Comparative Study of Analysis and Design of Pre-Engineered- Buildings and Conventional Frames

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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 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).

Keywords: **Conventional Steel Building, Pre-Engineered Building, STAAD Pro, Tapered I section.**

I. INTRODUCTION

Steel is a material which has high strength per unit mass. Hence it is used in construction of structures with large column-free space. The enclosures of these structures may be brick masonry, concrete walls or GI sheet coverings. 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. A combination of standard hot-rolled sections, cold-formed sections, profiled sheets, steel rods, etc. are used for the construction of industrial steel structures. Industrial buildings can be categorized as Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB), according to the design concepts. Steel industry is growing rapidly in almost all the parts of the world. The use of steel structures is not only economical but also eco friendly at the time when there is a threat of global warming. Here, "economical" word is stated considering time and cost. Time being the most important aspect, steel structures (Pre fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB). Pre Engineered Buildings are nothing but steel buildings in which excess steel is avoided by tapering the sections as per the bending moment's requirement. One may think about its possibility, but it's a fact many people are not aware about Pre Engineered Buildings. If we go for regular steel structures, time frame will be more, and also cost will be more, and both together i.e. time and cost, makes it uneconomical. Thus in pre engineered buildings, the total design is done in the factory, and as per the design, members are pre fabricated and then transported to the site where they are erected in a time less than 6 to 8 weeks.

The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behaviour 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/or expanded as per the requirements in future. In this paper we will discuss the various advantages of pre engineered buildings and also, with the help of three examples, a comparison will be made between pre engineered buildings and conventional steel structures.

A. Pre Engineered Buildings

Presently, large column free area is the utmost requirement for any type of industry and with the advent of computer software it is now easily possible. With the improvement in technology, computer software have contributed immensely to the enhancement of quality of life through new researches. Pre-engineered building (PEB) is one of such revolution. "Pre-engineered buildings" are fully fabricated in the factory after designing, then transported to the site in completely knocked down (CKD) condition and all components are assembled and erected with nut-bolts, thereby reducing the time of completion.

1. Advantages of PEB

Following are some of the advantages Pre-engineered building structures)

a) Construction Time*:* Buildings are generally constructed in just 6 to 8 weeks after approval of Drawings. PEB will thus reduce total construction time of the project by at least 40%. This allows faster occupancy and earlier realization of revenue. This is one of the main advantages of using Pre-engineered building.

b) Lower Cost: Because of systems approach, considerable saving is achieved in design, manufacturing and erection cost.

c) Flexibility of Expansion: As discussed earlier, these can be easily expanded in length by adding additional bays. Also expansion in width and height is possible by pre designing for future expansion.

d) Large Clear Spans: Buildings can be supplied to around 90m clear spans. This is one of the most important advantages of PEB giving column free space.

e) Quality Control: Buildings are manufactured completely in the factory under controlled conditions, and hence the quality can be assured.

f) Low Maintenance: PEB Buildings have high quality paint systems for cladding and steel to suit ambient conditions at the site, which in turn gives long durability and low maintenance coats.

g) Energy Efficient Roofing: Buildings are supplied with polyurethane insulated panels or fiberglass blankets insulation to achieve required "U" values (overall heat transfer coefficient).

h) Erection: Steel members are brought to site in CKD conditions, thereby avoiding cutting and welding at site. As PEB sections are lighter in weight, the small members can be very easily assembled, bolted and raised with the help of cranes. This allows very fast construction and reduces wastage and labour requirement.

From the numerous advantages of Pre-engineered building, in the present study, the points b and d are considered for the study, i.e. to save the steel, reducing cost and providing large clear spans, while all the other points are self explanatory.

II. STAAD PRO PROCEDURE

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

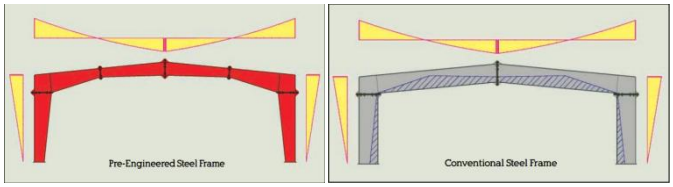

Fig: BENDING MOMENT DIAGRAM

III. LOADS

The loads acting on the structure includes dead load, live load, snow load, wind load, earthquake load, crane load, erection load, accidental load, etc. The load calculation for the structure can be carried out in accordance with IS : 875 – 1987 and IS : 1893 - 2000. For this structure wind load is critical than earthquake load. Hence, load combinations of dead load, live load, crane load and wind load are incorporated for design.

A. Dead Load

Dead load comprises of self-weight of the structure, weights of roofing, G.I. sheets, gantry girder, crane girder,

purlins, sag rods, bracings and other accessories. The dead load distributed over the roof is found to be 0.438 kN/m excluding the self weight. This load is applied as uniformly distributed load over the rafter while designing the structure by PEB concept. For CSB concept the load is applied as equivalent point load of 0.657 KN at intermediate panel points and half the value at end panel points over the roof truss.

B. Live Load

According to IS : 875 (Part 2) – 1987, for roof with no access provided, the live load can be taken as 0.75 kN/m2 with a reduction of 0.02 kN/m2 for every one degree above 10 degrees of roof slope. Total uniformly live load acting on the rafter of the PEB structure is found to be 4.5 kN/m. Similar to dead load, live load is also applied as point loads at panel points for CSB structure and is found to be 6.75 KN at intermediate panel points and half this value at end points.

C. Wind Load

Wind load is calculated as per IS: 875 (Part 3) – 1987. The basic wind speed for the location of the building is found to be 39 m/s from the code. The wind load over the roof can be provided as uniformly distributed load acting outward over the PEB rafter and as point loads acting outward over the CSB panel points. For side walls, the wind load is applied as uniformly distributed loads acting inward or outward to the walls according to the wind case. The wind loads over the roof and side walls comes in four different combinations.

IV. DESIGN

PEB design is rapid and efficient compared CSB design. Basic design steps are followed and optimization of materials while software analysis is possible for PEB, increasing the quality of design. CSB design is done with fewer design aids and each project needs to develop the designs which require more time. Connection design is also lesser for PEB when measured up to CSB.

A. Foundation

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 simplicity in design and reduction is cost of construction of foundation. Heavy foundation will be required for CSB structure.

B. Delivery of Materials

For PEB, delivery is done in around 6 to 8 weeks and for CSB it is 20 to 26 weeks.

C. Erection

Erection procedure is standard for all the projects and it is done free of cost by the manufacturer which results in faster and cost effective erection for PEB. Erection of CSB differs from project to project and separate labour has to be allocated, leading to 20 percent more expense than PEB.

D. Earthquake Resistance

Low weight flexible frames of PEB offer higher resistance to earthquake loads than rigid heavy frames of CSB.

E. Cost

PEB costs 30% lesser than cost for CSB. Outstanding architecture can be achieved at low cost for PEB. Single sourcing and co-ordination of PEB is highly cost effective than multiple sourcing system of CSB. Building accessories are mass produced for PEB which also leads to economy.

F. Change of Order

Due to standardized design, PEB manufacturers are able to stock large amount of elements and accessories which can be flexibly used in many types of PEB construction. Hence change of order can be fulfilled easily at any stage of construction. Cost for change of order is also lesser in this case. In case of CSB, change of order is expensive and time consuming as substitute sections are infrequently rolled by mills.

G. Future Expansion

Single sourcing of PEB is advantageous for future expansion whereas multiple sourcing of CSB poses difficulty. Future expansion is easy and simple for PEB whereas it is most tedious and costly for CSB.

H. Performance

All components of the PEB system are specially designed to act together as a system for highest efficiency.

PEB designs are revised regularly with respect to the actual field conditions and in accordance with various country codes, which resulted in improved standardized designs leading to high performance of the structure, CSB system components are conventionally designed for a specific project and the performance depends on how the individual project is designed.

V. APPLICATIONS

Pre-Engineered Building concept have wide applications including warehouses, factories, offices, workshops, gas stations, showrooms, vehicle parking sheds, aircraft hangars, metro stations, schools, recreational buildings, indoor stadium roofs, outdoor stadium canopies, railway platform shelters, bridges, auditoriums, etc. PEB structures can also be designed as re-locatable structures.

VI. CONCLUSION

This paper effectively conveys that PEB structures can be easily designed by simple design procedures in accordance with country standards. In light of the study, it can be concluded that PEB structures are more advantageous than CSB structures in terms of cost effectiveness, quality control speed in construction and simplicity in erection. The paper also imparts simple and economical ideas on preliminary design concepts of PEBs. The concept depicted is helpful in understanding the design procedure of PEB concept.

Comparison 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 buildings are the best solution for longer span structures without any interior column in between.

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

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