A Comparative Study of Analysis and Design of Pre-engineered Building and Conventional Steel Building for a Polymer Factory

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Abstract— Long span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfill this requirement along with reduced time and cost as compared to conventional structures. The present investigation aims at comparison of conventional steel building and pre-engineered building. In this investigation analysis of and design of pre-engineered building and conventional steel building will be carried out for spans like 15m, 20m, 25m, and 36 m using computer software STAAD Pro v8i.

Key words: Pre-engineered Building, Conventional Steel Building, Comparative Study, STAAD Pro v8i

I. INTRODUCTION

A. General

India has the second fastest growing economy in the world and a lot of it, is attributed to its construction industry which figures just next to agriculture in its economic contribution to the nation. In its steadfast development, the construction industry has discovered, invented and developed a number of technologies, systems and products, one of them being the concept of Pre-engineered Buildings (PEBs). As opposed to being on-site fabricated, PEBs are delivered as a complete finished product to the site from a single supplier with a basic structural steel framework with attached factory finished Cladding and roofing components. The structure is erected on the site by bolting the various building components together as per specifications. PEBs are developed using potential design software. The onset of technological advancement enabling 3d modeling and detailing of the proposed structure and coordination has revolutionized Conventional building construction. Pre-Engineered Buildings (PEB) is the future for India. Most of the Indian business community has just started to realize the benefits of PEB's. Where you have been building with concrete for as long as anyone can remember, it is difficult to change. However India's most progressive companies are seeing the benefits of PEB's.

1) Pre- engineered Buildings

Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. As the name indicates, this concept involves pre-engineering of structural elements using a predetermined registry of building materials and manufacturing techniques that can be proficiently complied with a wide range of structural and aesthetic design requirements. 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. The use of optimal least section leads to effective saving of steel and cost reduction. The typical PEB frame of the structure is as shown in figure.

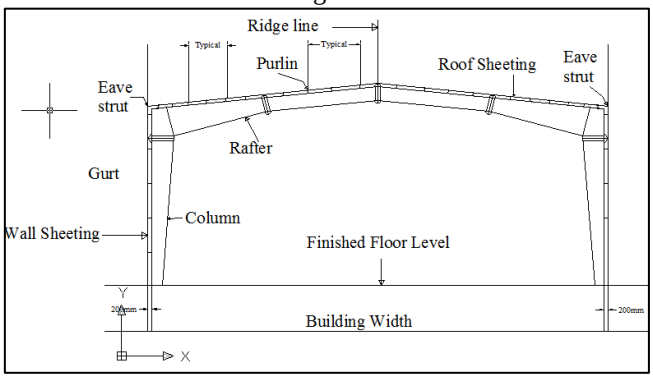

Fig. 1: PEB Frame

In pre-engineered building concept the complete designing is done at the factory and the building components are brought to the site in CKD (Completely knock down condition). These components are then fixed / jointed at the site and raised with the help of cranes. The pre-engineered building calls for very fast construction of buildings and with good aesthetic look sound quality construction. Pre-engineered Buildings can be used extensively for construction of industrial and residential buildings. The buildings can be multi storied (4-6 floors). These buildings are suitable to various environmental hazards. Pre-engineered buildings can be adapted to suit a wide variety of structural applications; the greatest economy will be realized when utilizing standard details. An efficiently designed pre-engineered building can be lighter than the conventional steel buildings by up to 30%. Lighter weight equates to less steel and a potential price savings in structural framework.

2) Conventional 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. For large pitch, Fink type truss can be used; for medium pitch, Pratt type truss can be used and for small pitch, Howe type truss can be used. Skylight can be provided for day lighting and for more day lighting, quadrangular type truss can be used. The selection criterion of roof truss also includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Several compound and combination type of economical roof trusses can also be selected depending upon the utility. Standard hot rolled sections are usually used for the truss elements along the gusset plates. The typical CSB frame is as shown below-

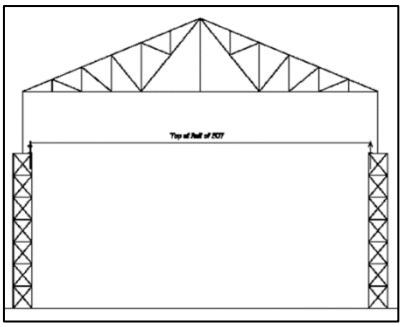

Fig. 2: Conventional steel building frame

II. REVIEW OF LITERATURE

C.M Meera [9]: This paper is comparative study of Pre-engineered building concept and conventional steel building concept. The study is achieved by designing a typical frame of proposed industrial warehouse building using both the concept and analyzing the designed frames using the structural analysis and design software STAAD PRO, from software analysis it was found that the PEB of Roof structure is almost 30% lighter than the CSB structure. Support reaction for PEB is much lesser than CSB as per the analysis. Hence light weight foundation can be adopted for PEB which leads to reduction in cost of foundation. PEB cost 30% lesser than that of CSB.

Syed Firoz, Sarath Chandra Kumar B. S. Kanakambara Rao [10]: The paper discusses about analysis of Pre-engineered building using STAAD-PRO it includes overview of staad-pro procedure for PEB. In this Paper the details related to model generation and verification in staad pro is highlighted. The Procedure for static and dynamic analysis is also discussed in this paper. The different types of configuration of PEB is illustrated which is important as it affects building stability and cost. The authors have concluded that to achieve economy in PEB the material should be chosen so that it will have low cost, strength, durability, design, flexibility, adaptability, recyclability.

Aijaz Ahmad Zende, Prof. A. V. Kulkarni, and Aslam Hutagi [13]: The present work involves the comparative study of static and dynamic analysis and design of Pre Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Staad Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost. Three examples have been taken for the study. Comparison of Pre Engineered Buildings (PEB) and Conventional steel frames is done in two examples and in the third example, longer span Pre Engineered Building structure is taken for the study. In the present work, Pre Engineered Buildings (PEB) and conventional steel frames structure is designed for dynamic forces, which includes wind forces and seismic forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987 and seismic analysis has been carried out as per IS 1893 (2002). As it is seen in the present work, the weight of steel can be reduced to 27% for the hostel building, providing lesser dead load which in turn offers higher resistance to seismic forces. Comparison in the second example showed that even though PEB structures provides clear span, it weighs 10% lesser than that of Conventional Buildings. For longer span structures, Conventional buildings are not suitable with clear spans. Pre-engineered building are the best solution for longer span structures without any interior column in between as seen in this present work, an industrial structure has been designed for 88m. With the advent of computerization, the design possibilities became almost limitless. Saving of material on low stress area of the primary framing members makes Pre-engineered buildings more economical than Conventional steel buildings especially for low rise buildings spanning up to 90.0 meters with eave heights up to 30.0 meters. PEB structures are found to be costly as compared to Conventional structures in case of smaller span structures. It is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces and further increase makes the weight heavier. To Conclude "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".

Rohit C. Pingle, P. J. Salunke, N. G. Gore, and V. G. Sayagavi [12]: The paper aims at comparison of conventional steel building with pre-engineered buildings for industrial warehouse, an attempt is made to compare the structure in terms of steel quantity, weight, and cost and foundation size requirement. In this investigation the portal frame of ware house of different spanning like 30 m, 25 m, 20m, 15m with the different crane capacity like 5 tons, 10 tons, 15tons, 20 tons on each span is carried out using standard computer software like STAAD PROV8i. And the design calculation is done with the help of IS800-2007. As well as for the cold formed sections IS801-1975 is used. The design is done for both conventional steel structure and Pre-engineered steel structure for the all spans with crane load. From the detail calculation and summary it is seen that the comparison between Conventional Steel Portal and Pre-engineered Steel Portal shows following results on an average

Parameters	Reduction
Steel quantity	13-15%
Concrete Quantity	30-35%
Cost	13-15%

Table 1: Parameters

And it is concluded that the comparative study on conventional and Pre – Engineered portal leads to the conclusion that PEB proves to be relevant and beneficial for warehouses equipped with cranes and the advantages of having a PEB portal over a traditional steel portal are far too many. Apart from the main parameters like structural load, Steel Quantity, Concrete Quantity and Cost. Speed and Quality of construction are also the benefits.

Pradeep V, Papa Rao [14]: The paper presents the comparative study and design of conventional steel frames with concrete columns and steel columns and Pre Engineered Buildings (PEB). In this work, an industrial building of length 44m and width 20m with roofing system as conventional steel truss and pre-engineered steel truss is analyzed and designed by using STAAD Pro V8i.This paper effectively conveys that PEB structures can be easily designed by simple design procedures in accordance with country standards. Low weight flexible frames of PEB offer higher resistance to earthquake loads. PEB roof structure is almost 26% lighter than Conventional Steel Building. In secondary members, light weight "Z" purlins are used for PEB structure, whereas heavier hot-rolled sections are used for CSB. Support reactions for PEB are lesser than CSB as per analysis. Light

weight foundation can be adopted for PEB which leads to simplicity in design and reduction in cost of construction of foundation. Heavy foundation will be required for CSB structure. PEB building cost is 30% lesser than the cost of CSB structure. PEB offers low cost, strength, durability, design flexibility, adaptability and recyclability. To conclude "Pre-Engineered Building construction gives end users a much more economical and better solution for long span structures where large column free areas are needed.

III. PROBLEM STATEMENT

Long span column free structures are most essential in any type of industrial structure and pre-engineered buildings (PEB) fulfill this requirement along with reduced time and cost as compared to conventional structures. In this project range of spans will be decided for which pre- engineered building can be provided economically. A comparative study of pre-engineered building and conventional steel building for spans 15m, 20m, 25m, is to be carried out. In addition to this a comparative study of PEB and CSB of 36m span for polymer factory at Dindori, Nashik will be conducted.

The comparative study will be based upon below criteria-

- Material takes off and cost
- Foundation size requirement

A. *Methodology*

In this project, for analysis and design of structure STAAD PRO V8i software will be used, in which 3D model of various spans for both PEB and CSB will be generated and analyzed by using STAAD PRO V8i(2007) For different load combinations. The data regarding bending moment, shear force, axial force, torsion etc. will be obtained from staad analysis so that the structure will be designed using tapered sections for PEB.

B. *STAAD Model for PEB and CSB:*

Following are the model of PEB and CSB generated using Staad pro v8i-

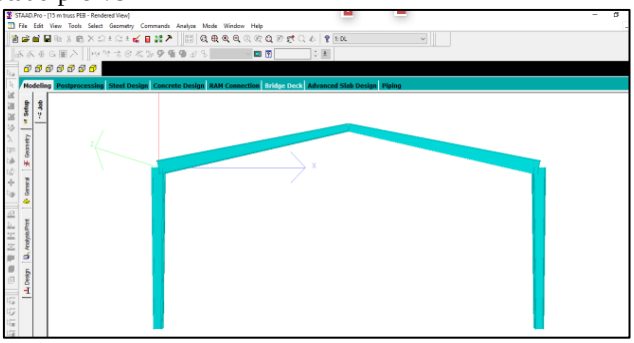

Fig. 3: Typical model of Pre- engineered building.

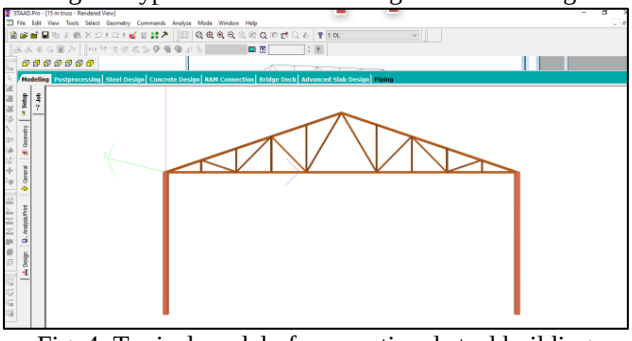

Fig. 4: Typical model of conventional steel building

IV. DESIGN DATA

A. *Structural Parameters*

Type of building- industrial building.
Location- Nashik.
Eave height- 5.5m.
Span width- Varying from 15, 20,25, and 36 m
Single bay length- 4m.
Support conditions- fixed.
CSB roof slope-21.8°

B. *Load Calculations*

1) *Dead load*

Dead load is calculated according to IS: 875 (Part I)-1987 [15]

Weight of the G.I sheeting = 0.131 kN/m2
Weight of fixings = 0.025 kN/m2
Weight of services = 0.1 kN/m2
Total weight = 0.256 kN/m2
Spacing of the purlin = 1.35 m
Total weight on purlins = 0.256 × 1.35 = 0.345 kN/m

2) *Live Load*

Live load on the sloping roof is = 750 – 20(α -10) N/m2
Where α = 21.8°, Therefore live load = 0.514 kN/m2
Live load on purlins = 0.514 × 1.35 = 0.9179 kN/m

3) *Wind Load*

Wind load is calculated as per IS: 875 (Part 3) – 1987
Basic Wind speed V_b = 50 m/sec
Risk Coefficient K_1 = 1
Terrain, Height and Structure size factor K_2 = 1
Topography factor K_3 = 1
Design Wind Speed $V_z = V_b K_1 K_2 K_3$ = 50 m/sec
Design Wind Pressure $P = 0.06\ V_z^2$ = 1.5 kN/m^2
The Internal Coefficients are taken as +0.5 and -0.5.
Wind Load on individual members are then calculated by

$$F = (Cpe – Cpi) \times A \times P$$

Where, Cpe – External Coefficient
Cpi – Internal Coefficient
A – Surface Area in m^2
P – Design Wind Pressure in kN/m^2

V. RESULT AND DISCUSSION

Span	Cost in Rs (As per prevailing market rates in Nasik)	
	CSB	PEB
15m	69278.00	93000.00
20m	98684.30	145050.00
25m	173121.30	160800.00
36m	431366.10	380625.00

Table 2: Result

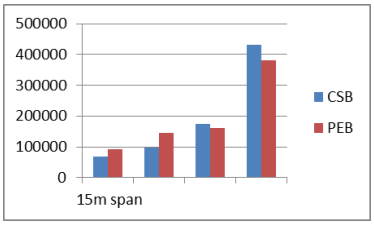

Fig. 5: Results

Cost of PEB is more for spans of 15m and 20m. Whereas for spans of 25m and 36m it is less as compare to conventional steel building.

VI. CONCLUSION

Pre-engineered building offers low cost, strength, durability, design flexibility, adaptability and recyclability. The STAAD analysis shows that the cost required for PEB for smaller span like 15m, 20m is 30-50% more than the conventional steel building hence PEB is uneconomical for smaller spans. For larger spans like 25, 36m it can be seen that PEB offers10 to 20% low cost as compare to CSB. It can be conclude that PEB are economical for larger spans. In light of the study, it can be concluded that PEB structures are more advantageous than CSB structures for larger spans in terms of cost effectiveness, quality control speed in construction and simplicity in erection.

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