Optimum Design of an Industrial Ware House

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Abstract: ***In recent years, the introduction of Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing the design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. Long Span, Column free structures are the most essential in any type of industrial structures. Pre Engineered Buildings (PEB) fulfill this requirement along with reduced time and cost as compared to conventional structures. In this study, an industrial structure (Ware House) is analyzed and designed by considering various types of sections using the structural analysis and design software STAAD-Pro. The sections used for comparison are hot rolled steel sections, tubular sections, pipe sections and PEB sections. The ware house is modeled with all these sections and the economy of the structure is discussed in terms of its weight, cost and degree of fabrication. A comparative study has also been carried out between cold formed sections as purlins with traditionally used hot rolled sections for industrial structures. Also the optimization in design of warehouse is done by adopting various light weight steel sections along with safety of structure.***

Keywords: *Ware House*, CSB, PEB, Optimization, STAAD-Pro.

1. Introduction

Warehouses are facilities that offer the adequate environment to store goods and materials that require protection from environmental factors and theft. When designing warehouses, many factors should be taken into account such as the capacity of storing the required materials, and lifting and delivery equipment as well as receiving, shipping and transferring operations and the related trucks and trailers, in addition to the needs of employees and workers, provided that lifting and delivery operations are carried out in the shortest time possible in order to achieve economic feasibility in the operation of warehouses.

A comparative study has been carried out for the optimum design of a warehouse by modeling it with different types of steel sections and economy of the structure is studied in terms of weight and cost.

2. Design of Various Types of Warehouses

2.1 Conventional Steel Building (CSB)

In conventional steel buildings mill-produced hot rolled sections (members of trusses, beams and columns) are used. The size of each member is selected on the basis of the maximum internal stress in the members.

In Conventional Steel Building, the roof truss components are designed by using hot rolled angle and channel sections for truss components and purlins respectively. Generally column sections are made up of I sections or built up sections based on the loading coming over the structure.

Structures are mostly site fabricated wherein it is difficult to monitor & control quality parameters. Cost is higher due to higher consumption of steel and other co-ordination issues involved.

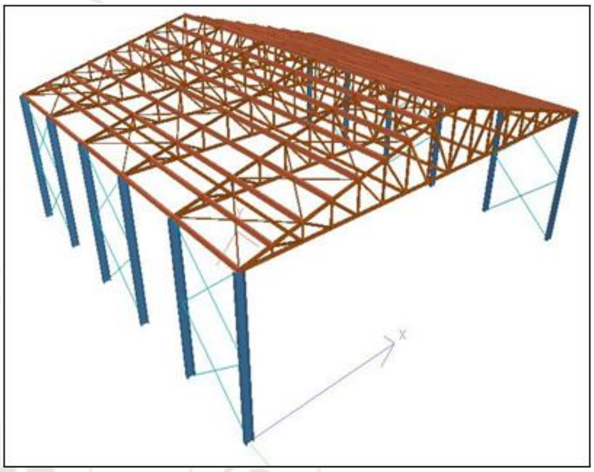

Figure 1: 3D View of Conventional Steel Building

2.2 Conventional Structure with Tube & Pipe Sections

An economy of an industrial building depends on the configuration of structure, type of roof truss and portal frame utilized, forces acting on building and selection of steel sections needed as per force employed. Steel sections are categorized namely as conventional steel section (channel, angle, rolled etc.), and Hollow steel section (square hollow section, rectangular hollow section, circular hollow section). The Present work includes designing Roof truss components for an industrial building using conventional tubular square steel sections and pipe sections (circular hollow section) and selecting most suitable section according to its advantages and disadvantages.

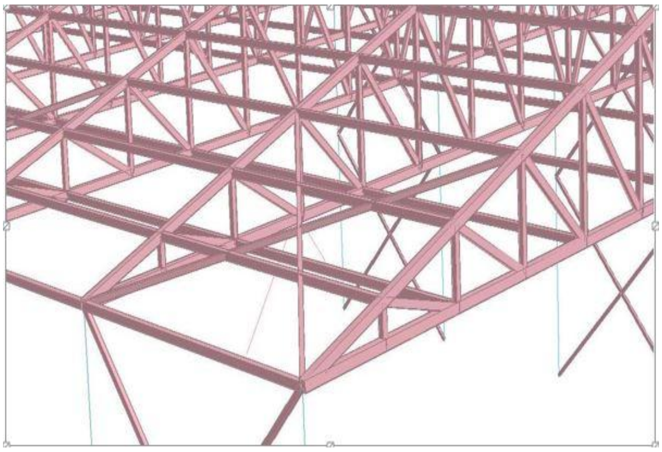

Figure 2: 3D View of Conventional Tubular Structure

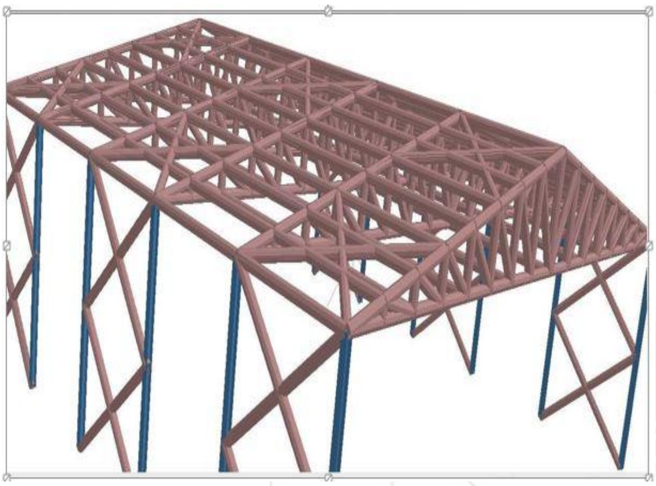

Figure 3: 3D View of Conventional Pipe structure

2.3 Pre-Engineered Building (PEB)

The Pre-Engineered steel building system construction has great advantages to the single story buildings, practical and efficient alternative to conventional buildings. The System representing one central model within multiple disciplines. Pre-Engineered Building concept involves the steel building prefabricated systems which are predesigned. 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.

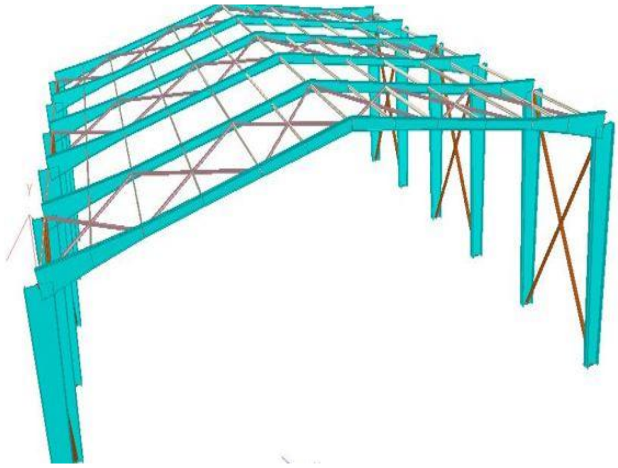

Figure 4: 3D View of Pre-engineering structure

3. Loads and Load Combinations

Following loads and loads combination are considered for analysis.

3.1 Dead loads

Dead load on the roof trusses in single storey industrial buildings consists of dead load of claddings and dead load of purlins, self-weight of the trusses in addition to the weight of bracings etc. Further, additional special dead loads such as truss supported hoist dead loads; special ducting and ventilator weight etc. could contribute to roof truss dead loads.

3.2 Live Load

The live load on roof trusses consist of the gravitational load due to erection and servicing as well as dust load etc. and the intensity is taken as per IS:875-1975. Additional special live loads such as snow loads in very cold climates, crane live loads in trusses supporting monorails may have to be considered.

3.3 Wind load

The wind load on the roof trusses, unless the roof slope is too high, would be usually uplift force perpendicular to the roof, due to suction effect of the wind blowing over the roof. Hence the wind load on roof truss usually acts opposite to the gravity load, and its magnitude can be larger than gravity loads, causing reversal of forces in truss members.

3.4. Load Combinations

Load combinations can be adopted according to IS: 800 – 2007. Twenty two different load combinations adopted for the analysis of the frame and few combinations are listed as follows:
LOAD COMBINATION 1 - 1.5 (DL + LL)
LOAD COMBINATION 2 - 1.2 (DL + LL + WIND 0 & -VE)
LOAD COMBINATION 3 - 1.2 (DL + LL + WIND 0 & +VE)
LOAD COMBINATION 4 - 1.2 (DL + LL + WIND 90 & +VE

4. Design of Conventional Steel Warehouse

4.1 Data for Analysis and Design

The data used for the conventional type steel of ware house is as follows. The sections used for truss members are of angle sections.

- Type of truss = Howe truss
- span of truss = 25m
- Rise of truss = 3m
- Spacing between two columns = 4m, 5m & 6m
- Height of column = 8m
- Location of building = Solapur
- Type of roofing = G.I. sheets
- Number of frames = 6
- Wind Permeability = low
- Panel Length = 1.55m

4.2 Load Calculations

4.2.1 Dead Load

Dead loads on the roof truss are estimated as per the Indian standard code IS:875-Part-I. The dead weight of sheeting, fastenings, bracings and self weight of purlins are calculated as per geometry of the truss and applied as panel loads on the truss.
Load on each panel point = 2.35 kN
Load on each end panel point = 1.18 kN

4.2.2 Live Load

Live loads on the roof truss are estimated as per the Indian standard code IS:875-Part-II. Based on the slope of roof truss and access provision condition for maintenance, the live load intensity is calculated as per the code. The loads on the panel points of the truss are estimated and applied.
Live load on each intermediate panel point = 5.44 kN
Live load on end panel point = 2.72 kN

4.2.3 Wind Load-

Wind loads on the roof truss are calculated as per the Indian standard code IS:875-Part-III.. Considering the location of ware house, slope, height and topography of the site, wind loads are calculated as per the code IS:875-Part-III. The panel loads at intermediate and end positions are evaluated and applied normal to the sheeting.

Wind load on each intermediate panel point = -10.6 kN (Uplift)

Wind load on end panel point = -5.3 kN (Uplift)

Similarly the loading on all conventional structures with angle sections, tubular sections, pipe sections and Pre-Engineered structures are estimated in similar way and applied at panel points except PEB structures. In PEB, loads are applied on the members as uniformly distributed loads. Fig. 5 and 6 show the loading on Conventional and PEB structures.

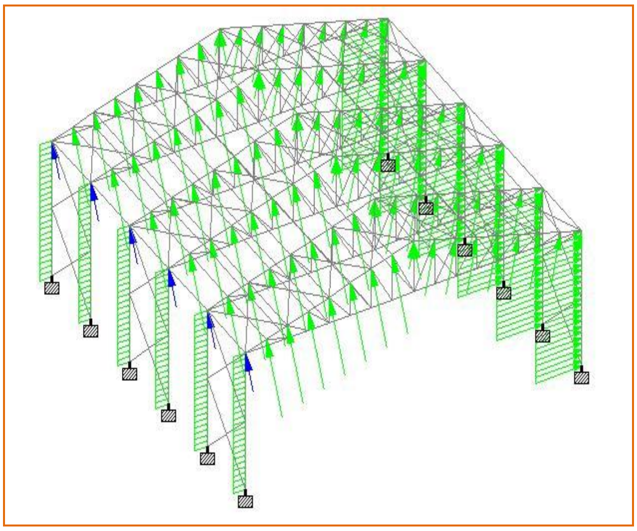

Figure 5: Loading on Conventional Trusses

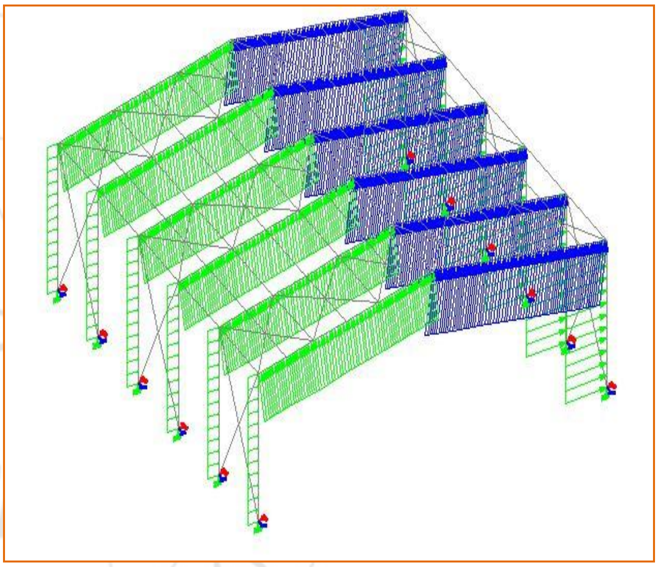

Figure 6: Loading on Pre-Engineered Building

5. Results

All four models of warehouse are analysed and designed in STAAD-Pro software. For all the models, the variation of column spacing of 4m, 5m and 6m is considered in the analysis and optimization of structure has been carried out. Following tables show results of design parameters for all four type of warehouse structure.

Purlins are designed using cold formed steel sections for optimising the weight in some models. The Indian standard code for cold formed sections IS: 801 is used for design of such sections which gave effective results in steel take off of the structure.

Table 1: Results of Warehouses of 4m spacing of Column

Para-meters	PEB Structure	CSB with Pipe sections	CSB with Tube sections	CSB with L sections
Steel Take Off (kN)	211.098	193.819	151.780	253.866
Support Reaction (kN)	106.190	99.512	97.882	110.401
Max. SF (kN)	86.412	36.653	36.943	34.846
Max. Moment (kNm)	366.368	79.971	81.615	65.457

Table 2: Results of Warehouses of 5m spacing of Column

Para-meters	PEB Structure	CSB with Pipe sections	CSB with Tube sections	CSB with L sections
Steel Take Off (kN)	213.708	223.795	240.130	300.302
Support Reaction (kN)	128.449	140.832	151.332	146.213
Max. SF (kN)	101.253	46.952	46.407	46.089
Max. Moment (kNm)	458.849	163.058	158.310	101.426

Table 3: Results of Warehouses of 6m spacing of Column

Para-meters	PEB Structure	CSB with Pipe sections	CSB with Tube sections	CSB with L sections
Steel Take Off (kN)	232.763	277.333	317.499	407.630
Support Reaction (kN)	149.656	147.010	150.998	167.282
Max. SF (kN)	122.118	58.872	58.923	58.272
Max. Moment (kNm)	536.269	163.502	163.703	158.772

Following tables show the total steel weight of the warehouse modeled with different sections and weight of purlins.

Table 4: Total Steel Takeoff

Spacing	PEB (kN)	CSB (TUBE) (kN)	CSB (PIPE)(kN)	CSB (L) (kN)
4M	211.098	151.78	166.862	253.863
5M	213.708	240.13	223.795	300.302
6M	232.763	269.475	236.898	407.63

Table 4: Purlins Steel Takeoff

Spacing	PEB (kN)	CSB (TUBE) (kN)	CSB (PIPE)(kN)	CSB (L) (kN)
4M	6.28	14.017	26.957	73.005
5M	11.189	35.325	29.732	103.424
6M	15.84	48.042	40.435	124.109

All these results are represented in graphical format for comparision purpose as shown in following graphs.

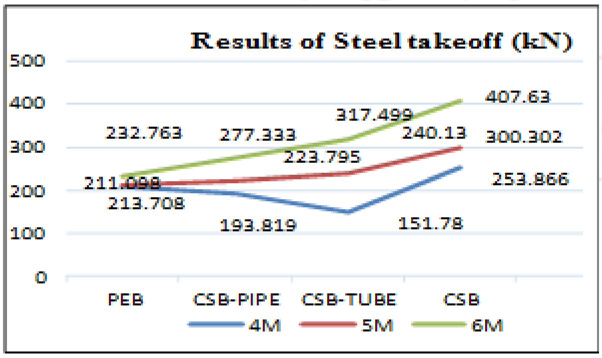

Figure 7: Results of Steel Takeoff

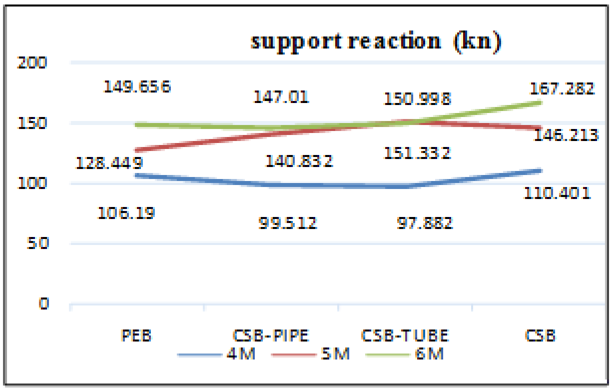

Figure 8: Results of support reaction

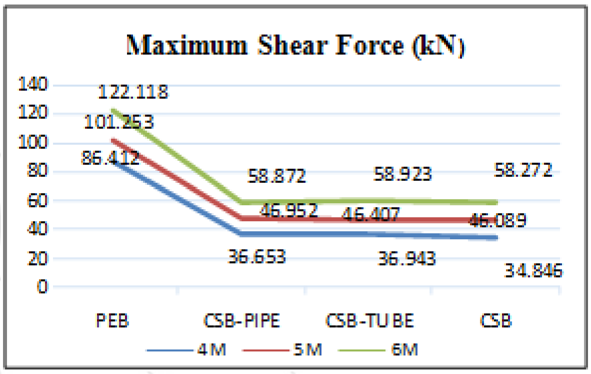

Figure 9: Result of Maximum Shear Force

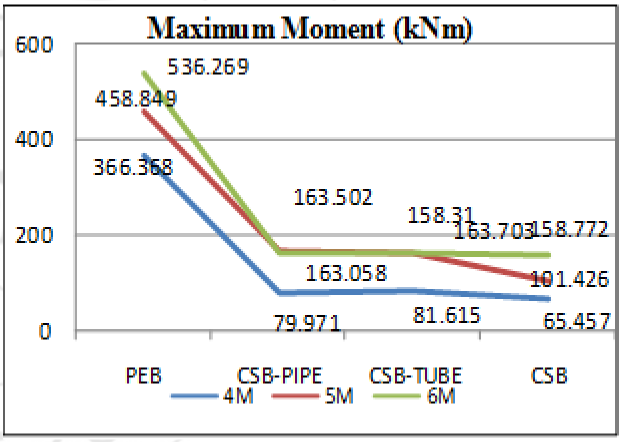

Figure 10: Result of Maximum Moment

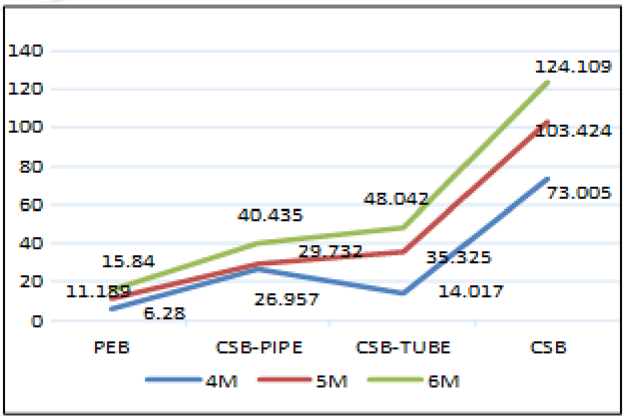

Figure 11: Result of Purlin Takeoff

6. Conclusions

According to the results obtained from the analysis of these Structures in which optimum steel sections were assigned to the various warehouse models for every member following conclusion can be made.

- The support reactions are more for conventional building as compared to other structures for various spacing of trusses. PEB gives lesser support reactions.
- Bending moment and shear force in column are maximum for PEB structure.
- The purlin sections used in conventional building are very heavy as compared to Tubes, Pipes and Z sections used in other structures.
- Z sections used in PEB structure are light weight and economical.
- The steel weight of CSB with tubular and pipe sections is less as compared to CSB with L or angle shaped structures. But PEB seems to be most economical.
- The total steel take-off for PEB with primary frame spacing of 5m is 28.84% less of the conventional steel building.
- Steel take-off is more for PEB with primary frame spacing of 4 m than PEB with primary frame spacing of 4 m. Hence PEB structures are economical for larger span and larger spacing of trusses.

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