National Conference on Recent Research in Engineering and Technology (NCRRET-2015)
International Journal of Advance Engineering and Research Development (IJAERD)
e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

Comparative Study of Design of an Industrial Workshop with Pre-Engineering Building

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Abstract—Long Span, Column free structures are the most essential in any type of industrial structures. Pre-Engineered Building (PEB) concept is a new concept in the construction of single storey steel industrial building which fulfils this requirement along with reduced time and cost as compared to conventional structures. The objective of this paper is to analyze and designs a Pre-Engineered Building (PEB) using cold formed steel 'Z' purlin section and compare it with Conventional Steel Building (CSB) with fink type truss. The objective is achieved by designing a typical frame system of a proposed Industrial Workshop Building using both the concepts and analyzing the designed frames using the structural analysis and design software Staad Pro V8i.

Index Terms—Cold- formed section, Conventional roof truss, Design Excel sheet, Industrial Workshop, IS Codes, Pre-engineered building, Staad Pro V8i,

1 INTRODUCTION

Steel industry is growing rapidly in almost all the parts of the world. Any building structure used by the industry to manufacture or repair the manufactured goods is known as an industrial workshop. Steel is a material which has high strength per unit weight. Therefore, a steel member of a small section which has little self weight is able to resist heavy loads is used in construction of industrial workshop having large column free space. There has been an increasing demand for structural steel for construction purposes in the United States and India. Structural steel members are usually used for construction of steel plants, automobile industries, utility and process industries, thermal power stations, warehouse, assembly plants, storage, garages, etc. In steel construction, there are two main types of structural members one is hot-rolled shapes and members built up of plate and other is cold formed steel sheet, strip, plates or flat bars in roll-forming machines. In present paper, Industrial unit is categorized as Conventional Steel Buildings (CSB) and Pre-Engineered Buildings (PEB) with cold formed elements, according to the design concepts.

Conventional steel buildings (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various configurations of roof truss are available for conventional steel building depending upon the span. The selection of roof truss includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Conventional steel buildings are manufactured or produced in the plant itself. Standard hot-rolled sections are used for the truss element along with gusset plates.

Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre-engineered buildings. The concept of Pre-engineered Building originated from United States of America in the 1960s. Although PEB systems are extensively used in industrial and many other non-residential constructions worldwide, it is relatively a new concept in India since 1990s. Pre-engineered buildings are those which are fully fabricated in the factory after designing shipped to site in completely knocked down condition and all components are assembled and erected at site with nut-bolts, thereby reducing the time of completion. Pre–engineered steel buildings use a combination of built-up sections, hot-rolled or cold formed elements.
Cold-Form Steel building concept originated during World War II in 1960's in the United States and it is introduced in India in late 1990's. In recent years, the cold formed steel sections are widely used over the hot rolled sections because of their economy and lowest high strength to weight ratio. The thickness of cold formed steel member ranges from 0.4 mm to 6.4mm.

2 METHODOLOGY

This paper includes the design of an Industrial Workshop structure located at Vadodara. The actual structure is proposed as a Conventional Steel Building frame with a fink type roof truss having 45 meters width, 18 meters length and an eave height of 10 meters. Pre-Engineered Building is also designed for the same geometric condition. In this paper, a typical Conventional Steel Building frame is taken into account and the design is carried out by considering wind load as the critical load for the structure. PEB frame is also designed for the same span considering an economical cold formed purlin sections. Both the designs are then compared to find out the economical output. The designs are carried out in accordance with the help of Indian Standards, Manual Structural Analysis, Design Excel Sheets and SoftwareStaad Pro V8i.

2.1 LOAD& LOAD COMBINATIONS

Various loads and loads combinations are taken in to account for analysis and designing the PEB frame and Conventional Steel Building.

1. Dead Load

Dead load includes the self-weight of the structure, weights of roofing material, weight of purlins, weight of roof truss, weight of gantry girder, weight of bracings and other accessories.

2. Live Load

As per IS : 875 (Part 2) – 1987, for roof with no access provided, the live load can be taken as 0.75 kN/m^2 with a reduction of 0.02 kN/m^2 for every one degree above 10 degrees of roof slope.

3.Wind load

Wind load is calculated as per IS: 875 (Part 3) – 1987. The basic wind speed for the location of the building is 44 m/s from the code.

As per IS 800:2007, various considered Load combinations are given below:

1. 1.5(DL+LL)
2. 1.5(DL+WL@90)
3. 1.5(DL+WL@0)
4. 1.2(DL+LL+WL@90)
5. 1.2(DL+LL-WL@90)
6. 1.2(DL+LL+WL@0)
7. 1.2(DL+LL-WL@0)

2.2 CONVENTIONAL STEEL BUILDING

As per the span criteria,eave height and gravity loads, the geometry of fink type roof truss are selected for designing. The configuration of fink type roof truss in an elevation of an industrial workshop building and 3D view rendering from Staad pro are shown in Fig 1 and Fig 2.

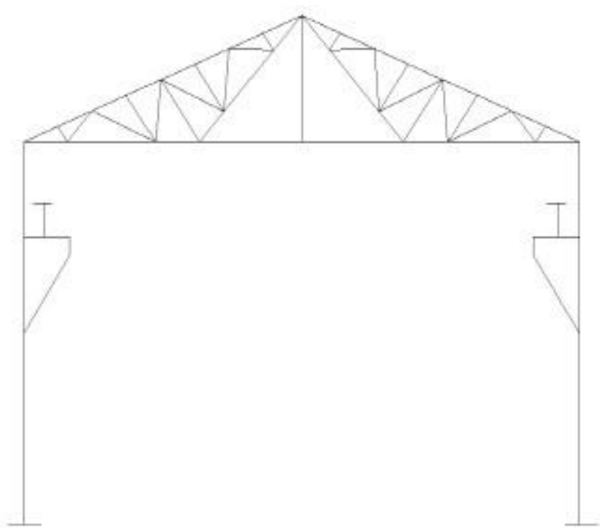

Fig 1 Fink Roof Truss

Fig. 2 3D Rendering View of Workshop

2.3 ANALYSIS AND DESIGN OF CONVENTIONAL ROOF TRUSS

The analysis and design is carried out by MicrosoftDesignExcel 2007 and Staad pro V8i.

Table 1 shown below shows the data considered in analysis of purlin and result obtained from considered data.

TABLE 1 Summary of Purlin Design from Excel sheet

Input Data	
Type of Roof Sheet	Asbestos Sheet
Access Provided	No
Basic Wind Speed	44 m/sec
Life of Structure	50 years
Output Data	
Dead Load	0.18kN/m
Live Load	0.70kN/m
Wind Load	1.10kN/m

Other data which are considered for the analysis of roof truss and result obtained from considered data are shown in Table 2.

TABLE 2 Summary of Roof Truss Design from Excel

Input Data	
Weight of Purlin	3.65 kN
Weight of Roof Truss	4.46 kN
Weight of Wind Bracing	0.49 kN
Output Data	
Dead Load on each intermediate nodes	2.15kN
Live Load on each intermediate nodes	2.12kN
Wind load on intermediate nodes	4.11 kN

Maximum axial load on various truss members are to be found out from Staad Pro V8i software by substituting the values obtained from design excel that is shown in Table 1 and Table 2 above. Fig 3 and Fig 4 shows the dead load, windload applied on Roof truss on intermediate nodes and end nodes.

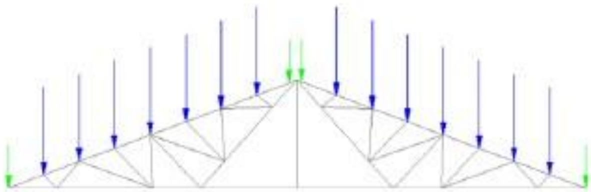

Fig 3. Application of Dead Load

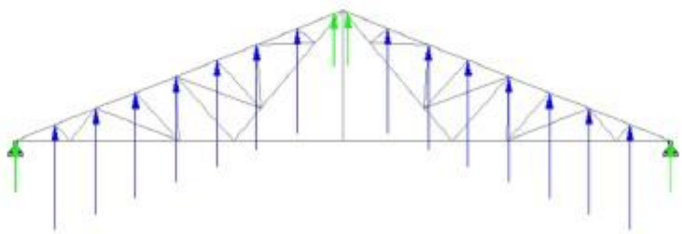

Fig 4. Application of Wind Load

Table 3 shows the maximum axial load on various members of roof truss obtained from StaadPro V8i by considering critical Load combinations.

TABLE 3 Maximum Axial Load

Component	Compressive Force	Tensile Force
Principal rafter	249.35 kN	156.76 kN
Main tie	72.194 kN	38.449 kN
Intermediate truss member (m1)	16.806 kN	31.556 kN
Intermediate truss member (m2)	96.465 kN	51.3 kN

2.4 MEMBERS PROPERTIES

The Table 4 below shows the various sectionsfor purlin, roof and column obtained while designing as per the above forces obtained from Table 3. The column section section is obtained by the reactions obtained from roof truss, horizontal surge load from gantry girder and loading consider due to cladding,windload etc.

TABLE 4 Sections Used in Workshop

Details	**Section**
Purlin	ISLC 150
Roof truss	
Bottom	ISA 40 X 40 X 6
Intermediate	ISA 60 X 60 X 6
Intermediate	ISA 45 X 45 X 6
Top	ISA 65 X 65 X 6
Column Section	ISHB 400

2.5 PRE ENGINEERING BUILDING BY STAAD PRO V8I

The Staad Pro V8i is a structural analysis and design software which helps in modelling, analyzing and designing the structure. The software supports standards of several countries, including Indian standard. The procedure of designing a PEB in Staad Pro v8i includes modelling the PEB structure, applying properties of structure including pre-fabricated tapered section of different sizes and their specifications, loads and load combinations and then analyzing and designing the PEB structure.

Advantages of PEB:

1. Saving in time: Saving in construction time of about 30 – 50% in total project schedule due to fast delivery and quick site erection.
2. Reduction in project cost: Reduction in project cost due to time saving in project implementation.
3. Flexibility: Buildings can be designed maintaining flexibility for future expansion in length, width and height.
4. Earthquake resistant: PEB provides resistant from earthquake because of lower weight and structural building plan.
5. Low maintenance: Buildings are supplied with high quality system for cladding and steel to suit ambient conditions at the site, which results in long durability and low maintenance costs.

Typical Pre Engineering Steel Structure

The Pre-engineered steel frame as shown in Fig 7 is designed for manufacturing or repairing the manufactured goods that provide durability, safety and very low cost-maintenance. Pre-engineered steel building is very simple and economical with the necessary Architectural, Engineering and Construction with pre-engineered steel buildings. The major components of a pre-engineered building are primary structure framing consisting columns and rafter having tapered I sections. The printshot of secondary framing consisting of cold formed sections used as roof purlins, property of tapered I section and Portal frame are shown in Fig 5, Fig 6 & Fig 7

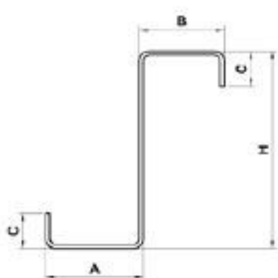

Fig 5 Cold formed Z purlin

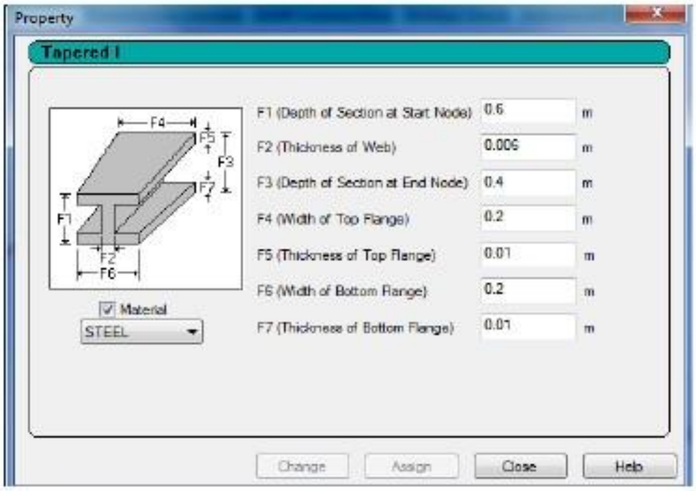

Fig 6 Member property for Tapered section

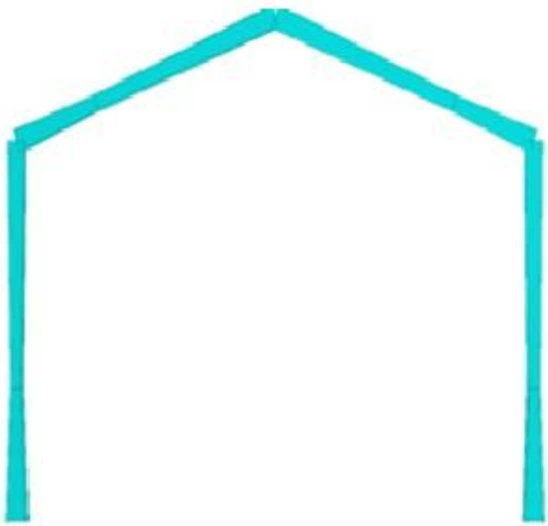

Fig 7PEB portal frame

Analysis and Design of PEB

The design of PEB in Staad Pro V8i consists of the following steps

1. Set up section sizes and brace locations based on the geometry and loading specified for the frame design.
2. Calculate moment, shear and axial force at each analysis point for each load combinations.
3. Design the optimum splice location and check to see whether the predicted sizes confirm to manufacturing constraints.
4. Using the web optimization mode, arrive at the optimum web depths for the next cycle and update the member data file.
5. At the end of all design cycle, an analysis is run to achieve flange brace optimization.

By applying loads combinations, the below Fig8, Fig 9 shows the Bending moment diagram for critical load combination as 1.5(DL+LL) and 1.2(DL+LL-WL@90)

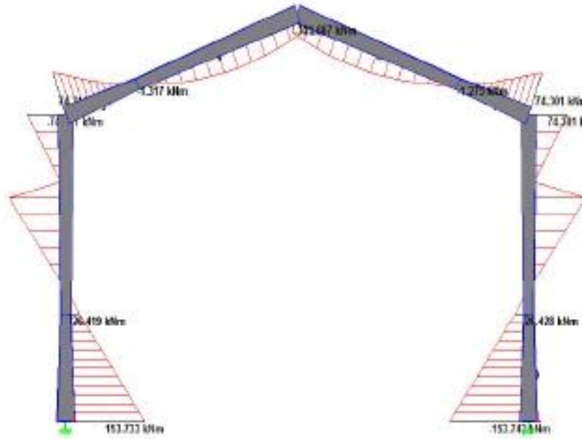

Fig 8 Load combinations for 1.5(DL+LL)

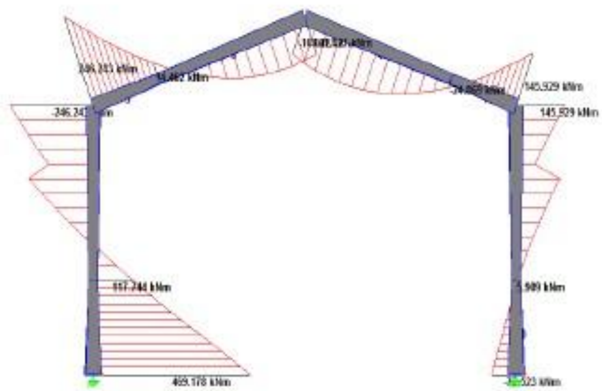

Fig 9 Load combinations for 1.2(DL+LL-WL@90)

The PEB frame is also checked for combined bending and axial compression.The Fig 10 below shows that it is safe agains bending and compression

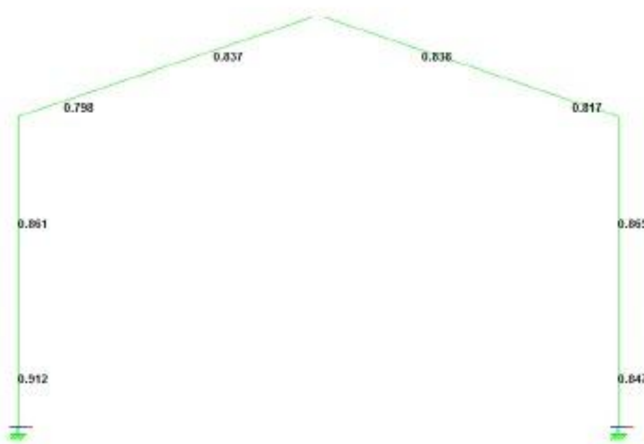

Fig 10 Combined Bending and Axial Compression

3 CONCLUSION

By comparision weight wise, it is found that the total weight of PEB Frame including cold form Z purlin comes out to be 280460 kg and that of conventional roof truss including channel purlin comes out to be as 440220 kg. Thus it is concluded that Price per square meter is around 30% lower than conventional steel building due to lighter weight. Moreover heavy foundation is required for conventional roof truss due to heavy loads on column. Thus we can say that―Pre-Engineered Building Construction gives the end users a much more economical and better solution for long span structures where large column free areas are needed‖

4 ACKNOWLEDGMENT

I now feel goodness to convey a heartily the sense of my gratitude, I would like to acknowledge first to God and then number of persons, who helped me to reach at this pinnacle.
I am highly grateful and indebted to my guide Mr. Tausif-Kauswala, Assistant Professor of Civil Engineering Department, for his constant inspiration, guidance and monitoring of my work for his generosity in devoting his valuable time and for explaining even minute details and also for excellent encouragement at every stage in preparation of this project.
I am also very much thankful to Mr. AnsarKauswala, Design Engineer in L&T for his help during my project work and providing sufficient guidance for designing of PEB structure and Mr. Ashokkumar, Head of Furnace and Foundry Equipment Co. for allowing us to visit their work shop industrial building.
Lastly, but not the least I appreciate the support and patience shown by my Parents during the entire period. Without their blessings and support this would not have been successful endeavour for me.

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