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Pre-Engineered Building Design of an Industrial Warehouse

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Abstract – *Pre-Engineering Building(PEB) concept of single story industrial construction. The Present work involves the comparative study and design of Pre-Engineering Buildings (PEB) and Conventional steel Building (CSB). Conventional Steel Building is old concept which take lots of time, quality and typical erection factor to modified that issues Pre-Engineering concept is developed. It introduced to the Indian market in 1990's.PEB concept is totally versatile not only due to its quality, prefabrication, light weight and economical construction. The study is achieved by designing a typical frame of Industrial warehouse shed using both the concept and analyzing the designed frame using the structural analysis and design software STAAD Pro.*

Key Words: Pre-Engineering Building, Conventional Steel Building, STAAD Pro.

1. INTRODUCTION

An Industrial Warehouse is a storage building and is usually characterized as single storey steel structures with or without mezzanine floors. The enclosures of these structures may be brick masonry, concrete walls or GI sheet coverings. These buildings are low rise steel structures characterized by low height, lack of interior floor, walls, and partitions. The roofing system for such a building is a truss with roof covering. The walls are generally non-bearing but sufficiently strong enough to withstand lateral forces caused by wind or earthquake. The designing of industrial warehouse includes designing of the structural elements including principal rater or roof truss, column and column base, purlins, sag rods, tie rods, gantry girder, bracings, etc. In Industrial building structures, the walls can be formed of steel columns with cladding which may be of profiled or plain sheets, GI sheets, precast concrete, or masonry. The wall must be adequately strong to resist the lateral force due to wind or earthquake. The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behavior in high winds. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Pre-engineered Buildings have bolted connections and hence can also be reused after dismantling. Thus, pre Engineered buildings can be shifted and expanded as per the requirements in future.

2. METHODOLOGY

The present study is included in the design of an Industrial Warehouse structure located at Nagpur. The structure is proposed as a Pre-Engineered Building of 30 meters width, 8 bays each of 7.5 meters length and an eave height of 6 meters. In this study, a PEB frame of 30 meter width is taken into account and the design is carried out by considering wind load as the critical load for the structure. CSB frame is also designed for the same span considering an economical roof truss configuration. Both the designs are then compared to find out the economical output. The designs are carried out in accordance with the Indian Standards and by the help of the structural analysis and design software STAAD pro v8i.

A. PRE ENGINEERED BUILDINGS

Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. The basis of the PEB concept lies in providing the section at a location only according to the requirement at that spot. The sections can be varying throughout the length according to the bending moment diagram. This leads to the utilization of non-prismatic rigid frames with slender elements. Tapered I sections made with built-up thin plates are used to achieve this configuration. Standard hot-rolled sections, cold-formed sections, profiled roofing sheets, etc. is also used along with the tapered sections, as in. The use of optimal least section leads to effective saving of steel and cost reduction. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure.

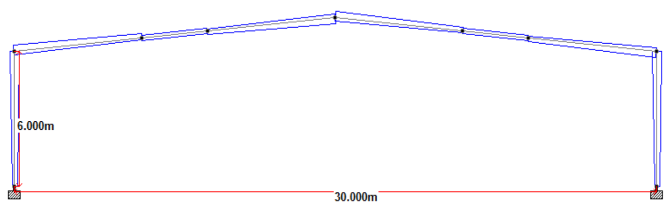

Figure 1. PEB frame

B. CONVENTIONAL STEEL BUILDINGS

Conventional steel buildings (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss. Conventional steel building can also be of portal frame type i.e. the frame is not tapering section. In this paper PEB is compared with both Truss type structure and Portal type structure.

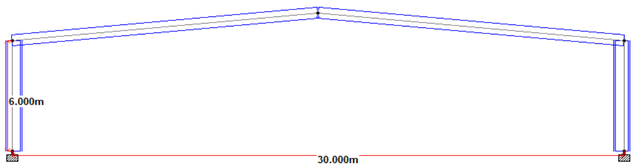

Figure 2. CSB (Portal) Frame

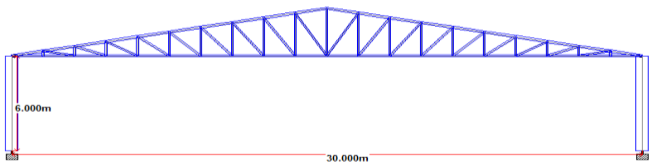

Figure 3. CSB (Truss) Frame

3.STRUCTURE CONFIGURATION DETAILS

Table 1: Structural Parameters

SR.NO.	DESCRIPTION	
1	Type of Structure	Single Storey Industrial warehouse
2	Location	Nagpur, India
3	Length	60 M
4	Width	30M
5	Height	6.0 M
6	Slope of PEB and CBS(Portal)	5.71˚
7	Slope of CBS(Truss)	11.30˚
8	Bay spacing	7.5 M
9	Wind Speed	44 m/sec
10	Wind Terrain Category	2
11	Wind Class	C

4. CALCULATION OF LOADS

a) Dead Load

Dead Load (Sheet + Purlin)= 0.15 KN/m^2

For 7.5 m bay D.L = 0.15 x 7.5 = 1.125 KN/m^2

b) Live Load

Live Load = 0.75 KN/m^2

For 7.5 m bay D.L = 0.75 x 7.5 = 5.625 KN/m^2

4.1 Calculation for Wind loads

Wind loads are calculated as per IS 875 Part-III (1987) & SP 64 in this example. For the present work, the basic wind speed (Vb) is assumed as 50 m/s and the building is considered to be open terrain with well scattered obstruction having height less than 10.0 m with maximum dimension more than 50.0 m and accordingly factors K1,K2 ,K3 have been calculated as per IS-875-Part-III (1987).

Terrain Category – 3

Building Class – B

K1 = Probability Factor (risk coefficient) = 1.0

(General buildings and structures)

K2 = Terrain height and size factor = 0.88

K3 = Topography factor = 1.0

Vb = 44 m/s (For Nagpur Zone)

Design Wind speed

Vz = Vb (K1 x K2 x K3)

Vz = 44 (1 x 0.0.88 x 1)

Vz = 38.72 m/s

Design Pressure

Pz = 0.06 Vz^2

Pz = 0.06 x $(38.72)^2$

Pz = 0.899 KN/m^2

Ratio = H/W = 0.20, L/W = 1.33

4.1.1 Wind Pressure Co-efficient

External and Internal wind co-efficient are calculated for all the surfaces for both pressure and suction. Opening in the building has been considered less than 5 % and accordingly internal co-efficient are taken as +0.2 and -0.2.

The external co-efficient and internal co-efficient calculated as per IS-875 Part-II (1987).

Wind load on individual member are then calculated as below:

F = (Cpe – Cpi) x A x P

Where, Cpe and Cpi are external co-efficient and internal co-efficient respectively and A and P are Surface area in $m^2$and design wind pressure in KN/m^2 respectively.

5. LOAD COMBINATION

5.1. Load combination of strength

1. 1.5D.L+1.5L.L+1.05*C.L
2. 1.2D.L+1.2L.L+0.6W.L.P+1.05*C.L
3. 1.2D.L+1.2L.L+0.6W.L.S+1.05*C.L
4. 1.2D.L+1.2L.L+0.6W.R.P+1.05*C.L
5. 1.2D.L+1.2L.L+0.6W.R.S+1.05*C.L
6. 1.2D.L+1.2L.L+0.6W.L.E.P+1.05*C.L
7. 1.2D.L+1.2L.L+0.6W.L.E.S+1.05*C.L
8. 1.5D.L+1.5W.L.P
9. 1.5D.L+1.5W.L.S
10. 1.5D.L+1.5W.R.P
11. 1.5D.L+1.5W.R.S
12. 1.5D.L+1.5W.L.E.P
13. 1.5D.L+1.5W.L.E.S

5.2. Load combination of serviceability

1. (D.L+L.L+C.L)*1
2. D.L+(L.L+W.L.P+C.L)*0.8
3. D.L+(L.L+W.L.S+C.L)*0.8
4. D.L+(L.L+W.R.P+C.L)*0.8
5. D.L+(L.L+W.R.S+C.L)*0.8
6. D.L+(L.L+W.L.E.P+C.L)*0.8
7. D.L+(L.L+W.L.E.S+C.L)*0.8
8. (D.L+W.L.P)*1
9. (D.L+W.L.S)*1
10. (D.L+W.R.P)*1
11. (D.L+W.R.S)*1
12. (D.L+W.L.E.P)*1
13. (D.L+W.L.E.S)*1

Note:-

D.L- Dead Load

L.L- Live Load

W.L- Wind Load

W.L.P- Wind Left Pressure

W.L.S- Wind Left Suction

W.R.P- Wind Right Pressure

W.R.S- Wind Right Suction

W.L.E.P- Wind Longitudinal Pressure

W.L.E.S- Wind Longitudianl Suction

6. STAAD.PRO PROCEDURE

The Staad.Pro software package is a structural analysis and design software which helps in modeling, analyzing and designing the structure. The software supports standards of several countries, including Indian standard. The procedure includes modeling the structure, applying properties, specifications, loads and load combinations, analyzing and designing the structure. This software is an effective and user-friendly tool for three dimensional model generation, analysis and multi-material designs.

7.RESULTS

Sr. no	Description	PEB	CSB (Portal)	CSB (Truss)
1	Displacement(mm)	278.707	81.99	44.861
2	Support Reaction(Fx)(KN)	195.855	277.218	48.756
3	Support	193.548	231.218	171.156

	Reaction(Fy)(N)			
4	Support Reaction(Mz)	404.019	947.317	148.981
5	Axial Force(KN)	212.628	294.43	557.477
6	Shear Force(KN)	195.855	277.516	48.756
7	Bending Moment(KNm)	771.235	947.317	148.981
8	Steel Take Off(KN)	511.733	940.882	704.951

8.DISCUSSION

Pre-Engineered Buildings have vast advantages over the Conventional Steel Buildings. The results of the software analysis and literature studies conducted for both the concepts suggest the same.

9.CONCLUSION

In this work, Analysis and design of Conventional Steel Building and Pre-Engineering Building has been carried out and comparison between both has been done. Following are the conclusion of this project.

1. Displacement
   - PEB model gives more displacement then CSB model for same loading condition due to less weight of structure.
2. Support Reaction
   - After analysis of PEB and CSB frame it is concluded that the support reaction is more for CSB(Portal frame) as compared to PEB and CSB(Truss frame) .
   - On CSB (Truss frame) the loading is nodal loading therefore the maximum load is taken care by member itself hence the support reaction is less for CSB (Truss frame).
3. The study of self-weight of the models showed that the self-weight for PEB is less than that of 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. By the modeling, it concludes that PEB building is 45% lighter than that of CSB(Portal frame) building and 27% lighter than CSB(Truss Frame)building.
4. Steel quantity depends on primary members and purlins. As spacing of frame is increased steel consumption decreased for primary members and increased for secondary members.
5. Low weight flexible frames of PEB offer higher resistance to wind loads.
6. Cold formed steel section over hot rolled section as purlin is almost lighter than 32 %.
7. Also material wastage plays a significant role in reducing steel quantity and cutting the cost of structure as all fabrication work for conventional steel frames are performed at site results in lots of wastage in material.
8. Reduction in Dead Load results in reducing the size of Foundation.

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