A Comparative study on the Performance of PEB with CSB considering various parameters

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Abstract- *In recent years, the introduction of Pre-Engineered Building (PEB) design of structures has helped in optimized design. The adoption of PEB design concept in place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are designed as per bending moment diagram thereby reducing the material requirement. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. This concept has many advantages over the CSB concept involving buildings with roof trusses.*
In this study, an industrial structure is analyzed and designed according to the Indian standards. One model each for PEB and CSB is considered and parametric study is carried out to access the performance of the models. Comparison is made in terms of weight, cost and time of construction.

KeyWords: Pre-Engineered Building (PEB), Conventional Steel Building (CSB), Structural analysis and design, Steel structures, Connections

1. INTRODUCTION

Steel structures are becoming famous in almost all the parts of the world. The use of steel became more popular when people got the knowledge about its various advantages. They are being used for both residential and commercial structures. Various types of steel structures are available now like arch buildings; clear span buildings, straight wall buildings. For agriculture purposes, the arch buildings are used as they are very strong and also durable. The straight wall buildings are less strong than arch buildings but have more space inside. The clear span buildings are mainly used for the storage of aircrafts.
Pre-fabricated buildings came into existence in 1960's. It had ceiling, floor, frame etc. These parts were put together to make the whole building. This made construction easier. Steel buildings are used in all kinds of applications and their demand is increasing. There are mainly two categories in steel buildings-

1) Conventional Steel Building [CSB]
2) Pre-Engineered Building [PEB]

1.1 Conventional Steel Building [CSB]

In today's world, steel is bringing elegance, artistry and is functioning in endless ways contributing to new solutions for the construction of formidable structures, which were once unthinkable. Steel offers speedy construction right from the start. Due to its important characteristics like ductility, flexibility etc, steel is been widely used in the construction industry. It bends under the application of heavy loads rather than undergoing crushing and crumbling. Due to its strength, less rate, stability, flexibility and recyclability, it makes a great choice to use steel in construction. It is also seen that steel has some reserve strength in them. The conventional steel buildings are stable. Usually hot rolled structural members are used in these buildings. Here the members are fabricated in factories and then transported to the site. The changes can be made during the erection by welding and cutting process. Normally trusses are used in this system.

Fig.-1: CSB structure

1.2 Pre-Engineered Building [PEB]

These are produced in the plant itself. Here according to the requirements of the customer the manufacturing of the members is done. The components are made in completely ready condition for transportation. These are then sent to the site and then the erection process starts. The manufacturing process doesn't takes place at the site. The pre-engineered buildings are normally constructed for office, shop fronts, ware houses etc. Here the extra amount of steel is avoided because the sections are tapered according to the bending moment diagram.

Fig.-2: PEB structure

1.3 Components of PEBs

The pre-engineered building is made up of the following components-

- Primary Components
- Secondary Components
- Accessories

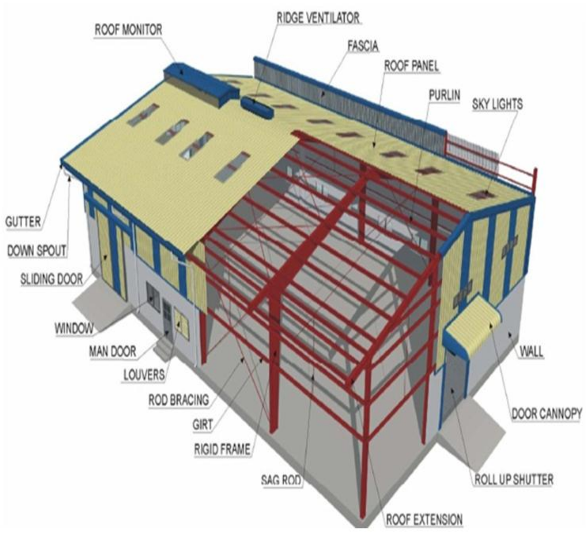

Fig.-3: Components of PEBs

1.3.1 Primary Components

1) Main Frame

It generally includes the main components of the building. It includes tapered columns and rafters (also known as built-up I sections). These tapered sections are manufactured where the webs are fillet welded to flanges. Then the splice plates are connected to the ends of tapered members. The PEB frame is then raised by connecting the members by the use of bolts. The columns can be either tapered or of uniform depth. The webs are connected to the flanges by continuous fillet welding. The base plates, splices, stiffeners etc are welded at factory on the structural members.

2) Columns

Their main function is transferring the vertical loads to the foundation. But also some part of lateral load is also transferred by the columns. Usually these are made up of 'I' sections which are found to be less costly than other sections. Its depth goes on increasing from bottom end to the top end of column. The column is made of 'I-section' consisting of flanges and web connected to each other by welding.

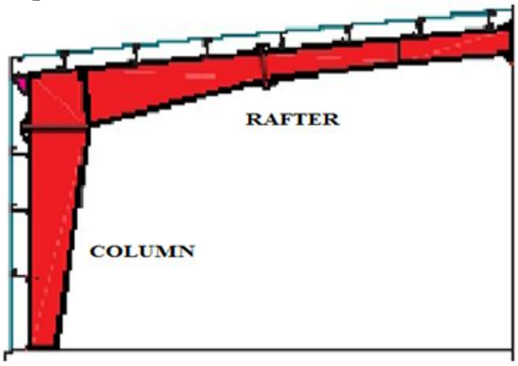

Fig.-4: Columns & Rafter

3) Rafters

These are the series of inclined members (beams) which stretch from ridge to wall plate, eave and are generally designed to support the roof and to take the loads.

1.3.2 Secondary Components

Girts and purlins form the secondary components which are used as a support system for walls and panels of roofs. The purlins are used on roofs and girts are used on walls. The main function of the secondary members is that it acts as struts which help in counter acting the part of loads which act on the building like wind and seismic loads and they provide lateral bracings to the flanges in compression of the members of the main frame thereby increasing the capacity of the frame. The secondary components are pre galvanized or painted at factory with minimum of 35 microns of corrosion protection primer.

Fig.-5: Sections used for Purlin and Girt

1.3.3 Accessories

1) Anchor Bolts

These are used to anchor the members to the floor of concrete, concrete foundations or to other supports. These bolts are usually referred to the ones at the bottom of the columns. These are produced with circular rods with threading at top for bolting and bent at below for foundation.

Fig.-6: Anchor Bolts

2) Turbo Ventilator

It is a spinning ventilator of roof which works on wind energy. If the wind pressure between outside & inside the building is different, the air moves through its opening and maintains the equilibrium condition. The main use of using these is that they improve the circulation of air and suffocation is being eliminated.

Fig.-7: Turbo Ventilator

3) Walking Doors

These are usually 920mm or 1840mm wide x 2140mm high which are made of electro galvanized steel. Even door fixtures are provided.

4) Aluminium Windows

These are designed for installation along with double side wall panel; self scintillating pre glazed clear glass. The standard size is 1000mm x 1000mm.

5) Sheeting

The sheets which are used for the construction of steel structures consists of a base metal made up of either galvalume coated steel conforming to ASTM 792 M grade, 345 B or aluminium conforming to ASTM B 209M. By weight, the coating of galvalume is 56 percent aluminium & around 44 percent zinc. The exterior surface is coated with 25µ of primer of epoxy along with highly resistant finish of polyester. The interior surface is coated with 12µ of primer of epoxy along with modified polyester. The tensile strength of sheet is around 550MPa.

Fig.-8: Sheets used for PEB

2. MODELING

The models of the Conventional Steel Building (CSB) and Pre-Engineered Building (PEB) are analyzed and designed using STAAD.Pro software. One model each for CSB and PEB was prepared. The details about the models and the data adopted for the study are presented below in Table 1 and Table 2.

Table-1: Data adopted for CSB Model

Parameter	Type/Value
Location	Belagavi, Karnataka
Total length	40 m
Total width	20 m
Clear height	6 m
Slope of roof	21.8^0
Single bay length	4 m
Column section	ISHB 200 @ 40kg/m
Purlin section	ISMC 200 @22.1 kg/m
Truss members (Principal rafter, main tie, struts, ties)	110 x 110 x 15 (Single angle)

Table-2: Data adopted for PEB Model

Parameter	Type/Value
Location	Belagavi, Karnataka
Total length	40 m
Total width	20 m
Clear height	6 m
Slope of roof	5.71^0
Single bay length	4 m
Column and Rafters	Tapered ISHB 350 to ISHB 300
Purlin section	200x80x5

The typical plan, elevation and STAAD 3D rendered view of the CSB and PEB models are presented below from Fig.-9 to Fig.-14.

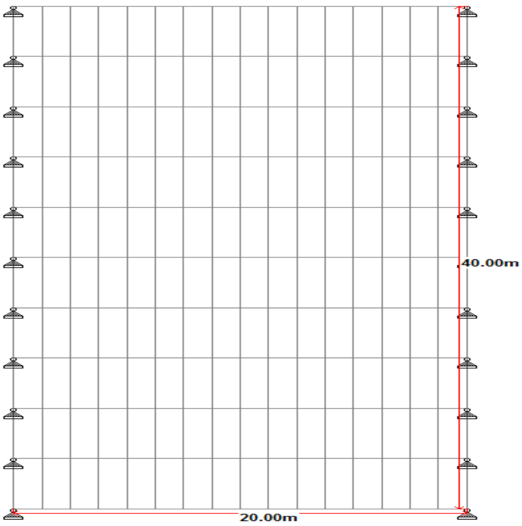

Fig.-9: Plan of CSB Model

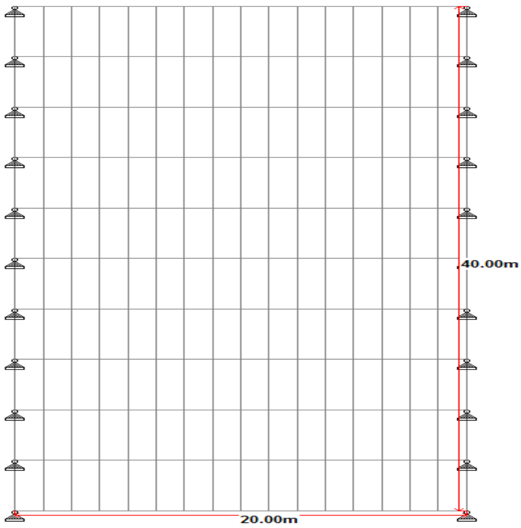

Fig.-12: Plan of PEB Model

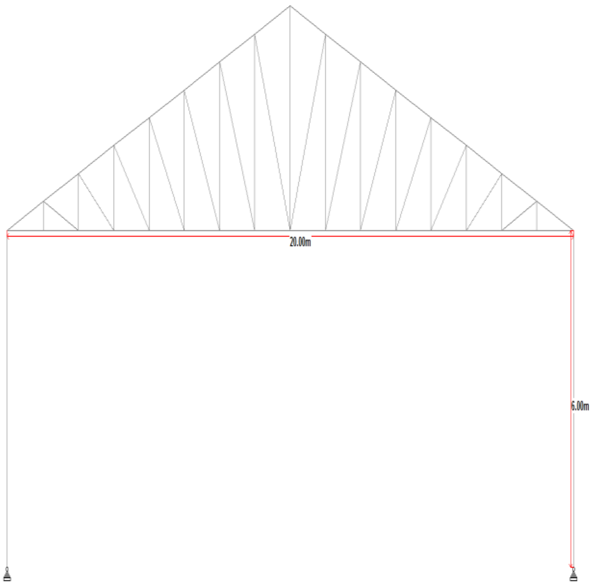

Fig.-10: Elevation of CSB Model

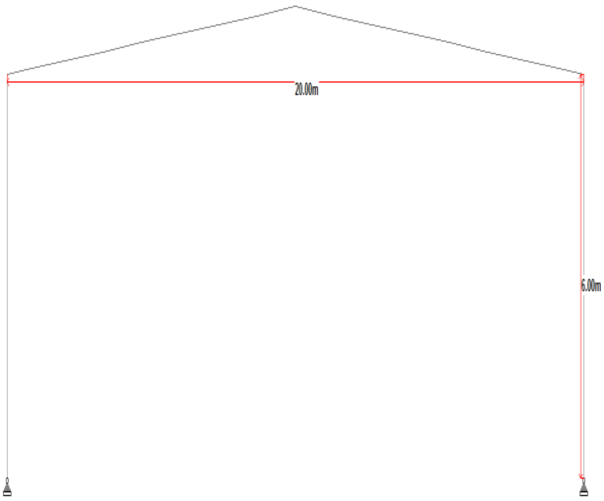

Fig.-13: Elevation of PEB Model

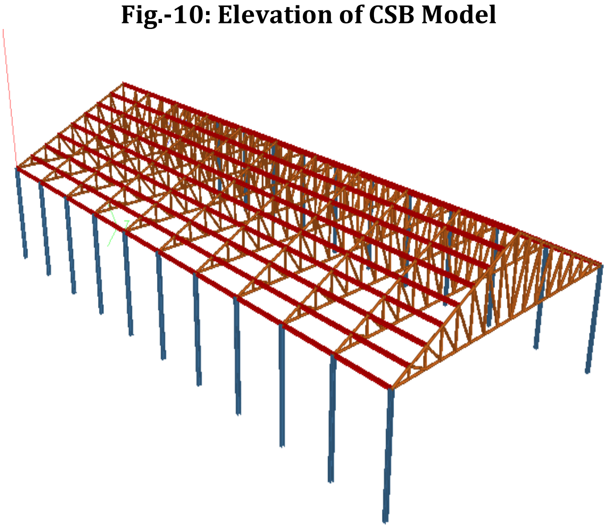

Fig.-11: 3D Rendered view of CSB Model

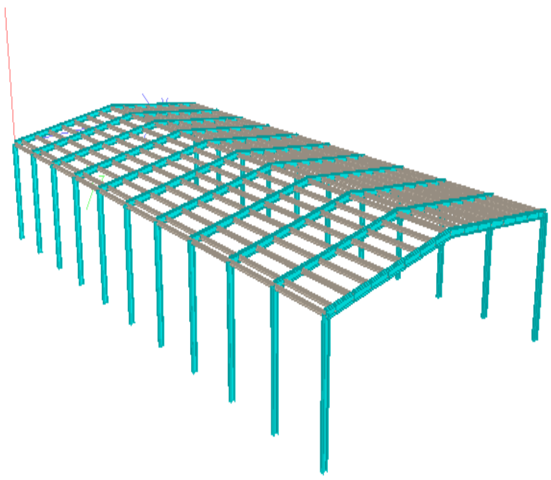

Fig.-14: 3D Rendered view of PEB Model

3. STRUCTURAL ANALYSIS AND DESIGN

The loads taken for the analysis and design of the buildings are as follows-

- Dead Load (DL)
- Live Load (LL)
- Wind load 0^0 (pressure)
- Wind load 0^0 (suction)
- Wind load 90^0 (pressure)
- Wind load 90^0 (suction)

Following are the load combinations used in the present study-

- 1.5 (DL+LL)
- 1.5 (DL+ Wind load 0^0 (pressure))
- 1.5 (DL+ Wind load 0^0 (suction))
- 1.5 (DL+ Wind load 90^0 (pressure))
- 1.5 (DL+ Wind load 90^0 (suction))

Fig.-15 to Fig.-18 depicts the typical CSB and PEB models from STAAD.Pro subjected to various loads. All the loads were worked out according to the IS codes and applied on the models and the analysis was carried out. Later, the structural designs were done using MS-Excel sheets.

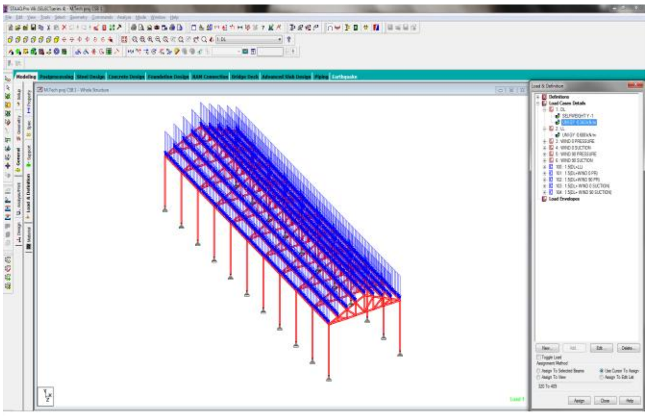

Fig.-15: CSB subjected to Dead Load and Live Load

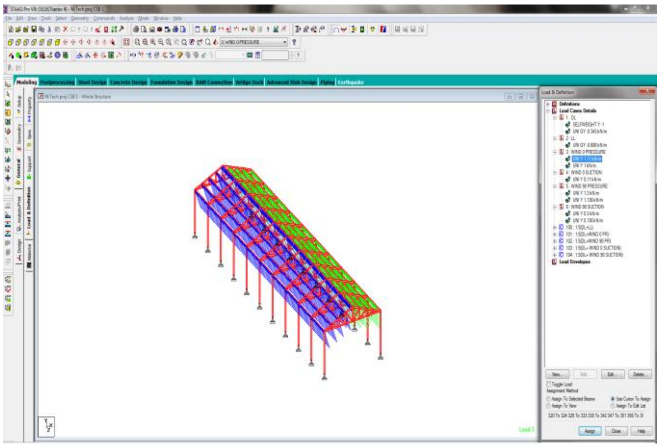

Fig.-16: CSB subjected to Wind Load

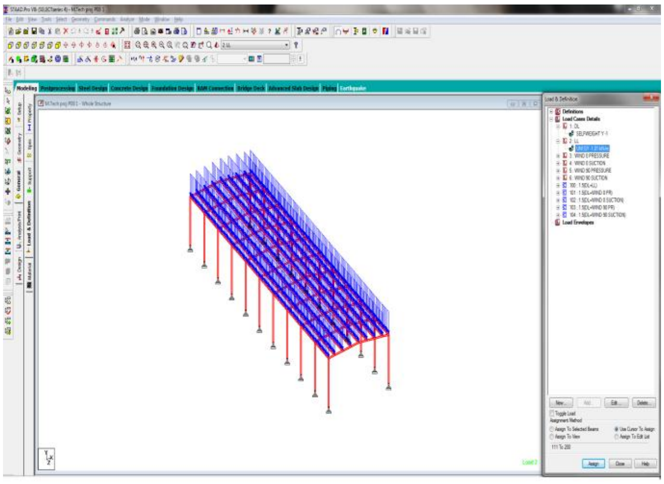

Fig.-17: PEB subjected to Dead Load and Live Load

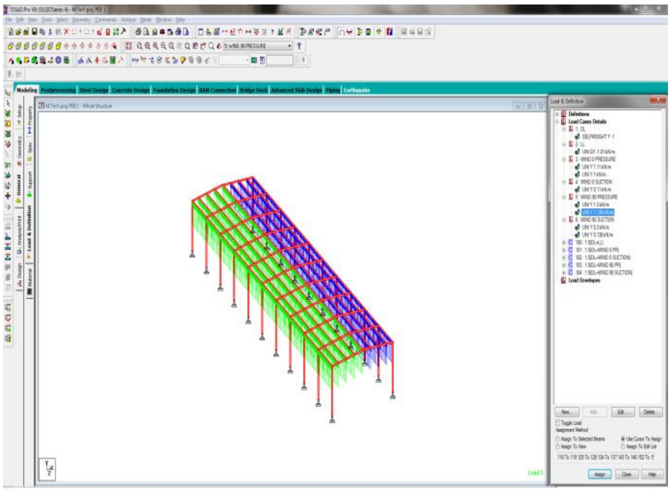

Fig.-18: PEB subjected to Wind Load

4. RESULTS AND DISCUSSION

Each of the two models was modeled and analyzed using STAAD.Pro and designed using validated MS-Excel sheets. Later, the results obtained for the CSB and the PEB models were compared by using various parameters and the performance of the models was evaluated.

Following are the three parameters considered for the comparison of the results for CSB and PEB models-

1) Self weight of the Structure
2) Cost of Construction
3) Time of Construction

Each of these three parameters was worked out for both the models which are presented below in Table-3, Table-4 and Table-5 respectively. The weight of the connections was assumed as 12.5% of total weight for CSB model and 7.5% of total weight for PEB model.

Table-3: Comparison of the Self-Weight of the models

Model	Weight of the Components (MT)				Total Self-Weight (MT)
	Rafter	Column	Purlin	Connections	
CSB	29.8	5.1	14.8	6.2	56.0
PEB	14.2	8.3	8.9	2.3	33.7

Table-4: Comparison of Cost of Construction

Model	Self-Weight (kg)	Rate of material per kg (Rs.)	Material Cost (Rs.)	Labour Cost @ Rs.15 per kg (Rs.)	Total Cost of Construction (Rs.)
CSB	56000	40	2240000	840000	30,80,000
PEB	33700	43	1449100	505500	19,54,600

% saving in Cost for PEB compared to CSB = 35%

Table-5: Comparison of Time of Construction

Model	Geometry of the Structure		Approx. Time of Construction (Weeks)
	Working Space (m^2)	Height (m)	
CSB	800	6	12
PEB	800	6	08

5. CONCLUSIONS

Following conclusions can be drawn from the present study-

1. The study of Self-Weight of the models showed that the Self-Weight for PEB was lower than CSB for the same geometry. With reduction in Self-Weight, the loads and hence the forces on the PEB will be relatively lesser, which decreases the effective sizes of the structural members.

2. The study of Cost of Construction of the models showed that PEB structures are economical since the effective sizes of the structural members in PEB structures are lesser than CSB structures. Hence, the quantity of steel required for PEB structures will be lower than the CSB structures. It was seen that there was about 35% saving in cost for PEB compared to CSB.

3. The study of Time of Construction of the models showed that PEB structures can be constructed in a lesser time compared to the CSB structures for the same geometry. On an average, the PEB structures can be constructed in about 35% lesser time duration than CSB structures. Also, PEB technology can be adopted for the bigger sized structures more effectively than the smaller sized structures.

In CSB structures, the components are custom designed for a specific application on a specific job. Design and detailing errors are possible while assembling the diverse components into unique buildings. In PEB structures, the components are specified and designed specifically to act together as a system for maximum efficiency, precise fit and peak performance in the field. Hence the use of PEB technology is preferred in today's world since it is advantageous by all means as compared to the CSB technology.

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