Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

Comparitive Study of Pre-Engineered Building and Truss Arrangement Building for Varying Spans

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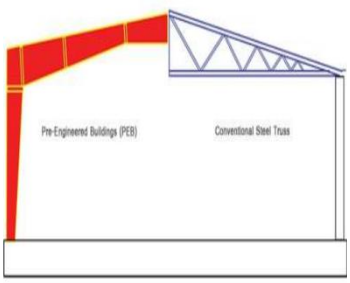
***Abstract*—Steel has been gaining massive popularity over RCC due to the very advantages it offers like malleability, re-usability, fire resistance and so on. Pre- Engineered building is a type of building system which employs built-up sections for the structural members which are engineered and manufactured at factories and assembled at site. This results in good quality control and saves a lot of time. Study of past research shows a lack of research on the effectiveness of Pre-Engineered building system for smaller and larger span buildings and also most comparitive study works in the past are between PEB and Conventional Steel Buildings. For the research work, three plan dimensions 15x30m, 40x80m and 90x180m for an industrial pitched roof building are considered and each checked for a PEB and truss arrangement building configuration and a detailed comparitive study is done. A comparitive study of analysis results, deformations and material take-off is done and subsequently the effectiveness of Pre-Engineered Building for a building of given span and size is checked.**

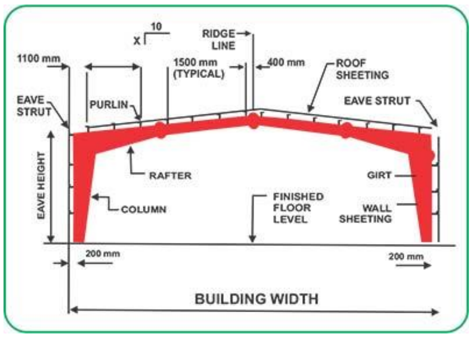
Keywords:- Pre-Engineered Building, Truss Arrangement Building

I. INTRODUCTION

Statistical data has shown that Pre-Engineered buildings have shown a reduction in steel in range of 20-30% and time saving of 30-50% and has become a preferred choice over the past few years. The advent of computer aided design has made it possible to come with customized design as per requirement.



Primary Structural Elements of PEB are:



1) Purlins and girts support roof and wall sheeting respectively.They constitute 10-25% of total steel.
2) Eaves strut supports gutter
3) Bracings are used to give longitudinal stability.
4) The lateral stability is given by frame structure as shown in figure.

II. LITERATURE REVIEW

Beedle et al. (1973) explained the need for ways other than re-sizing the members for optimization. Some of the techniques for optimization suggested are:

1) Use ways to capitalize strength and ductility.
2) Exploit the potentials of load factor and limit states of design.
3) Consider stiffness contribution of walls, partitions and floors acting with structural frames.
4) Utilization of additional strength that can be exploited in bi-axial columns.
5) Interior beam to column connection need not have stiffeners.
6) Going for optimal geometric configuration.

Ajizaz Ahmad et al. (2013) carried out a comparitive study between PEB and
Conventional steel frame building.The following conclusions were deduced:

1) PEB gives lighter sections and hence effect of seismic Forces is reduced.
2) It was deduced that for building of length 80m with Columns provided at 8m,8.88m,10m,11.425m and 13.3m, 8.8m and 11.425m gave economy.
3) It was observed that 27% reduction in steel took place.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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4) In case of long span structures, PEB gave more economy.

5) Weight of PEB depends on bay spacing with increase beyond a certain limit increases weight of steel..

Kavya Rao et al. (2014) carried out a comparitive study between Pre-Engineered building and conventional steel building. The following were the observations:

1) PEB reduces steel used by 36% than that required by conventional steel building.

2) The analysis forces are lesser in PEB as compared to Conventional Steel Building.

3) Since the reactions in PEB are lesser due to lighter sections used,foundations are comparitively lighter.

4) Delivery time is as follows

PEB- 6 to 8 weeks

CSB- 20 weeks

5) 30% cost reduction was observed in PEB as compared to CSB.

Pradeep S. et al. (2015) took up the study of various types of roof trusses like Warren, N, Pratt and Howe truss systems. It was seen that the Warren truss is most economical among all.

Anil V.Bandre at al. (2019) carried out a study to compare design using hot rolled steel section and built up sections. It has been concluded that the shear force,bending moment and displacements are comparitively lower in PEB than in using hot rolled steel section.

Umesh L.Mali et al. (2020) carried out a comparitive study between various lateral load resisting systems for varying heights.The following conclusions were deduced:

1) For buildings in the range of 20m to 35m height- Shear walls are efficient.

2) For buildings in the range of 20m- X Bracings are efficient

3) X bracing is most efficient in high seismic zones.

4) Concrete outrigger system is more efficient than steel.

5) U,L Shapes are more critical.

III. MODELLING AND ANALYSIS

A. Skeletal Modelling (STAAD.Pro Design Software)

1)Spans of 15x30m, 40x80m and 90x180m are considered.

2)A uniform height of 7m and bay spacing of 6m is considered for all models.

3)Hinged support is provided at base as it helps to get an optimal structural design.

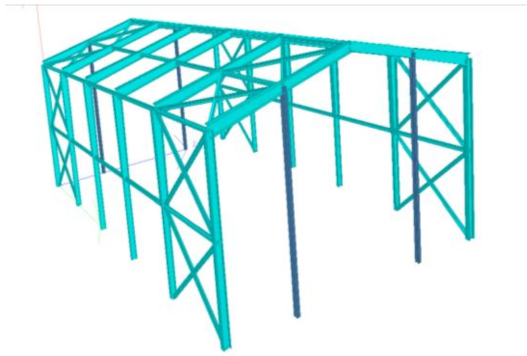


Fig 1. 3D Model of PEB Structural Configuration(15x30m)

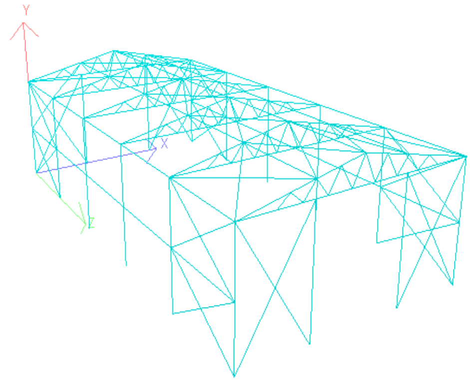


Fig 2. 3D Model of Truss Arrangement Configuration(15x30m)

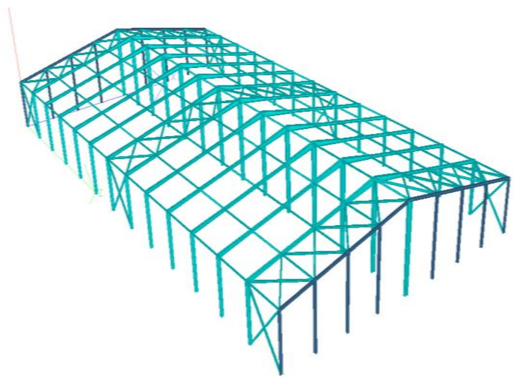


Fig 3. 3D Model of PEB Structural Configuration(40x80m)

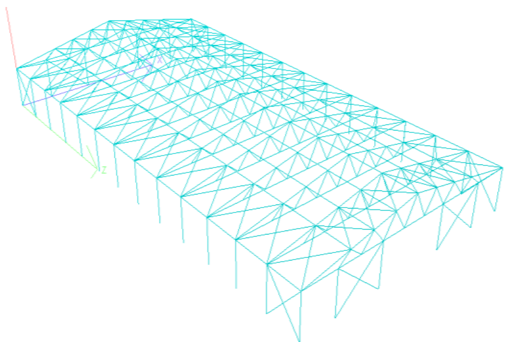


Fig 4. 3D Model of Truss Arrangement Configuration(40x80m)

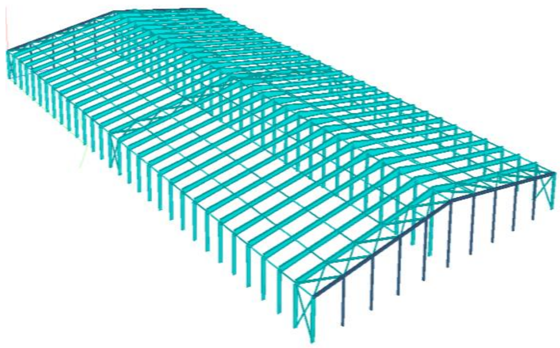


Fig 5. 3D Model of PEB Structural Configuration(90x180m)

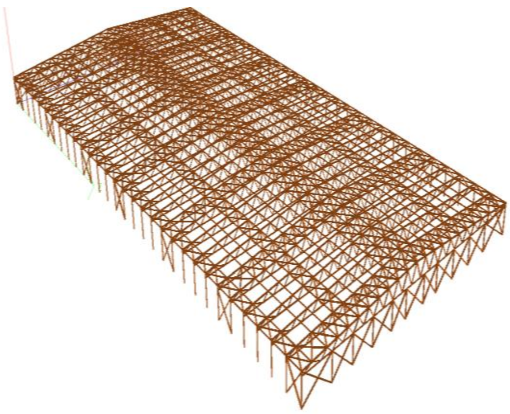


Fig 6. 3D Model of Truss Arrangement Configuration(90x180m)

B. Loads

1) Dead Loads

Self weight and a multiplication factor of 1.15 is taken to account for weight of connections

Calculations:

a) Roof loads:

Loads on main rafters:

*Assume weight of 0.5mm galvanized sheet as 5 kg/m2.
*Assume weight of sag rods, flange braces etc as 5 kg/m2.
*Assume weight of collateral load as 10kg/m2.
*Total load = 20 kg/m2
*u.d.l on main rafter = 0.2x6 =1.2kg/m2
*No. of purlins = 7.64/1.5 + 1 = 6.093~7 (Assume purlins spaced at 1.5m c/c)
* Self weight of lipped Z section 270x75x20x2.55 = 8.77 kg/m
*u.d.l due to purlins on main rafters
= (8.77x6x7x10)/(7.64x1000)
= 0.482 kn/m
* u.d.l due to purlins on gable end rafter = 0.24 kn/m
*Total load on main rafter = 1.2 + 0.482 = 1.682 kn/m
*Total load on gable end rafter = 0.84 kn/m

b) Wall loads:

*Assume weight of 0.5mm thick wall sheeting as 5kg/m2.
*Assume weight of sag rods,flange braces as 5 kg/m2.
*Total = 10 kg/m2
*u.d.l on main column = 0.6 kn/m
*u.d.l on intermediate column = 0.3 kn/m

*Purlin load:
* No. of purlins = (7/1.5) +1 (Assume purlins spaced at 1.5m c/c)
= 5.66 ~ 6
*Purlin load = (6x6x8.77x10)/(7x1000)
= 0.45 kn/m
*Total load on main column = 1.05 kn/m
*Total load on intermediate column = 0.525 kn/m

2) Seismic loads:

Seismic parameters considered:
1)Response reduction factor = 4
2)Importance factor = 1
3)Rock and Soil Site factor = 2
4)Type of structure = 2
5)Damping ratio (DM) = 0.05
6)Region = Chennai

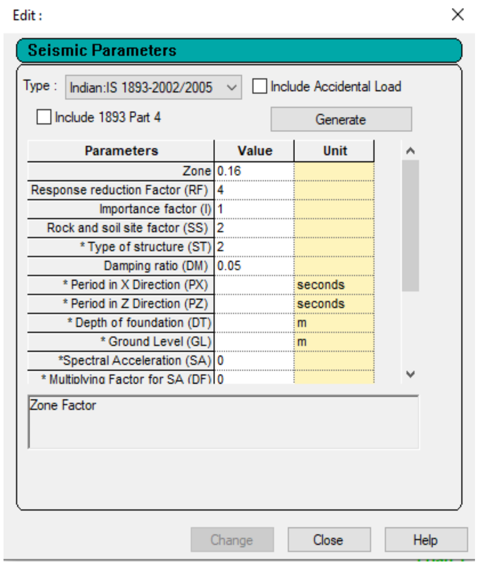


Fig7. Seismic Parameters in STAAD.Pro.

3) Wind load :

1)Location= Chennai
2)Wind basic speed(Vb)= 50m/s
3)Probability factor(k1)= 1
4)Terran roughness and height factor(k2)= 1
5)Topography factor(k3)= 1
6)Importance factor for cyclonic region(k4)= 1.15 (Industrial Building)
7)*Vz= Vbxk1xk2xk3xk4
= 50x1x1x1x1.15
= 57.5 m/s
*Wind pressure(pz)= 0.6xVz^2
= 0.6x57.5^2
= 1.988 kn/m2
* Pd= kd x ka x kc x pz
1)kd(wind directionality factor)= 1 (The area of location is cyclone affected)
2)Ka=area averaging factor
Least tributary area= 7x6
= 42m2
Tributary area(m2)   ka

25	0.9
42	x
100	0.8

Ka=0.87 by interpolation

3)Kc=0.8

Pd= 1.983x1 x0.87x0.8

= 1.38 kn/m2

Assume opening as 5-20%

Internal pressure coefficient= +/-0.5

For h/w= 0.466

l/w= 30/15= 2

TABLE 1 Wind Load Calculations for Rafter

Wind angle Θ	Cpe for surfaces			
(degrees)		B	C	D
0	+0.7	-0.25	-0.6	-0.6
90	-0.5	-0.5	+0.7	-0.1

Wind Angle	Cpe	Cpi+	Cpi-	Cpe+Cpi+	Cpe+Cpi-	Pd(kn/m2) (Cpe+Cpi+)	Pd(kn/m2) (Cpe+Cpi-)	Spacing (m)	Wd(kn/2) (Cpe+Cpi+)	Wd(kn/m2) (Cpe+Cpi-)
0deg EF	-0.8	+0.5	-0.5	-1.3	-0.3	-1.794	-0.41	6	-10.76	-2.46
0deg GH	-0.4	+0.5	-0.5	-0.9	0.1	-1.24	+0.138	6	-7.44	0.82
90deg EG	-0.8	+0.5	-0.5	-1.3	-0.3	-1.79	-0.41	6	-10.74	-2.46
90deg FH	-0.4	+0.5	-0.5	-0.9	0.1	-1.24	+0.138	6	-7.44	0.82

TABLE 2 Wind Load Calculation for Columns

Wind Angle & Surface	Cpe	Cpi+	Cpi-	Cpe+Cpi +	Cpe+Cpi-	Pd(kn/m2) (Cpe+Cpi+)	Pd(kn/m2) (Cpe+Cpi-)	Spacing (m)	Wd(kn/2) (Cpe+Cpi +)	Wd(kn/m 2)(Cpe+Cpi -)
0deg A	+0.7	+0.5	-0.5	0.2	1.2	0.27	1.65	6	1.62	9.9
0deg B	-0.25	+0.5	-0.5	-0.75	0.25	-1.03	0.34	6	-6.18	2.04
0deg C	-0.6	+0.5	-0.5	-1.1	-0.1	-1.51	-0.138	6	-9.06	0.828
0deg D	-0.6	+0.5	-0.5	-1.1	-0.1	-1.51	-0.138	6	-9.06	-0.828
90deg A	-0.5	+0.5	-0.5	-1	0	-1.38	0	6	-8.28	0
90deg B	-0.5	+0.5	-0.5	-1	0	-1.38	0	6	-8.28	0
90deg C	+0.7	+0.5	-0.5	0.2	1.2	0.276	1.65	6	1.65	9.9

IV. PROCEDURE FOR ANALYSIS AND DESIGN

1)Collection of data for the proposed model - span of building, location of building, initial proportioning of building as per client specifications, wind and seismic parameters as per IS Code.

2)Modelling in staad and applying the loads calculated as per codal

specifications.

3)Optimization is done so as to arrive at an economic structural configuration.

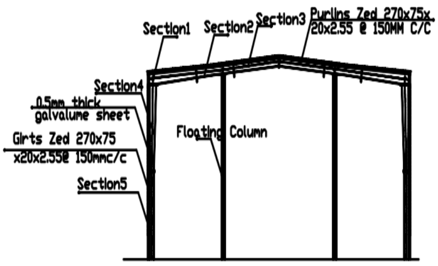
4)Extract the results required for comparison.

V. SERVICIBILITY CHECKS

As per table 6 from IS 800:

1)For rafters,permissible deflection is span/180.

2)For columns,permissible deflection is span/150.



SHEDULE OF MEMBERS

BUILDING MODEL	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	TIE BEAM	FLOATING COLUMNS	NO. OF FLOATING COLUMNS PER END BAY	BRACINGS
PEB1	350x18-414x7-350x18-314x7	300x10-330x7-300x10-330x7	300x10-330x7-300x10-330x7	300x10-330x7-300x10-330x7	300x10-330x7-300x10-330x7	2 ISA 90x90x8 (SA)	UC 203x203x52	4	ISA90x90x8(SA) ISA100x100x10(SA)
PEB2	300X14-372X6-300X14-272X6	300x14-272x6-300x14-272x6	360x16-618x6-300x16-328x6	300x18-414x7-300x18-314x7	220x16-268x6-220x16-268x6	2 ISA 90x90x6 (SA)	UC 254x254x89.5	7	2 ISA 150x150x16(SA)
PEB3	400x30-890x12-400x30-690x12	450x30-740x10-450x30-690x10	450x30-1340x10-450x30-690x10	400x30-890x12-400x30-690x12	400x30-890x12-400x30-690x12	2 ISA 80x80x6(SA)	UC 356x406x287	9	2 ISA 150x150x16 (SA)

Note: The Built-up Beam properties in the table is given as Bf1xtf1 - dw1xtw1 - Bf2xtf2 - dw2xtw2

Where Bf1- Width of beam at end 1
tf1 - Thickness of flange of beam at end 1
dw1- Depth of web of beam at end 1
tw1 - Thickness of web of beam at end 1
Bf2 - Width of beam at end 2
tf2 - Thickness of flange of beam at end 2
dw2 - Depth of web of beam at end 2
tw2 - Thickness of web of beam at end 2

Fig8. Typical Cross Section Profile

VI. RESULTS

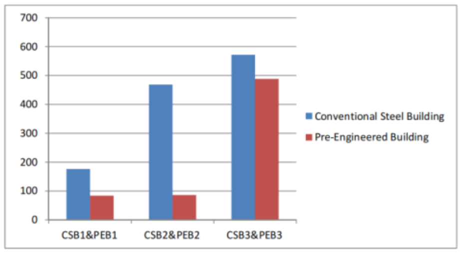


Fig9. Comparison of Reaction Force Fx between CSB and PEB Models

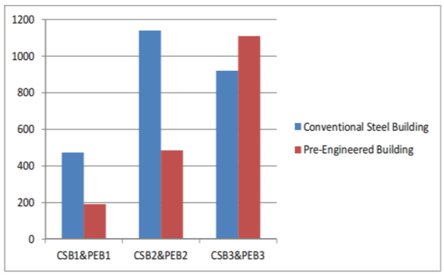


Fig10. Comparison of Reaction Force Fy between CSB and PEB Models

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 10, October-2021

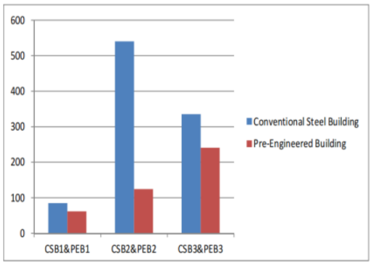


Fig11. Comparison of Reaction Force Fz between CSB and PEB Models

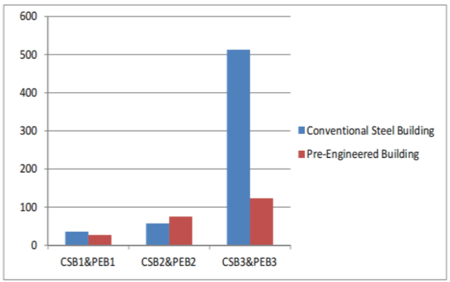


Fig12. Comparison of Roof Deflections between CSB and PEB Models

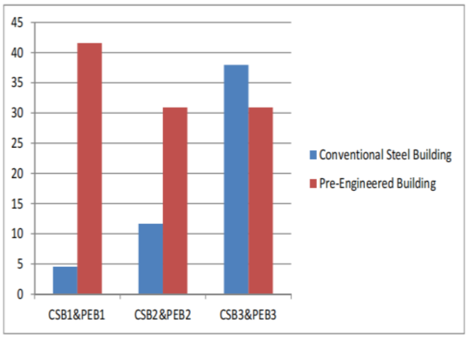


Fig13. Comparison of Column Lateral Deflections between CSB and PEB Models

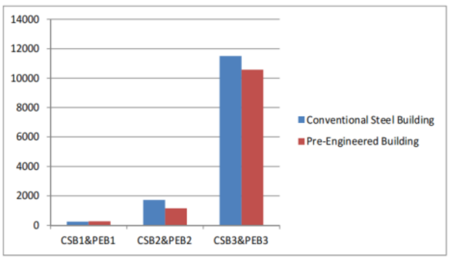


Fig14. Comparison of Steel takeoff between CSB and PEB Models

VII. CONCLUSIONS

The major objective of this study was to carry out a comparitive study between Pre-Engineered building and truss arrangement steel building for varying spans and hence arrive at an economical configuration for a given span. The results obtained are summarized as follows:

1)PEB is found to be more economical than CSB for mid and large span industrial building structures in the range of 40-90m.There is seen to be an increase in steel consumption in CSB as compared to PEB for the 15m building.

2)The size of steel cross sections was greatly influenced by the serviceability requirements in CSB models.The CSB model for 90m(large span building) showed great joint displacements and greatly influenced the member section sizes,hence giving comparatively lesser economy in steel take off as compared to PEB.

3)Due to the rigidity of the joints,PEB model members carried lesser forces than CSB and also due to the variation of member profiles along the length,there was more economy in material in PEB than in CSB.But in small span building 15x30m,the CSB had lighter members and hence was more economical.

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