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A Comparative Study of Pre-Engineered and Conventional Multi-Span Industrial Building

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Abstract: Steel is one of the oldest construction materials and become a popular construction material in late seventeenth and eighteenth century. Environment friendly, rapid construction, easy availability and better fire rating are some of inherent advantages of steel construction. In current modern world, steel structure contributes a highest number of industrial buildings and sheds in the world building inventory. Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. This particular study includes the design of industrial storage structure which is situated in Mangalore. The actual structure is of pre-engineered structure of 90m width of three spans each span 30m width, and running 42m length and of eave height 6m with roof slope 1:10. The analysis and design is carried out by considering the live loads, dead loads, wind loads and earthquake load using relevant IS codes for the given PEB structure. The whole Pre-engineered building and Conventional steel structure is analyzed by using staad pro V8i SS6 software and designed by limit state method as per IS 800-2007. The moment, shear force and axial force decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness. Deformation decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness. Base shear and displacement decreases in PEB structure as compared to CSB structure, due to increase in stiffness. The percentage decrease in weight in PEB structure is 16.28% in comparison to CSB structure, hence cost of PEB structure reduces. Reduction in steel quantity reduces the dead load ultimately reduces the size of the foundation

Keywords: pre-engineered building, STAAD pro.

I. INTRODUCTION

Structures are one of the most seasoned development exercises of people. The development innovation has progressed since the start from crude development innovation to the present idea of current house structures. The present development technique for structures requires the best stylish look, excellent and quick development, financially saving and creative touch.

Steel Buildings

It is the material of the decision for the outline since it is naturally pliable and adaptable, it flexes under extraordinary loads as opposed to smashing and disintegrating. Auxiliary steels ease, quality, solidness, outline adaptability, flexibility and recyclability keep on making it the material of decision in building development.

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The present auxiliary steel encircling is bringing beauty, craftsmanship and capacity together in relatively boundless ways and is putting forth new arrangements and chances to make testing structures, which were once thought unthinkable. Steel structures have hold quality; basic "stick" outline in the steel framings enables development to continue quickly from the beginning of erection.

Conventional Steel Buildings

Traditional steel structures are specialist and preservationist. The auxiliary individuals are hot rolled and are utilized as a part of regular structures. The materials are created or made in the plant and are moved to the site. The crude materials are prepared in the site for the coveted from and rose. The changes should be possible amid erection by cut and weld process. Here Truss frameworks are used as a part of ordinary frameworks.

Pre Engineered Steel Buildings

Pre-designed steel structures are fabricated or delivered in the plant. The assembling of auxiliary part is done on client prerequisites. The point by point structure individuals are intended for their separate area and are numbered, which can't be modified; in light of the fact that individuals are fabricated concerning configuration includes these segments are made in particular or totally thumped condition for transportation. These materials are transported to the client site and are raised welding and cutting procedure are not performed at the client site. No assembling procedure happens at the client site.

II. OBJECTIVES

Main objective of the project is to analyze the industrial structure for different load cases. Analysis and design of the structure carried out with STAAD. Pro software using IS codes.

A. To analyze the multi span pre-engineered industrial building for wind and earthquake load.

B. To analyze the multi span conventional industrial building for wind and earthquake load.

C. Comparisons of results between pre-engineered building and conventional steel building using staad pro analysis.

III. REVIEW CRITERIA

1) *S.D. Charkha and Latesh S (June 2014)*

Observes that, the excess of steel can be reduced by tapering the sections of pre engineering buildings as compared to conventional steel buildings as result of reducing the steel quantity the dead load is also reduced and also size of the foundation can be reduced. Using of PEB increase the Aesthetic view of structure.

2) *C.M.Meera(June2013)*

Observes that the Pre- Engineered Building (PEB) concept is a new concept especially for single storey industrial building construction. This method is adopted not only for its quality of pre-designing and prefabrication, but also for its light weight and economical in construction.

The concept includes providing tapered sections for columns and rafters so that excess of steel can be reduced. In this paper the comparisons between PEB and CSB is studied. Pre-Engineered Building concept can be applied including warehouses, metro stations, factories, auditoriums, offices, gas stations, showrooms, vehicle parking sheds, aircraft hangars, workshops, schools, indoor stadium roofs, outdoor stadium canopies, recreational buildings, railway platform shelters, bridges, etc.

IV. METHODOLOGY

This particular study includes the design of industrial storage structure which is situated in Mangalore. The actual structure is of pre-engineered structure of **90m** width of three spans each span **30m** width, and running **42m** length and of eave height **6m** with roof slope **1:10.** The analysis and design is carried out by considering the live loads, dead loads, wind loads and earthquake load using relevant IS codes for the given PEB structure. The whole Pre-engineered building and Conventional steel structure is analyzed by using staad pro V8i SS6 software and designed by limit state method as per IS 800-2007.

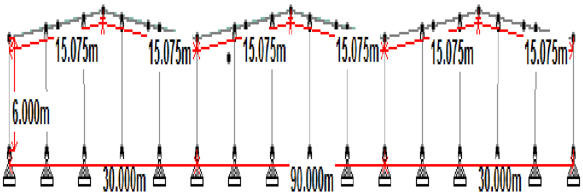

Fig: 1 SECTION OF PROPOSED STRUCTURE

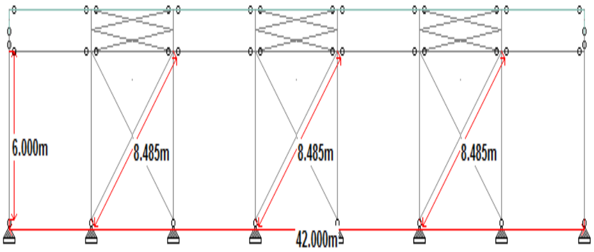

Fig: 2 END VIEW OF A PEB BUILDING

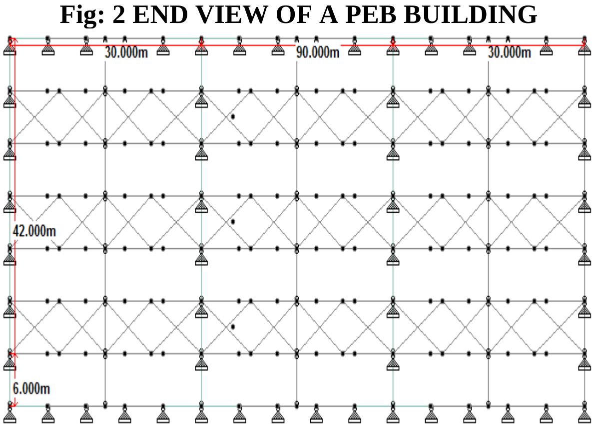

Fig:3 PLAN OF A PEB BUILDING

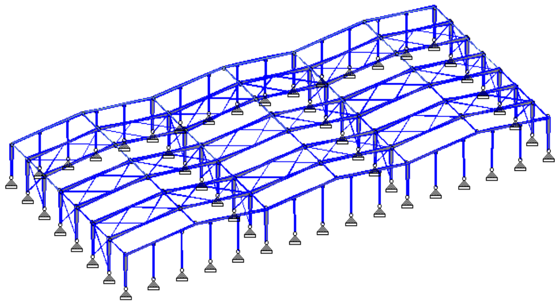

Fig:4 FULL SECTION OF A PEB BUILDING

STEPS TO BE FOLLOWED FOR ANALYSIS AND DESIGN

- Load calculation
- Preparing model
- Assigning materials and material properties
- Assigning loads and load combinations
- Run and analyse the model
- Design the components of structure by using analysis results

V. CALCULATION OF WIND PRESSURE:

Table 1 Partial Safety Factors for Loads, (Yf), For Limit States

Load combinations	Partial safety factors for loads,(Yf), for limit states							
	Limit state of strength (member design forces)				**Limit state of serviceability** (deflection and support reaction)			
	DL	LL		WL/EL	DL	LL		WL/EL
		Leading	Accompanying			Leading	Accompanying	
DL+LL+CL	**1.5**	**1.5**	**1.05**	**-**	**1**	**1**	**1**	**-**
DL+LL+CL+EL+WL(A)	**1.2**	**1.2**	**1.05**	**0.6**	**1**	**0.8**	**0.8**	**0.8**
DL+LL+CL+EL+WL(B)	**-**	**-**	**0.53**	**1.2**	**1**	**-**	**-**	**1**
DL+WL/EL	**1.5**	**-**	**-**	**1.5**	**1**	**-**	**-**	**1**

Typical Load Combinations

Table 2: Load Combinations Considered

IS800-2007
Limit state of serviceability: **(DL+LL)** **(DL+LL+WL/EL)** **Limit state of strength:** **1.5*(DL+LL)** **1.5*(DL+LL+WL/EL)**

As per clause 5.3 of IS: 875(part 3)-1987, we have

$V_z=V_b \times K_1 \times K_2 \times K_3$

Where, V_z=design wind speed at any height

V_b=basic wind speed at given location

K_1=probability factor or risk co-efficient

K_2=terrain, height and structure size factor

K_3=topography factor

Project location is **"MANGALORE",**

Basic wind speed value for mangalore region as per clause 5.2 we have

V_b = 39 m/s

For basic wind speed of 33m/s and for all general buildings and structures as per clause 5.3.1

K_1 = 1

The value of topography factor from clause 5.3.3 of IS: 875 (part 3)-1987

K_2 = 0.98

Value for wind slope of less than 3^o as per clause 5.3.3.1 we have

K_3=1

Wind pressure P_z is calculated by using the following formula as per clause 5.4

$P_z=0.6 \times V_z^2$

Design wind speed (V_z) = 38.22m/s

Design wind pressure (Pz) =0.876 kN/m^2

Height(m)	**K_2**	**V_z(m/s)**	**P_z(KN/m^2)**
7.5	**0.98**	**38.22**	**0.876**

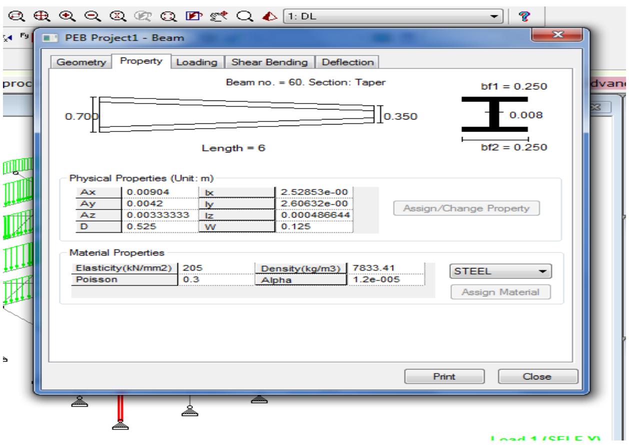

Fig:5 Section properties of column and beam (TAPERED)

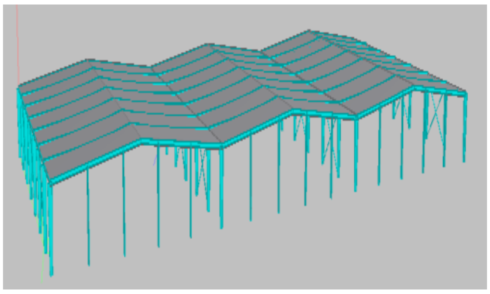

Fig:6 PROPOSED PEB MODEL BY STAAD.Pro

SEISMIC ANALYSIS:

The analysis of pre engineering building is analyzed by STAAD.Pro software the pre engineering building is studied and which is subjected with seismic force actions under **seismic zone III** since structure is located in Mangalore.

The following factors to be considered for seismic definition:

1. Response reduction factor R= 5
2. Importance factor I= 1.0 for industrial steel building
3. Soil type S = medium soil
4. Damping D = 5%
5. Load combinations considered as 1.5 (DL+LL) from IS 800-2007

Axial Force, Bending Moment And Displacements Are Shown In Below Diagrams For Peb

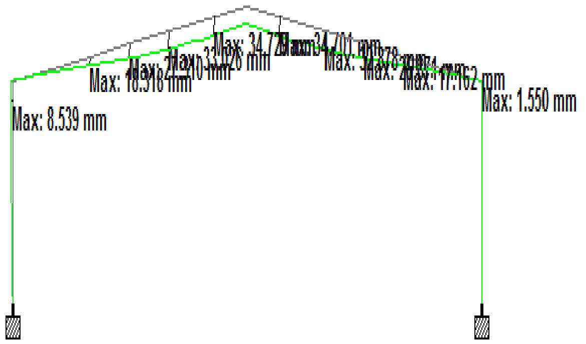

Fig.7 Maximum Displacement

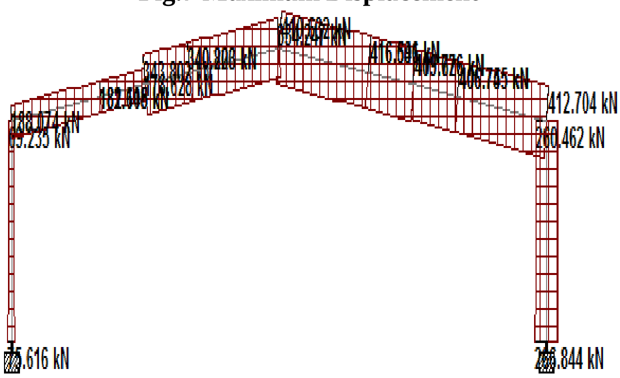

Fig.8 Maximum Axial Force

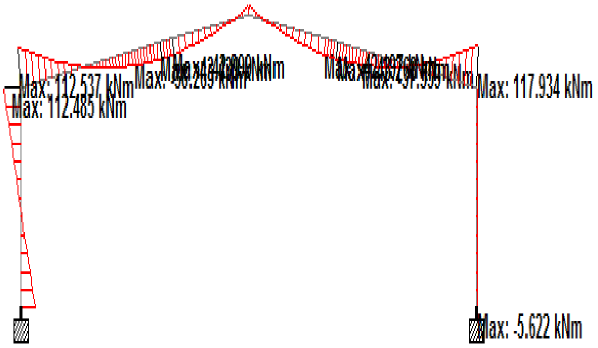

Fig9.Maximum Bending Moment

Axial Force, Bending Moment And Displacements Are Shown In Below Diagrams For Csb

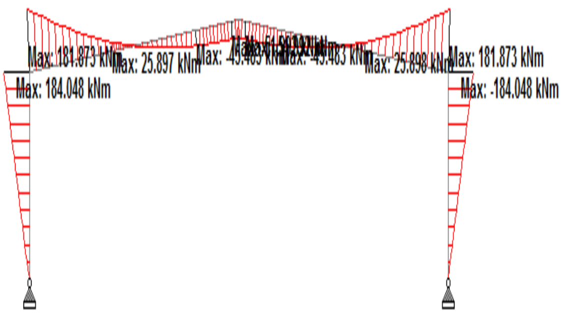

Fig:10 Maximum Bending Moment

Fig11: Maximum Axial Force

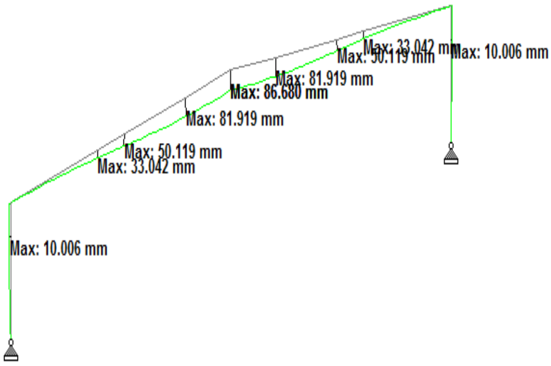

Fig:11 Maximum Displacement

Table 3: bending momemt, shear force, axial force and deflection in column and rafter of CSB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Column	Rafter	Column	Rafter	Column	Rafter	column	Rafter
1	DL+LL	95.68	108.27	61.256	37.26	5.024	61.27	67.59	12.237
2	DL+LL+WL	184.73	181.87	110.56	71.24	10.006	86.06	110.18	30.412
3	DL+LL+EL	174.35	130.76	75.83	54.87	7.958	72.55	84.23	21.144

Table 4: bending momemt, shear force, axial force and deflection in column and rafter of PEB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Column	Rafter	Column	Rafter	Column	Rafter	Column	Rafter
1	DL+LL	71.23	62.48	52.36	46.28	6.019	21.23	41.77	9.234
2	DL+LL+WL	112.56	110.82	75.26	67.25	9.688	34.72	84.23	25.57
3	DL+LL+EL	94.88	86.94	69.07	53.89	8.256	28.927	68.29	13.81

Table 5: bending momemt, shear force, axial force and deflection in purlin and girt of CSB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Purlin	Girt	Purlin	Girt	Purlin	Girt	Purlin	Girt
1	DL+LL	4.78	2.15	4.44	2.71	9.06	2.01	2.87	1.94
2	DL+LL+WL	9.67	4.63	6.84	4.37	15.10	6.08	6.44	3.71
3	DL+LL+EL	7.96	3.84	5.08	3.34	12.14	4.98	5.83	3.10

Table 6: bending momemt, shear force, axial force and deflection in purlin and girt of PEB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Purlin	Girt	Purlin	Girt	Purlin	Girt	Purlin	Girt
1	DL+LL	4.83	1.18	1.93	1.03	9.84	3.93	1.57	0.97
2	DL+LL+WL	6.93	3.34	3.72	2.98	12.03	5.75	3.67	2.82
3	DL+LL+EL	5.45	2.75	2.24	1.76	11.05	4.84	2.33	1.54

Table 7: bending momemt, shear force, axial force and deflection in base plate and bracing of CSB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Base plate	Bracing	Base plate	Bracing	Base plate	Bracing	Base plate	Bracing
1	DL+LL	47	32	16	6	6.89	6.12	37.86	11.75
2	DL+LL+WL	65	54	35	12	10.28	9.28	53.23	16.24
3	DL+LL+EL	58	44	28	10	9.06	8.74	45.55	15.02

Table 8: bending momemt, shear force, axial force and deflection in base plate and bracing of PEB structure

SI NO	Load Com-bination	Max. bending moment in KN-m		Max. Shear force in KN		Max. deflection in mm		Max. axial force in KN	
		Base plate	Bracing	Base plate	Bracing	Base plate	Bracing	Base plate	Bracing
1	DL+LL	32.94	19.88	15.95	4.45	6.67	3.97	20.05	6.24
2	DL+LL+WL	54.08	36.28	27.22	7.25	10.27	5.04	41.97	10.93
3	DL+LL+EL	45.92	29.17	21.78	6.98	8.75	4.66	34.82	9.82

Table 9: Design Forces for CSB

Components	Moment in KN-m	Axial Force in KN	Shear Force in KN	Deflection in mm
Column	184.048	110.18		
Rafter	45.483	30.412		
Purlin	9.67		6.84	15.1
Girt	4.63		4.37	6.08
Base plate	65	53.23	35	
Bracings		16.24	12	

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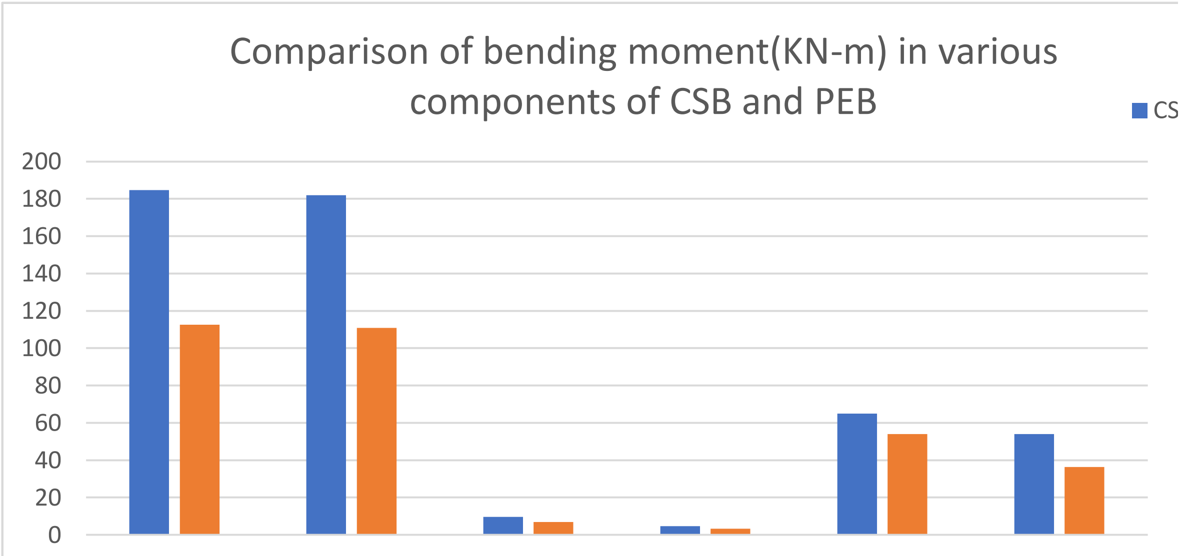
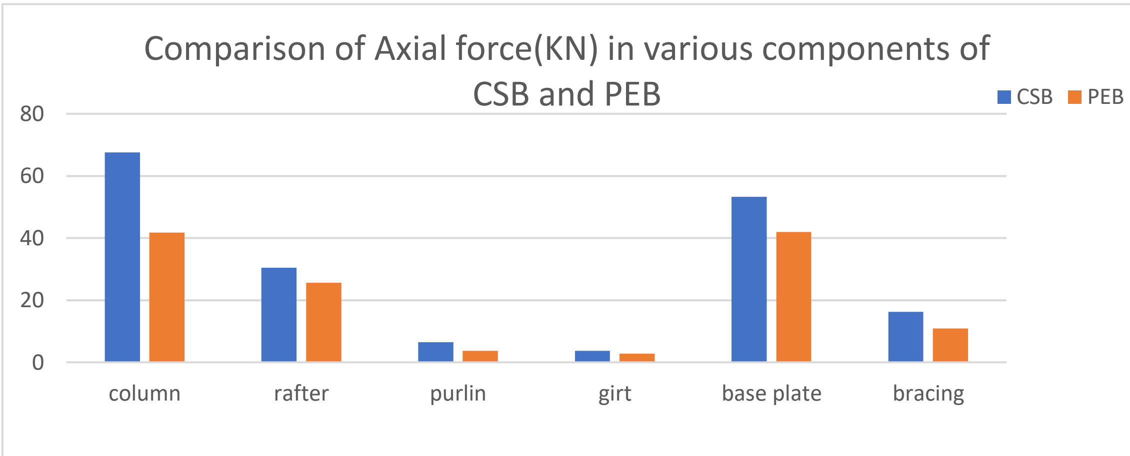
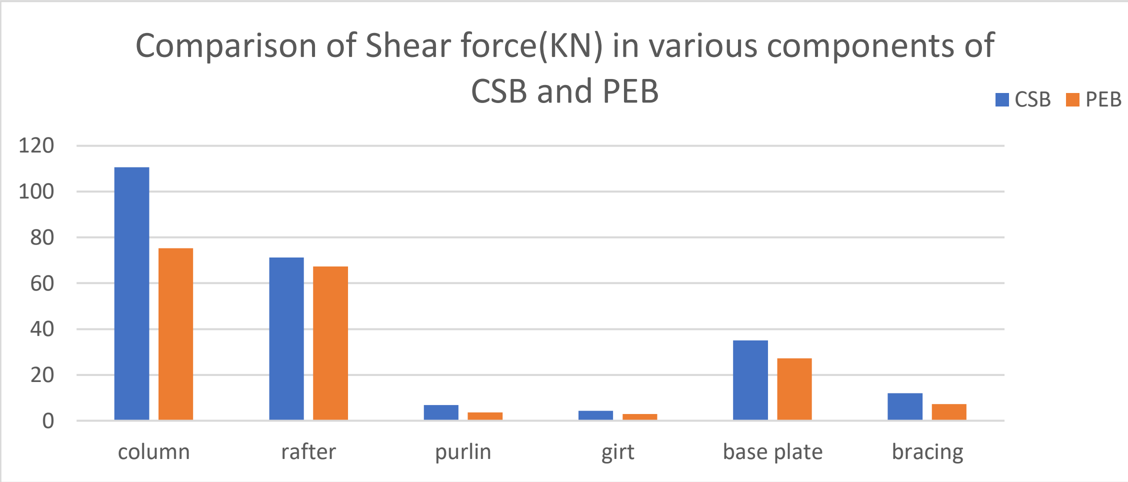
Table 10: Design Forces for PEB

Components	Moment in KN-m	Axial Force in KN	Shear Force in KN	Deflection in mm
Column	112.56	84.23		
Rafter	110.82	25.57		
Purlin	6.93		3.72	12.03
Girt	3.34		2.98	5.75
Base plate	54.08	41.97	27.22	
Bracings		10.93	7.25	







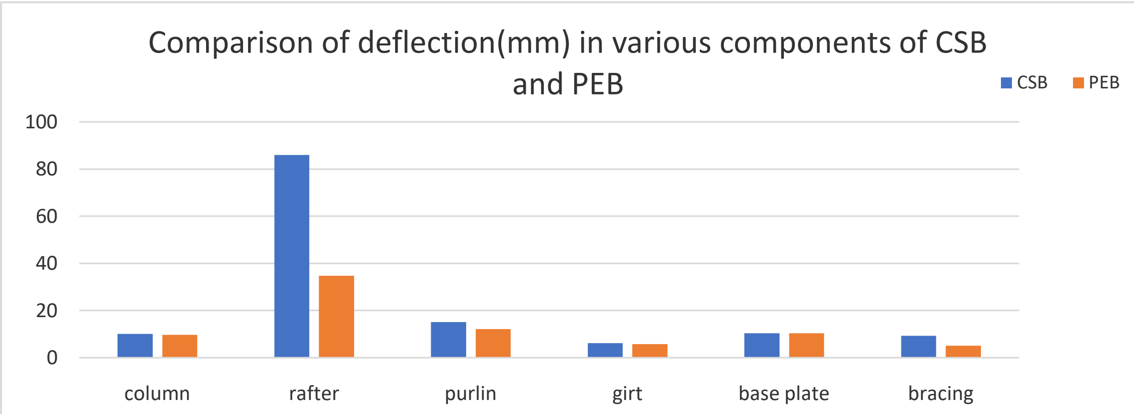


Table11: Displacement

SEISMIC ZONE	HEIGHT IN (M)	DISTPLACEMENT(cm) for PEB	DISTPLACEMENT (cm) for CSB
ZONE III	0	0	0
ZONE III	3	0.0586	0.0612
ZONE III	6	0.0618	0.0724
ZONE III	7.5	0.0915	0.0995

Table12: Base shear

STRUCTURE	Zone	Z	Time (sec), T=0.085h0.75 IS 1893:2016	Sa/g	Ah	Weight of structure (kN)	Base Shear, VB=Ah x W(kN)
CSB	III	0.16	0.365	2.5	0.04	94000	3760
PEB	III	0.16	0.365	2.5	0.04	78900	3156

Table 13: Weight Comparisons

Description	CSB WEIGHT(Kg)	PEB WEIGHT(Kg)	Comparisons
			Difference In Weight
Total	94000	78691	16%

VI. RESULT AND DISCUSSION

1. The both structural components of CSB and PEB are analysed and designed by STAAD.Pro v8i software.

2. The section of structural components used in CSB are

RAFTER: **ISMB450**

COLUMN: **ISMB300**

PURLIN and GIRTS: **ISMC 150**

BRACINGS (side and roof bracings): **60x60x8mm**

3. The section of structural components used in PEB(TAPERED) are

F1: Depth of section at start node

F3: Depth of section at end node

COLUMN: **F1=0.35m, F3=0.7m**

RAFTER: **F1=0.35m, F3=0.35m**

PURLIN and GIRTS: **Z 200mmX1.5mm**

BRACINGS (side and roof bracings): **RD-60mm**

4. From table **3** and **4**, it seen that the moment, Axial Force, deflection and shear force in Column in case of CSB and PEB are **184.73KN-m, 110.18KN, 10.006mm** and **110.56KN** and **112.56KN-m, 84.23KN, 9.688mm** and **75.26KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **39.06%, 23.55%, 3.18% and 31.92%**respectively in comparison to CSB structure.

5. From table **3** and **4**, it seen that the moment, Axial Force, deflection and shear force in Rafter in case of CSB and PEB are **181.87KN-m, 30.412KN, 86.06mm and 71.24KN** and **110.82KN-m, 25.57KN, 34.72mm and 67.25KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **39.06%, 15.92%, 59.65% and 5.6%** respectively in comparison to CSB structure.

6. From table **5** and **6**, it seen that the moment, Axial Force, deflection and shear force in Purlin in case of CSB and PEB are **9.67KN-m, 6.44KN, 15.10mm and 6.84KN** and **6.93KN-m, 3.67KN, 12.03mm and 3.72KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **28.33%, 43.01%, 20.33%**

and 45.61% respectively in comparison to CSB structure.

7. From table **5** and **6**, it seen that the moment, Axial Force, deflection and shear force in Girt in case of CSB and PEB are **4.63KN-m, 3.71KN, 6.08mm and 4.37KN** and **3.34KN-m, 2.82KN, 5.75mm and 2.98KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **27.86%, 24.59%, 5.43% and 31.8%** respectively in comparison to CSB structure.

8. From table **7** and **8**, it seen that the moment, Axial Force, deflection and shear force in Base plate in case of CSB and PEB are **65KN-m, 53.23KN, 10.28mm and 35KN** and **54.08KN-m, 41.97KN, 10.27mm and 27.22KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **16.8%, 21.15%, 0.1% and 22.23%** respectively in comparison to CSB structure.

9. From table **7** and **8**, it seen that the moment, Axial Force, deflection and shear force in Bracing in case of CSB and PEB are **54KN-m, 16.24KN, 9.82mm and 12KN** and **36.28KN-m, 10.93KN, 5.04mm and 7.25KN** respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is **32.81%, 32.67%, 48.67% and 39.58%** respectively in comparison to CSB structure.

10. From table **11**, it seen that the average displacement in case of CSB and PEB are **0.0995cm** and **0.0915cm** respectively. The percentage decrease in average displacement in PEB structure is **8.04%** in comparison to CSB structure.

11. From table **12**, it seen that the Base shear in case of CSB and PEB are **3760KN** and **3156KN** respectively. The percentage decrease in Base shear in PEB structure is **16.06%** in comparison to CSB structure.

12. From table **13**, it seen that the weight of structure in case of CSB and PEB are **94000KN** and **78691KN** respectively. The percentage decrease in weight in PEB structure is **16.28%** in comparison to CSB structure.

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VII. CONCLUSION

- The bending moment, shear force and axial force decreases in various components of pre-engineered multi-span industrial structure(PEB) as compared to conventional multi-span industrial structure(CSB), due to increase in stiffness.
- Displacement decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness.

- PEB structure subjected to seismic loading, base shear and displacement decreases in comparison to CSB structure.
- The percentage decrease in weight in PEB structure is **16.28%** in comparison to CSB structure, hence cost of PEB structure reduces.
- Reduction in steel quantity reduces the dead load ultimately reduces the size of the foundation.

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