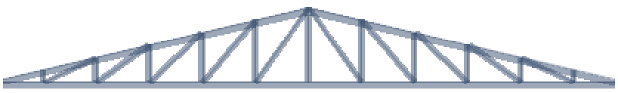
1. Trapezoidal howe truss.



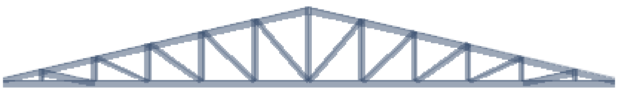
2. Trapezoidal pratt truss.



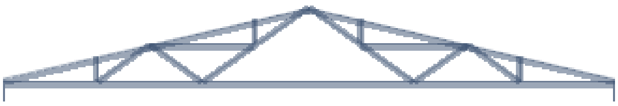
3. Triangular howe truss.



4. Triangular pratt truss.

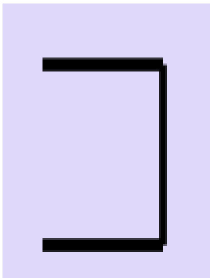


5. Triangular fink truss.

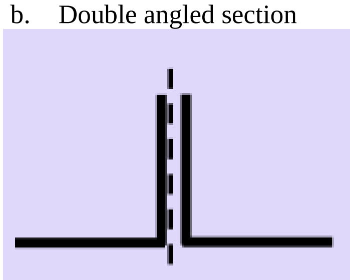


More configurations have been considered by adopting different sectional properties for the above types of trusses. The sectional properties considered are as follows:

a. Channel section.



b. Double angled section



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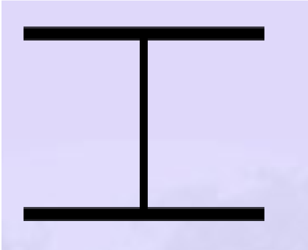
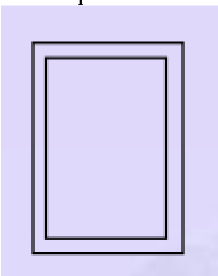
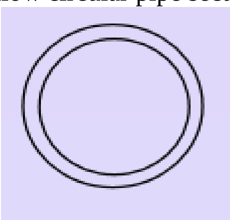
c. I section.



d. Hollow square tube section.



e. Hollow circular pipe section.



Further the different frame sections has been compared. 3 types of frames were considered for the analysis. They are as follows:

i. Composite frame with steel roofing and RCC columns.
ii. Steel frame.
iii. Portal frame.

Table 3. section properties of frame elements.

| | | |
|---|---|---|
| 1 | Channel section | ISMC150 |
| 2 | Double angled section | 75x75x6 |
| 3 | I section | ISMB300 |
| 4 | Hollow square tube section | ISB 91.5x91.5x3.6 |
| 5 | Hollow circular pipe section | ISNB100H |
| 6 | Steel frame (column sectional property, truss sectional property, type of truss) | ISMB500, ISB91.5x91.5x3.6, triangular fink truss |
| 7 | Portal frame(column sectional property, roof girder sectional property) | ISMB500, ISB91.5x91.5x3.6 |

## IV. RESULTS AND DISCUSSION

In this section the results obtained from the lateral load analysis of all the models that includes different truss configuration and different frame sections was carried out using standard FEM software package ETABS and results are as shown.

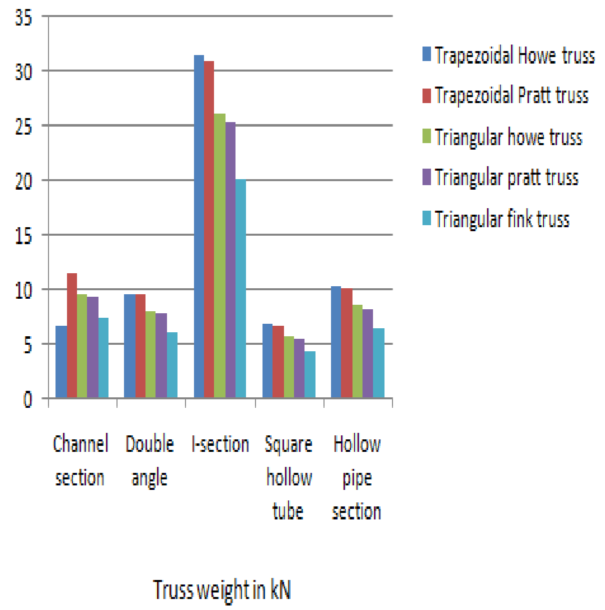
*1. Weight of the truss*

The structural weight of the truss is calculated manually for all types of truss configurations. And the result ascertains that the Triangular fink type of truss with hollow square tube section is the lightest truss configuration of all. In contrast I section, trapezoidal howe type truss is observed to be heavier truss which makes it uneconomical.

Table 4. Structural weight of the truss.

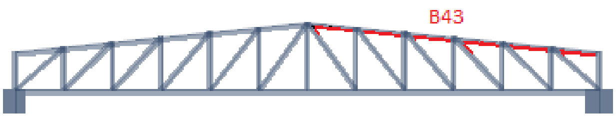
| No. | Type of truss | Section property | Weight in kN |
|---|---|---|---|
| 1.a | Trapezoidal howe truss | Channel section | 11.615 |
| 1.b | | Double angled section | 9.63 |
| 1.c | | I section | 31.3 |
| 1.d | | Hollow square tube section | 6.848 |
| 1.e | | Hollow circular pipe section | 10.268 |
| 2.a | Trapezoidal pratt truss | Channel section | 11.428 |
| 2.b | | Double angled section | 9.4748 |
| 2.c | | I section | 30.796 |
| 2.d | | Hollow square tube section | 6.737 |
| 2.e | | Holow circular pipe section | 10.103 |
| 3.a | Triangular howe truss | Channel section | 9.64 |
| 3.b | | Double angled section | 7.993 |
| 3.c | | I section | 25.98 |
| 3.d | | Hollow square tube section | 5.684 |
| 3.e | | Holow circular pipe section | 8.523 |
| 4.a | Triangular pratt truss | Channel section | 9.353 |
| 4.b | | Double angled section | 7.755 |
| 4.c | | I section | 25.207 |
| 4.d | | Hollow square tube section | 5.514 |
| 4.e | | Hollow circular pipe section | 8.269 |
| 5.a | Triangular fink truss | Channel section | 7.461 |
| 5.b | | Double angled section | 6.186 |
| 5.c | | I section | 20.108 |
| 5.d | | Hollow square tube section | 4.399 |
| 5.e | | Hollow circular pipe section | 6.596 |

Fig.3. Graph representing weight of truss.




*2. Member forces of different truss configuration.*

The member forces in the elements of the truss are obtained after the wind and seismic analysis. The 4 load combinations of wind and seismic loads are considered. The highest of the member force among 4 load combination is considered. Only few common elements among different truss configurations are available as the pattern varies from one type of truss to another. And those few elements were chosen for comparison.

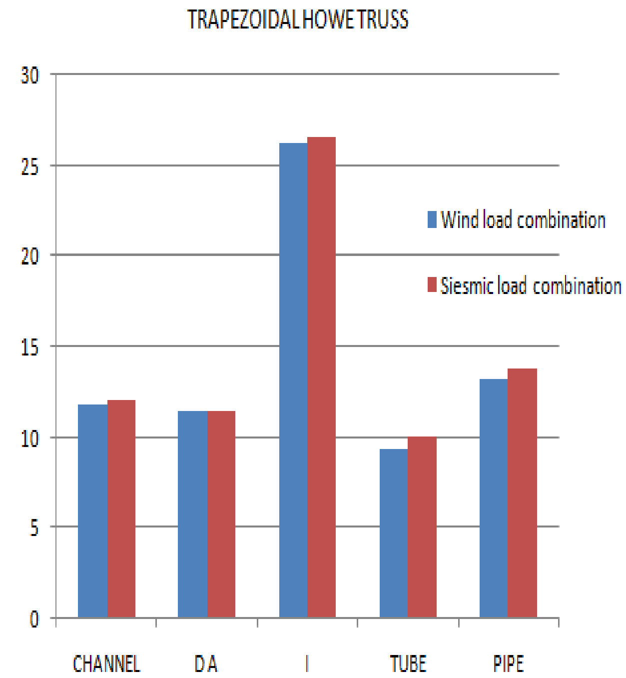



Considering the above highlighted chord member labeled B43 in trapezoidal howe truss, the analysis is carried out for all types of section properties. The results are as follows.

Table 5. Member forces of different section properties.

| Trapezoidal howe truss | | |
|---|---|---|
| | Axial force, P kN | |
| B43 | Wind load combination | Seismic load combination |
| Channel section | 11.846 | 12.12 |
| Double angled section | 11.466 | 11.54 |
| I section | 26.28 | 26.65 |
| Hollow square tube section | 9.4 | 10.09 |
| Hollow circular pipe section | 13.23 | 13.77 |

Fig. 4. Graph representing Member forces of different sectional properties



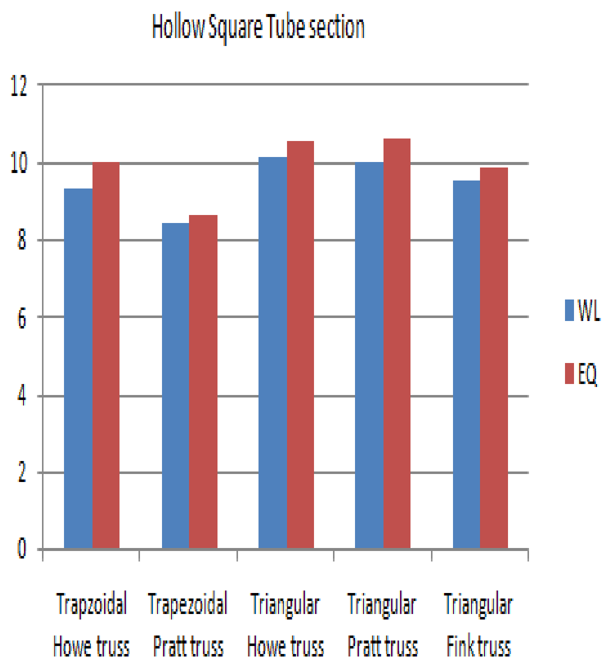

From the previous graph it is observed that the hollow square tube section induces least axial force under the action of lateral loads and also is the lightest section according to fig.3. Hence this section is considered for further analysis.

Table. 6. Member forces of different types of trusses.

| Hollow square tube section | | |
|---|---|---|
| | Axial force, P kN | |
| B43 | Wind load combination | Seismic load combination |
| Trapezoidal howe truss | 9.4124 | 10.0944 |
| Trapezoidal pratt truss | 8.4564 | 8.6573 |
| Triangular howe truss | 10.1877 | 10.5877 |
| Triangular pratt truss | 10.0648 | 10.611 |
| Triangular fink truss | 9.6041 | 9.9084 |

The above table interprets that the axial force in chord members adjacent to supports is decreased in Trapezoidal trusses whereas axial forces increases in chord members of triangular trusses. This is represented graphically in the following graph.

Fig 5. Graph representing member forces of types of trusses



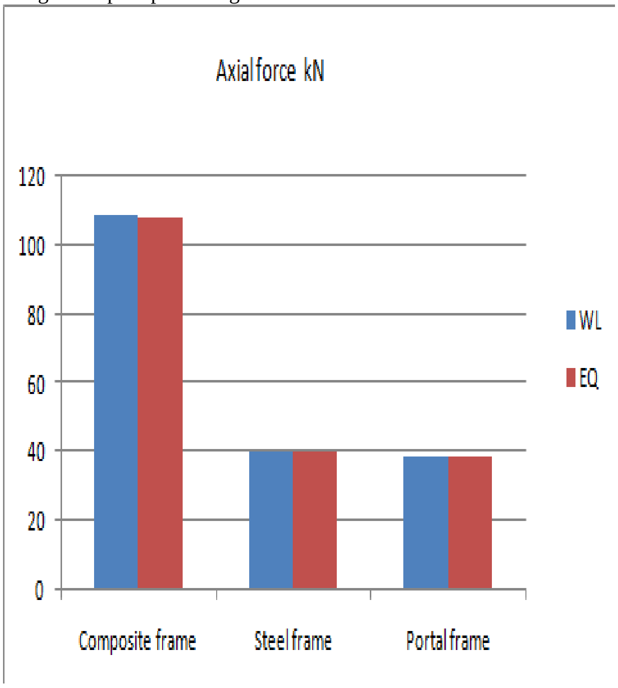

### 3. *Column forces of different frame sections*

The frame sections are analyzed for different frames and their column forces are tabulated. A few columns were chosen for the comparison and their forces are tabulated corresponding to wind and seismic load combination. The 3 type of frame sections like composite frame (which is of RCC column and steel truss), steel frame and portal frame are considered. The following table shows the column forces of a certain column C31 for types of frame sections.

Table 7. column forces of different frame sections

| C31 | Axial force, P kN | |
|---|---|---|
| | Wind load combination | Seismic load combination |
| Composite frame | 109.02 | 108 |
| Steel frame | 40.53 | 40.19 |
| Portal frame | 39.12 | 38.9 |

Fig.6. Graph representing column forces of different frame sections



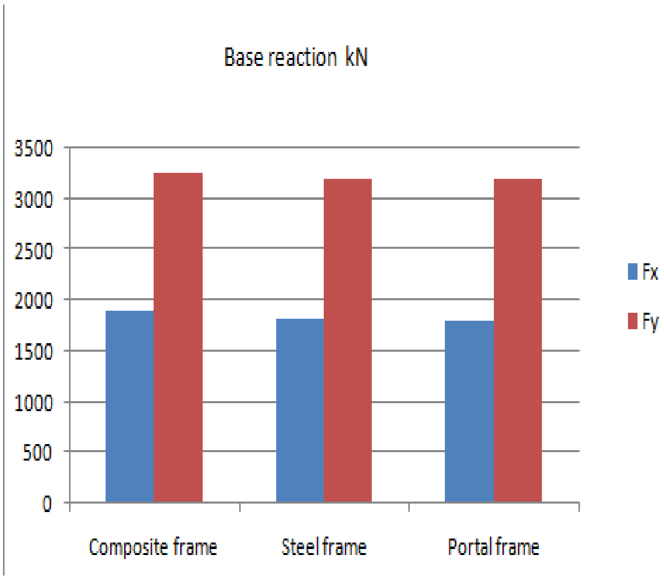

### *4. Base reaction of different frame sections*

The base reaction of different frames is listed corresponding to X and Y directions. And this ascertains the variations in base reaction of entire structure as the frame section is replaced by 3 different types of frames.

Table 8. Base reaction of different frame sections

| C31 | Base reaction, kN | |
|---|---|---|
| | Fx | Fy |
| Composite frame | 1895.644 | 3258.915 |
| Steel frame | 1811.387 | 3191.51 |
| Portal frame | 1809.243 | 3189.795 |

Fig 7. Graph representing base reaction of different frame sections




## V. CONCLUSION

The structural behavior of an industrial structure with different configurations has been studied in the present paper. The main conclusions are stated below.

- It has been observed according to fig.3 & 4 that structurally light truss among all the different truss configuration is triangular fink truss with hollow square tube section, which makes it economical. It is also easy to fabricate. The hollow square tube section has less maintenance as it is enclosed section and prevents corrosion, hence durable.
- In the different truss configuration, there are only few common elements available for comparison among all types of trusses as the pattern varies. Referring to fig 5, the trapezoidal truss decreases the axial forces in the chord members adjacent to support. However it cannot be concluded as "one particular truss is efficient because it induces less internal forces". Each type of trusses has varied flow of axial forces through their members as their pattern changes. Hence they are preferred according to the requirement of the structure. But the triangular fink type truss with hollow square tube section is concluded as the most economical truss because it is lightest and induces less internal forces (as per fig.4), which performs well even under heavy loading as well as the action of lateral loads.
- The parameter like column forces are observed for different frame section and referring to fig 6, the results show that RCC columns has increased axial forces wherein portal frame and steel frame show similar behavior and decreased axial forces. However portal frame has least axial forces among all the frame section and is structurally light, economical, easy to fabricate and has less maintenance.
- The base reaction of different frame section is observed. As per the results obtained, referring to fig 7, there is no major variation as the frame section is replaced. However portal frame induces lesser base reaction of all. Hence concluded as the efficient frame

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