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ANALYTICAL STUDY OF DIFFERENT STRUCTURAL SYSTEMS FOR LONG SPAN INDUSTRIAL STRUCTURES

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Abstract- ***Now a day's use of steel structures is increasing in the manufacturing and other types of industries. Many reasons are there behind failure of a truss. The most effecting parameter is wind therefore the design accordingly to the wind and type of location and atmospheric condition is must.so for designing the steel structure the location and type of steel structure is very useful for effective design. In present study, 125*45 meter long span industrial structure is designed for the dynamic effects (wind and earthquake) for the different structural systems and different wind load. In this research work I will go to be use STAAD PRO and such design and analysis of industrial building. The prepared software is very user friendly. By providing suitable input data it will give a most economical section design with respect to wind zones and different frame spacing considering all necessary checks. The prepared software apply all necessary loads such as Dead loads, live load, wind loads and also generates all required load combination and importing all analysis result value from STADD PRO. Standard Steel Sections, which are given in steel table and approved by I.S., are used. And these Standard Sections are easily available and widely used in practice. The purpose of this research project work is to decide which type of system is compatible and economical with respect to wind zones and spacing of frames Stability-comparison of different structural system for long span roof industrial structures.***

Keywords-STAAD PRO, Structural, Forces, failure of truss, Eco- Friendly, loads, gust factor method, etc.

INTRODUCTION

Many type of material used in the industrial building; steel is perhaps the most universally acceptable as a versatile material for construction. This is of course, the result of its many fine qualities so eminently suited to modern engineering structure. The primary function of all the structure is to withstand stresses due to loads such as dead load, live load, wind loads, earthquake loads, etc. without failure or undue distress such as excessive deflection. The term structural design therefore signifies a process by which a structural engineer puts together a functionally efficient, economically affordable and structurally safe system for a set of given applied loads.

What is a long span roof?

Long span roofs are generally defined as those that exceed 15 m in span. Long span roofs can create flexible, column free internal spaces and can reduce substructure costs and construction times. They are commonly found in a wide range of building types such as factories, warehouses, agricultural buildings, hangars, large shops, public halls, gymnasiums and arenas. Long span roofs can be fabricated in from a number of materials such as steel, aluminum alloy, timber, reinforced concrete and pre-stressed concrete. Steel is often preferred due to its high strength.

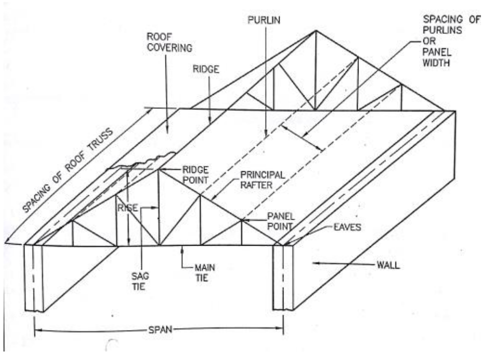

Figure 1 General layout of steel roof structure

Truss Members

The members of trusses are made of either rolled steel sections or built-up sections depending upon the span length, intensity of loading, etc. Rolled steel angles, tee sections, hollow circular and rectangular structural tubes are used in the case of roof trusses in industrial buildings. In long span roof trusses and short span bridges heavier rolled steel sections, such as channels, I sections are used. Members built-up using I sections, channels, angles and plates are used in the case of long span bridge trusses.

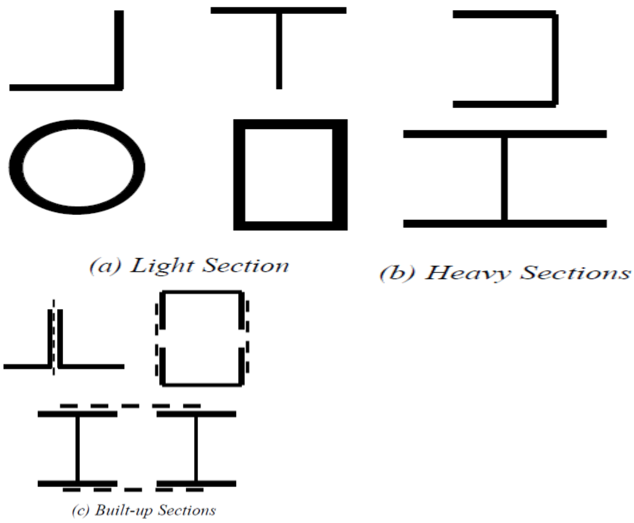

Figure -2 Different section of truss

Objective of Study

- To study the utility and compatibility of different structural system for long span roof trusses.
- Similarly, the stability-comparison in various conditions of different structural system for long span roof trusses.
- The building will also be compared with different wind zones and different frame spacing.

Scope of Study

- In this comparative study of long span industrial roof structure of 125*45 meter is designed for the dynamic effect in various wind zones and spacing of different structural systems.
- The building is modelled for the purpose of industrial use.
- In comparative work like:

1. Horizontal forces,
2. Deflection,
3. Vertical and lateral displacements & stresses

- Axial forces going to be study for the different structural system.
- Than cost and stability comparison has to be done on these parameters basis.

SOFTWARE SELECTION & VALIDATION

Selection of Software

For the present work various software like ETABS,

STAAD/Pro, NISA, SAP 200 etc. had been evaluated and finally ETABS has been selected for performing the analysis of Space frame as for analysis.

The main purpose of selecting this software for the present task is some of its features such as:

- Non-prismatic frame elements
- Unlimited capacity of degrees of freedom
- The ability to merge independently defined meshes
- A fully-coupled 6 by 6 spring stiffness
- Fast equation solvers
- Well-developed Graphical User Interface etc.

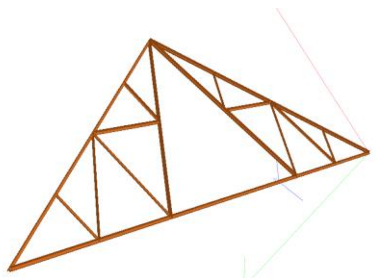

Figure-3 3D view of roof truss

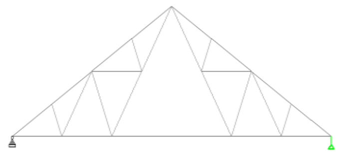

Figure-4 Elevation of roof truss

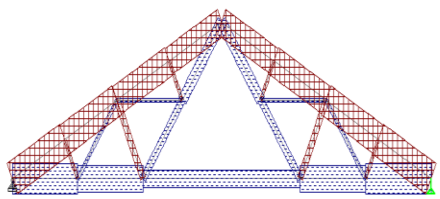

Figure-5 Axial forces

PRILIMINARY DATA:
Span of the truss = 16m
Rise of the truss = 4m
Height of eaves = 8m
Roofing shall be of G.I. sheets
The truss is supported on 400mm thick brick walls.
The building is located in Pondicherry
Take risk co-efficient k1 = 1
Terrain factor k2 = 0.82
Topography factor k3 = 1

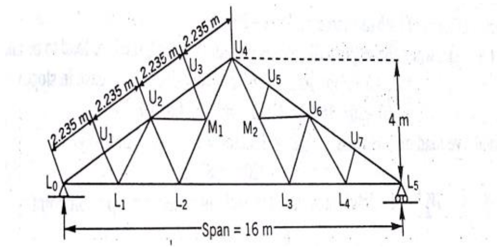

Figure-6 Design calculations of forces

Solution:
Let A be the inclination of the roof with the horizontal

$$\text{Tan} \propto = \frac{4}{8} = \frac{1}{2}$$

$$\therefore \propto = 26°.56$$

Length of the principal rafter = 8.94m
Distance between successive panel point of the top chord = 8.94/4
= 2.235 m
Loads
Dead load per sq. meter
Roof covering = 150 N/m²
Purlins = 80 N/m²

Weight of truss = (span/3+5)10
= (16/5+5)10
= 103 N/m²
Wind bracing = 12 N/m²

Total dead load = 345 N/m²

Dead load analysis

Total dead load on one truss = span * spacing * dead load intensity

= 16*4*345

= 22080 N

Load transmitted to each end joint = W/2

8W/2 = 22080

$\therefore w = 2760$ N

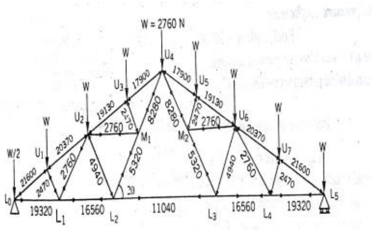

Figure-7 Dead load forces

Live load forces

Inclination of the roof with the horizontal $\propto = 26°.56$

As per I.S. code, when the slope of the roof is greater than 10°, the live load to be taken = 750 N/m² minus 20 N/m² for every degree increase in slop over 10 degree

= 750-20*16.57

= 420 N/m²

Total live load on one truss = span * spacing *live load intensity

= 16* 4* 420

= 26880 N

Live load transmitted to each end joint = Wl / 2

8 Wl = 26880

Wl = 3360 N

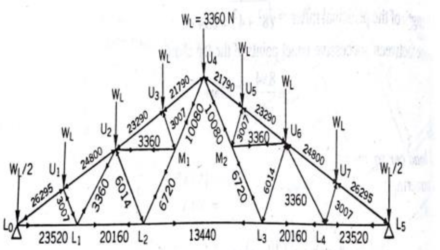

Figure-8 Live load forces

Wind load analysis

Basic wind speed at Pondicherry = 50 m/s

Design wind speed Vd = K1 K2 K3 Vb

= 1*0.82*1*50

= 41 m/s

Design wind pressure Pd = 0.6 Vd²

= 0.6*41²

= 1010 N/m²

$$\frac{h}{W} = \frac{8}{16} = \frac{1}{2}$$

Wind pressure coefficients

Roof angle $\propto = 26°.56$

Case (1). Wind blowing normal to ridge.

External wind pressure co-efficient Cpe

For wind ward slope = - (0.4 – 6.56/10 *10.4)

= - 0.1376

For lee-ward slope = - 0.4

Internal wind pressure co-efficient Cpi = ±0.2

Case (2). Wind blowing parallel to ridge.

External wind pressure co-efficient Cpe

For both slope = -0.7

Total pressure (Cpe - Cpi) = -909 N/m²

We find that the most critical wind load is – 909 N/m² on both slope

Total wind load on one sloping length = 8.94 * 4 * 909

= 32505.8 N

Wind load transmitted to one intermediate top chord joint

4We = 32505.8

$\therefore We = 8126\ N$

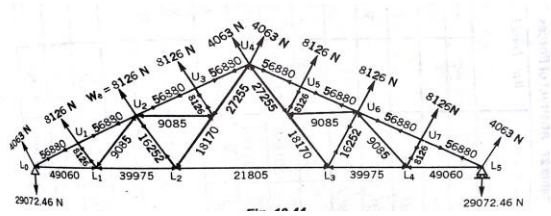

Figure-9 Wind load forces

Member	Deal Load force (N)		Live Load Force (N)		Wind Load Force (N)		Dead Load Force + Live Load Force (N)		Dead Load Force + Wind Load force (N)	
	Comp.	Tensile	Comp.	Tensile	Comp.	Tensile	Comp.	Tensile	Comp.	Tensile
L_0U_1, L_5U_7	21600		26295			56880	47895			35280
U_1U_2, U_6U_7	20370		24800			56880	45170			36510
U_2U_3, U_5U_6	19130		23290			56880	42420			37750
U_3U_4, U_4U_5	17900		21790			56880	39690			38980
L_0L_1, L_4L_5		19320		23520	49060			42840	29740	

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L_1L_2, L_3L_4		16560		20160	39975			36720	23415	
L_2L_3		11040		13440	21805			24480	10765	
U_1L_1, U_7L_4	2470		3007			8126	5477			5656
U_3M_1 ,U_5M_2	2470		3007			8126	5477			5656
U_2L_2, U_6L_3	4940		6014			16252	10954			11312
L_1U_2, L_4U_6		2760		3360	9085			6120	6325	
U_2M_1 ,U_6M_2		2760		3360	9085			6120	6325	
M_1L_2 ,M_2L_3		5320		6720	18170			12040	12850	
M_1U_4 ,M_2U_4		8280		10080	27255			18360	18975	

Table-1 COMPARISON

Axial forces at L_0U_1 ,L_5U_7

Manually,

Dead load + live load = 47895 N

Model,

Dead load + live load = 47890 N

3-D DESIGN ANALYSIS

MODEL OF REGULER STRUCTURE

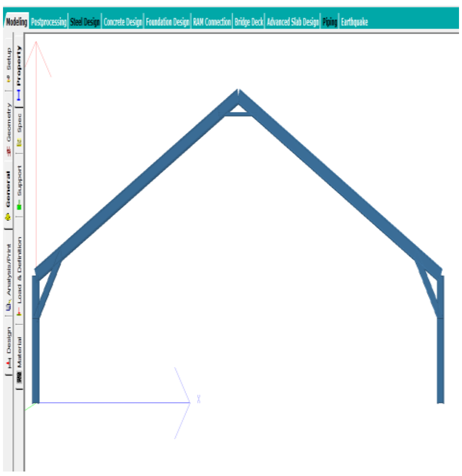


Figure-10 3D view of without center column

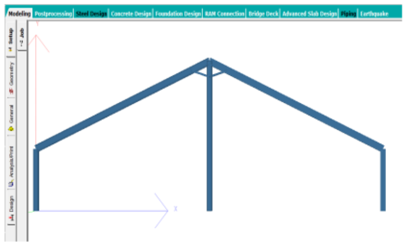


Figure-11 3D view of with center column

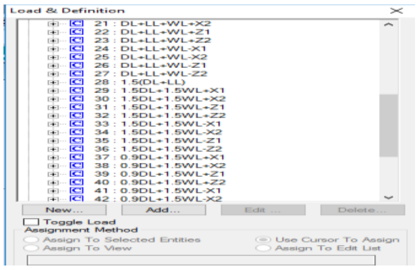


Figure-12 load combination in stadd

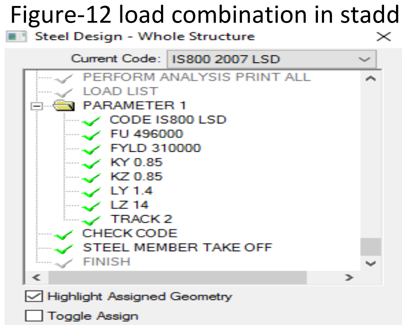


Figure-13 define parameters in modal

Where, FU is Ultimate tensile strength of steel (KN/m²)

FYLD is Yield strength of steel (KN/m²)

KY is K value in local Y-axis usually minor axis

KZ is K value in local Z-axis usually major axis

LY is length is local Y-axis for slenderness values KL/r

LZ is length is local Z-axis for slenderness values KL/r

TRACK 2 is print the design output at maximum detail level

Regular structure		
	Without column	**with column**
Property	ISMB 600 TB	ISMB 600 TB
	ISMB 500	ISMB 600
	ISMB 150	ISMB 150
Weight	72 Kg/m²	65 Kg/m²
Max Deflection		
X	24 mm	17 mm
Y	23 mm	5 mm
Lateral forces		
col-1	210 KN	22 KN
mid column		-4 KN
col-2	-210 KN	-18 KN

Table-2 MODAL OF PEB STRUCTURE

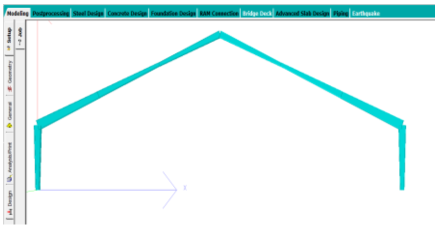


Figure-14 3D view of without column

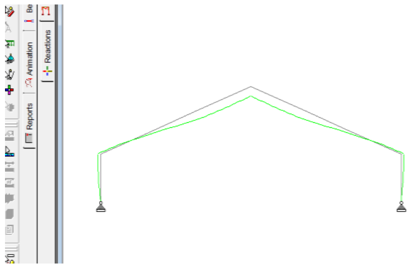


Figure-15 deflection diagram of without column PEB structure

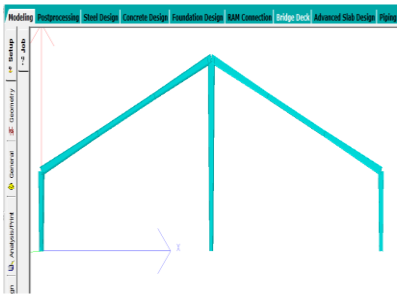


Figure-16 3D view of with column

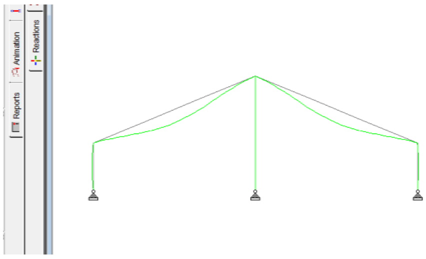


Figure-17 deflection diagram of with column PEB structure

PEB structure		
	Without column	**with column**
Property	Taper section	Taper section
	Taper section	Taper section
	Taper section	Taper section
Weight	35 Kg/m²	30 Kg/m²
Max Deflection		
X	60 mm	51 mm
Y	109 mm	74 mm
Lateral forces		
col-1	168 KN	55 KN
mid column		0 KN
col-2	-168 KN	-55 KN

Table-3 MODAL OF TRUSS MEMBER

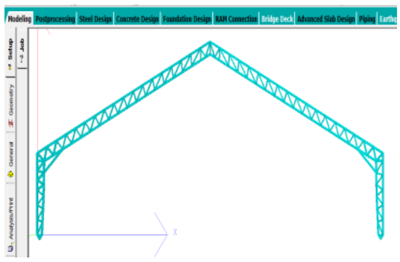


Figure-18 3D view of without column truss member

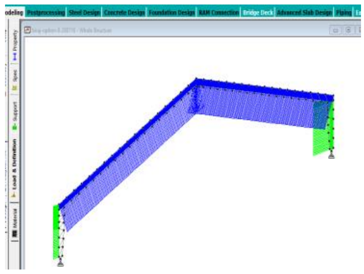


Figure-19 load applied on modal

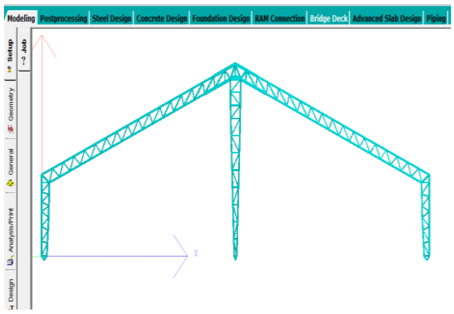


Figure-20 3D view of with column truss member

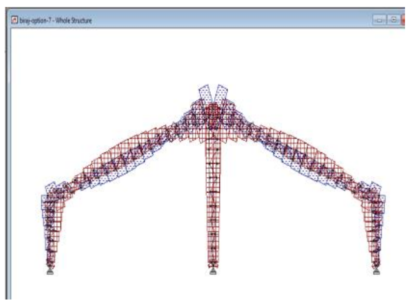


Figure-21 axial forces diagram

Truss structure		
	Without column	**with column**
Property	150x150x4.0 SHS	200x100x5.0 RHS
	100x100x4.0 SHS	122x61x5.4 RHS
	180x180x4.0 SHS	96x48x4.0 RHS
	145x82x4.8 RHS	66x33x4.5 RHS
Weight	14 Kg/m²	12 Kg/m²
Max Deflection		

X	80 mm	73 mm
Y	151 mm	95 mm
Lateral forces		
col-1	136 KN	35 KN
mid column		0 KN
col-2	-136 KN	-35 KN

Table-4 Truss Structure Analysis

RESULTS AND COMPARISON

Comparison of different parameters in different structural systems with respect to comparing in various wind zones and different wind spacing. Different parameters like comparison of weight, comparison of deflection, comparison of lateral forces.

Weight Comparison of Main Structure

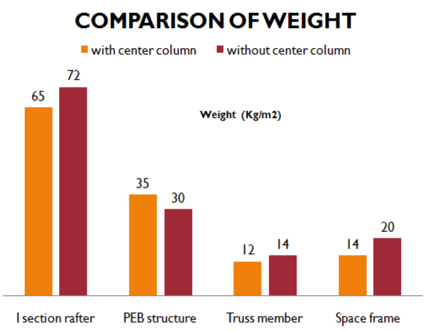


Figure-22 Comparison of Weight

Weight Comparison of Purlin, Cladding and Tie Runner and Connection Plate

1) For I section rafter use ISMB 150
Rafter length =24.05 m
Eaves height=6 m
Center to center spacing of purlin = 1.4 m
No of purlin = rafter length / c/c spacing of purlin
= 24.05/1.4
= 17
Weight of purlin = no of purlin × unit weight (kg/m) × c/c spacing of truss
= 17 × 14.9 × 6
= 1520 kg
No of cladding runner = eaves height / c/c spacing of purlin
= 6/ 1.4
= 4
Weight of cladding runner = no of purlin × unit weight (kg/m) × c/c spacing of truss
= 4 × 14.9 × 6
= 358 kg

Member	weight of I section rafter (kg)	
	without center column	with center column
Main portal frame	19440	17550
Purlin	1520	1520
Cladding runner	358	358
10% connection plat of (1+2+3)	2131	1943
Total (kg)	23449	21370

Table-5 Member Weight of I Section Rafter

2) For PEB member use Z purlin (H=250, B=70, A=20, t=2.8)
Rafter length =24.05 m
Eaves height=6 m
Center to center spacing of purlin = 1.4 m
No of purlin = rafter length / c/c spacing of purlin
= 24.05/1.4
= 17
Weight of purlin = no of purlin × unit weight (kg/m) × c/c spacing of truss
= 17 × 9.5 × 6
= 969 kg

No of cladding runner = eaves height / c/c spacing of purlin
= 6/ 1.4
= 4
Weight of cladding runner = no of purlin × unit weight (kg/m) × c/c spacing of truss
= 4 × 9.5 × 6
= 228 kg

Member	weight of PEB member (kg)	
	without center column	with center column
Main portal frame	8100	9450
Purlin	969	969
Cladding runner	228	228
10% connection plat of (1+2+3)	930	1065
Total (kg)	10227	11712

Table-6 Member Weight of PEB Member

3) For Truss member use RHS 172 × 92 × 4.8
Top chord length =24.5 m
Eaves height=6.3 m
Bottom chord length = 23.5 m
Center to center spacing of purlin = 1.4 m
Center to center spacing of tie runner = 2.8 m
No of purlin = rafter length / c/c spacing of purlin
= 24.5/1.4
= 18
Weight of purlin = no of purlin × unit weight (kg/m) × c/c

spacing of truss

= 18 × 20.88 × 6

= 2255 kg

No of cladding runner = eaves height / c/c spacing of purlin

= 6.3/ 1.4

= 5

Weight of cladding runner = no of purlin × unit weight (kg/m) × c/c spacing of truss

= 5 × 20.88 × 6

= 627 kg

No of tie runner = bottom chord length / c/c spacing of tie runner

= 23.5/ 2.8

= 8

Weight of tie runner = no of tie runner × unit weight (kg/m) × c/c spacing of truss

= 8 × 20.88 × 6

= 1002 kg

Member	weight of Truss member(kg)	
	without center column	with center column
Main portal frame	3780	3240
Purlin	2255	2255
Cladding runner	627	627
Tie runner	1002	1002
10% connection plat of (1+2+3)	766	712
Total(kg)	8430	7836

Table-7 Member Weight of Truss Member

4) For Space frame member use PIP 1651M
Arc length =53 m
Eaves height=4 m
Bottom chord length = 53 m
Center to center spacing of purlin = 1.4 m
Center to center spacing of tie runner = 2.8 m

No of purlin = rafter length / c/c spacing of purlin

= 53/1.4

= 38

Weight of purlin = no of purlin × unit weight (kg/m) × c/c spacing of truss

= 38 × 18.90 × 6

= 4309 kg

No of cladding runner = eaves height / c/c spacing of purlin

= 4/ 1.4

= 3

Weight of cladding runner = no of purlin × unit weight (kg/m) × c/c spacing of truss

= 3 × 18.90 × 6

= 340 kg

No of tie runner = bottom chord length / c/c spacing of tie runner

= 53/ 2.8

= 19

Weight of tie runner = no of tie runner × unit weight (kg/m) × c/c spacing of truss

= 8 × 18.90 × 6

= 2154 kg

Member	weight of Space frame member(kg)	
	without center column	with center column
Main portal frame	5400	3780
Purlin	4309	4309
Cladding runner	340	340
Tie runner	2154	2154
10% connection plat of (1+2+3)	1220	1058
Total(kg)	13424	10584

Table-8 Member Weight of Space Frame

Comparison of Cost

As per the site survey price of steel is 85 Rs. /kg for I section rafter, Truss member, Space frame and 100 Rs. /kg for PEB structures.

different structural system		price (Rs./kg)	weight (kg)	Total cost (Rs.)
I section rafter	without centre column	80	23449	1875920
	with centre column		21370	1709600
PEB member	without centre column	100	10227	1171200
	with centre column		11712	1022700
Truss member	without center column	100	8430	843000
	with center column		7836	783600

Table-9 Cost of One Portal Frame for Different Structural System

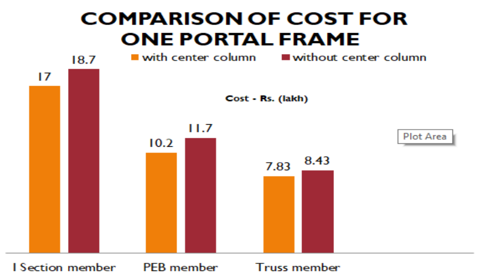
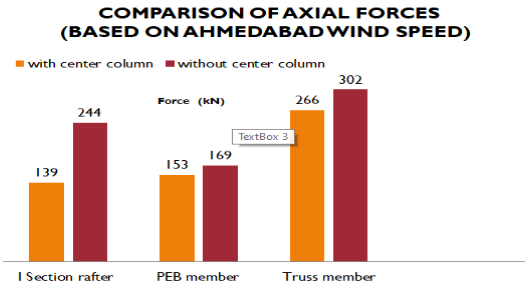
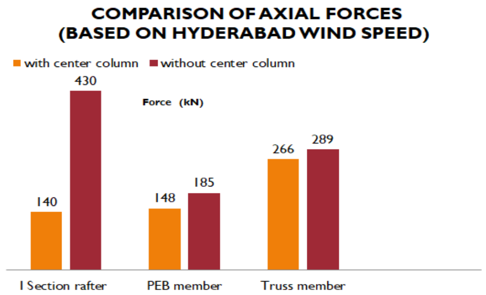


Figure-23 Comparison of cost

Comparison of frame with various wind zones

1) Axial forces comparison





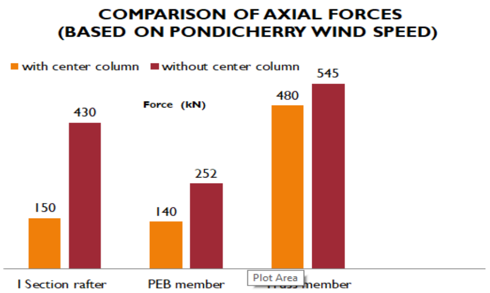
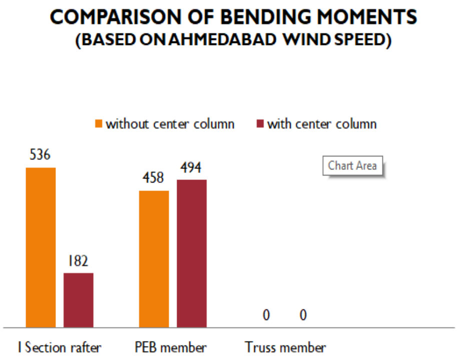
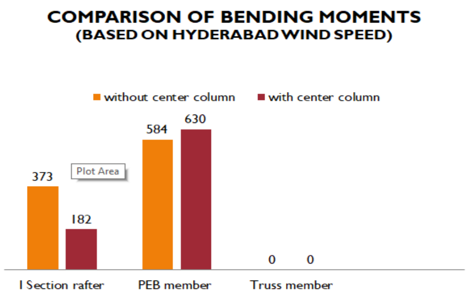


Figure-24 Comparison of Axial forces

2) Bending moment comparison





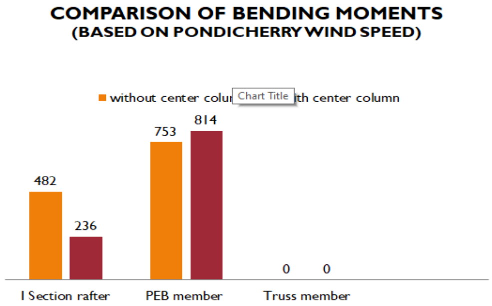
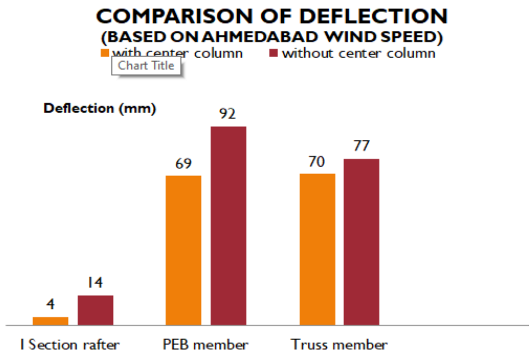
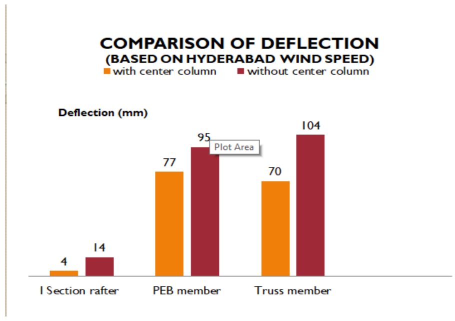


Figure-25 Comparison of Bending moment

3) Deflection comparison





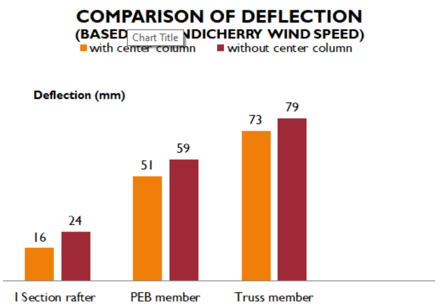


Figure-26 Comparison of deflections

Comparison of frame with frame spacing difference

1) For 6m frame spacing

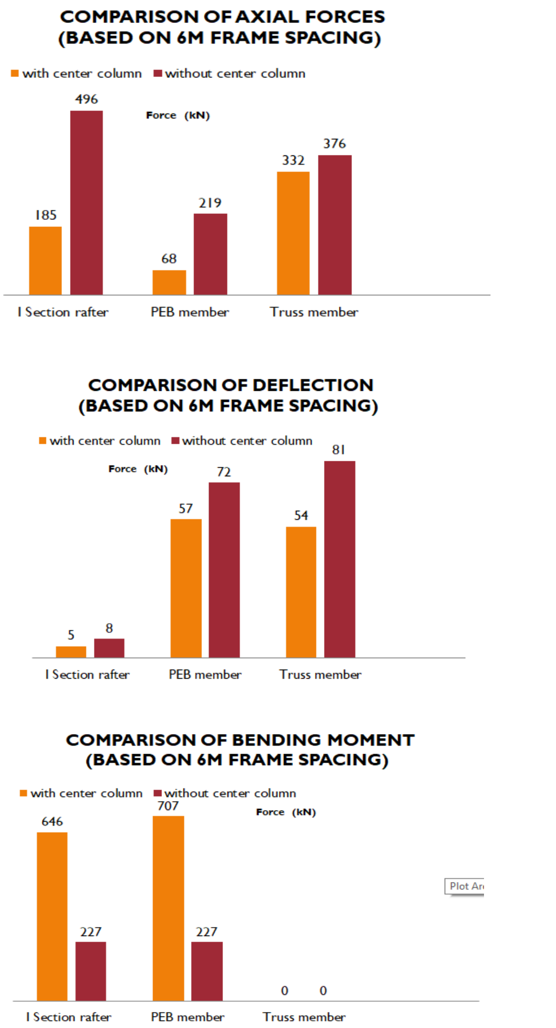


Figure-27Comparison of parameters for 6m frame spacing

2) For 7.5m frame spacing

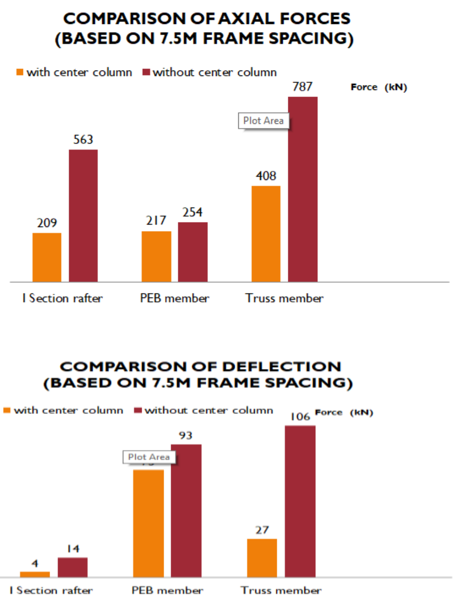
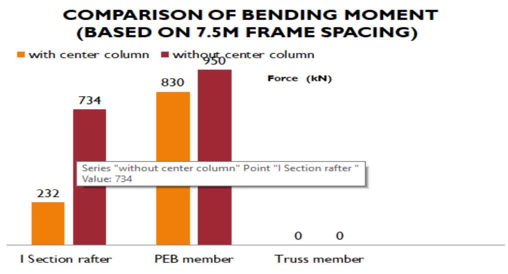


Figure-28 Comparison of parameters for 7.5m frame spacing.



CONCLUSION

Comparison for wind differences on different type of structure shows the lower value for (axial, lateral force and deflection) most of the parameters is PEB member so going for various zones and locations PEM member can resist all parameters more conveniently. Comparison for frame spacing on different type of structure shows the lower value for(axial , lateral force and deflection) most of the parameters is truss member so when need of changing the frame spacing (ex. Need to increase or decrease for site conditions or as per layout requirements) truss member should be used. Truss member is cost and weight effective compare to all other types of long span structures. So Based on this research study, it can be concluded that truss member structural system is the most economical compare to another systems as mentioned in brief description with percentage of cost compare to other sections. Lateral forces are maximum in I section rafter and minimum in space frame structure without center column. Lateral forces are maximum in PEB structure and minimum in I section rafter without center column. The reduction of cost where compared with I section rafter member for respectively Truss member, Space Frame member and PEB member is 63%, 50%, 28% reduction respectively.

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