A Study of Performance of Pre-Engineered Building of An Industrial Shed For An Accidential Load

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Abstract- *The steel sector is rapidly expanding globally. Steel constructions are not only cost effective but also eco-friendly in an era of global warming. "Economic" implies taking into account time and cost. Pre-engineered buildings are steel structures that prevent using excess steel by tapering the sections to the required bending moment. Pre-engineered structures may therefore be relocated or enlarged in the future. This study will explain the benefits of pre-engineered buildings and compare them to traditional steel constructions using three examples. As shown in this study, the steel weight may be lowered by 27% for the PEB, reducing dead load and increasing resistance to accidental loads. In the second example, even though PEB structures have a clear span, they weigh 10% less than conventional buildings. Increasing the number of CST and PEB bays reduces axial deformation by 10-15% and longitudinal displacements by 10%. Conventional buildings are not appropriate for longer span constructions. Pre-engineered buildings are the greatest choice for longer span constructions without inner columns, as seen in this example, a 72 m industrial structure. In smaller span constructions, PEB structures are more expensive than conventional structures. The weight of PEB also relies on the Bay Spacing; increasing the Bay Spacing decreases the weight up to a point, but increasing it makes it heavier.*

Keywords- Industrial shed, wind load, PEB, CST,accidential load.

I. INTRODUCTION

1.1 GENERAL

Steel industry is growing speedily in almost all the parts of the world. The use of steel structures is not only economical but also ecofriendly at the time when there is a danger of global warming. Here, "economical "word is means 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 extra 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 known about Pre Engineered Buildings. If we go for regular steel structures, time span 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 known 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 demolished. Pre Engineered Buildings have bolted connections and hence can also be reused after demolishing. Thus, pre-engineered buildings can be shifted 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.

1.2 CONCEPT OF PEB

"Pre-engineered steel buildings" are those which are fully fabricated in the factory after designing, shipped to site in CKD (completely knocked down) condition; and all components are assembled and erected at site with nut-bolts, thereby reducing the time of completion. Pre–engineered means, generally speaking, is any part of a structure that is manufactured firstly to its arrival on the building site. The concept of the pre-engineered building (PEB) is one where the fabrication is completed in a controlled environment with the recent technology, and then after erection is carried out. Though initially only off the shelf products were available in these configurations dependent by the technological development tailor made solutions are also made using this technology in very small durations. The designs were ready-made but the building components were either ready-made or manufactured against specific orders. These buildings were pre-designed or 'pre-engineered' into standard sizes, spans, bays and heights, and use standard details for fixing cladding, roofing, gutters, flashing, windows, doors taking advantage of industrial practices of mass production of components economically. Although PEB systems are extensively used in industrial and many other non-residential constructions worldwide, it is relatively a new concept in India. These concepts were introduced to the India in the late 1990's with the opening up of the economy; and a number of multi–nationals setting up their projects. The current pre– engineered steel building manufacturing capacity is 6.0 lac ton per annum. The industry is growing at the compound rate of 25 to 30%. With respect to design of the structure and aesthetic appearance India is way behind. Indian manufacturers are trying to catch up; comparatively PEB is a new concept in India. A healthy trend in the form of growth in demand for construction works in residential, Commercial, Institutional industrial and infrastructure sectors are being seen over the past decade. Modern Structures are much more complex and stagy as compared to earlier period. One of the major changes which are being felt by all is that the present structures are taller and thinner. Latest day requirement of structures is that these should be lighter yet not compromising on functionality. Civil engineering construction has seen a continuous economic competition between steel, concrete and other construction materials. Currently, the total steel production in the country is about 45MN Ton against 1280MN ton of world. Per capita steel consumption in India is 42kg whereas it is 270kg in China. About 10% of steel goes to the construction industry and amidst it PEB accounts only for the 0.5MN ton. as on date. In the next 5 years, the steel production will be doubled and with efforts of organisations like BIS and INSDAG, steel intensive construction may rise up to 22MN ton. Owing to advantages of PEB, separate nonconventional segments are also getting attracted to use PEB and the potential will rise up to 2.2MN ton which is four to five times of today's scenario. Subsequent paragraphs are only a humble attempt to present the various aspects of immaterial development, technology of design and manufacture; and future growth aspects of Pre–engineered building Industry in India along with its grey areas.

1.3 OBJECTIVE

AIM

To study performance of pre-engineered building of an industrial shed for an accidental load in accordance with IS 1893 part 4(2005), IS 875 part 5 (1987).

OBJECTIVE

1. To compare Pre-engineered building for industrial shed with conventional building for accidental load in accordance with IS 1893 part 4, IS 875: part 5
2. To validate model by comparing results of axial force, bending moment, shear force and support reaction in STAAD-Pro.
3. To check performance of Pre-Engineered Building for various tapered sections and bracing systems for load combinations
4. To study performance analysis of PEB for multi span (2 bays, 3 bays etc.) For various heights.

II. LITERATURE REVIEW

Aijaz Ahmad Zende (Jan-Feb 2013). Comparative Study of Analysis and Design of Pre-Engineered- Buildings and Conventional Frames. 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. Large and clear spans allow housing almost any type or business comfortably and efficiently, as well as to expand in future and change their setup whenever they desire. Structures with long span need to be carefully designed keeping a balance of all the aspects like its weight, deflections and also foundation forces. There are many combinations of designing large spans, like conventional truss & RCC column combination, truss & steel columns, Pre-engineered building (PEB) etc.

C. M. Meera (June-2013). Pre-engineered Building Design of an Industrial Warehouse. Pre-Engineered Building (PEB) concept is a new conception of single storey industrial building construction. This methodology is versatile not only due to its quality predesigning and prefabrication, but also due to its light weight and economical construction. The paper starts with the discussion of methods adopted in the study. Introduction to PEB systems and CSB systems are then described followed by the details of case study. Loads and the load combinations adopted for carrying out the analysis of the structure is well defined in the further portions. A section depicting the importance of the software used and the software procedure followed is included. Final portion explains the results obtained from the software analysis of the case study and the inferences from the literature studies. The paper aims at developing a perception of the design concepts of PEB structures and its advantages over CSB structures. The PEB structures are more advantageous than CSB structures in terms of cost effectiveness, quality control speed in construction and simplicity in erection.

Jatin D. Thakar (Sept-2013) Comparative Study of Pre-engineered Steel Structure by Varying Width of Structure. Pre-engineered building are steel building wherein the framing members and other components are fully fabricated in the factory after designing and brought to the site for assembly, mainly by nut-bolts, thereby resulting into a steel structure of high quality and precision. In conventional steel construction, we have site welding involved, which is not the case in P.E.B using nut-bolt mechanism. International codes are referred in their design as per the MBMA (Metal Building Manufacturers Association) standards which are more flexible allowing the use of built - up sections of minimum 3.5 mm thickness against 6 mm as minimum criteria in conventional steel sections. There is use of steel of high strength (345MPa) which prominently speaks about greater strength with judicious use of steel as a result of tapered profile. The tapered section concept was first adopted in U.S.A keeping in mind the bending moment diagram. At locations of high bending moment values, greater depth is used while less moment encouraged the use of lesser depths.

G. Sai Kiran (2014). Comparison of Design Procedures for Pre Engineering Buildings (PEB). In recent years, the introduction of Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. In this study, an industrial structure (Ware House) is analysed and designed according to the Indian standards, IS 800-1984, IS 800-2007 and also by referring MBMA-96 and AISC-89. Steel is the material of choice for design because it is inherently ductile and flexible. In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer, to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. PEB can be fitted with different structural accessories including mezzanine floors, canopies, fasciae, interior partitions, etc.

III. METHODOLOGY

3.1 INTRODUCTION

In analysis of PEB structures, CST and PEB structures for 3 bays and 9 bays are compared for static loadings as IS code.

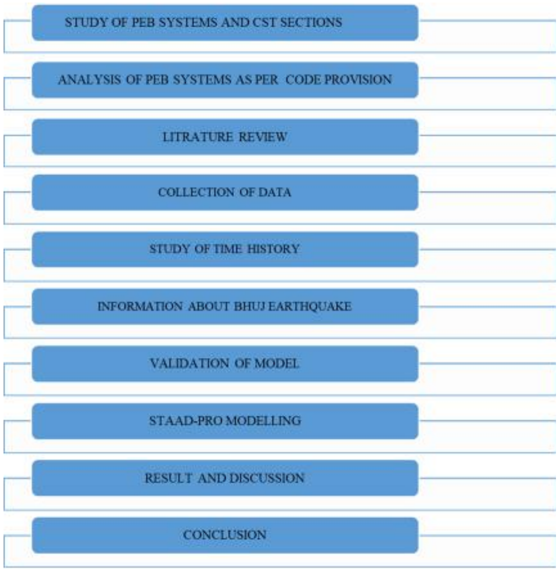


Fig 1FLOW CHART

3.1.1 Loads acting on industrial sheds for CST and PEB

1. Dead and Collateral Loads

Dead load is the weight of all permanent construction materials, such as roofing, framing, and other structural elements. Being well defined and known in advance, dead load is assigned a relatively low factor of safety in the ultimate (load factor) design. Collateral or superimposed dead load is a specific type of dead load that includes the weight of any materials other than the permanent construction. It may account for the weight of mechanical ducts, pipes, sprinklers, electrical work, future ceilings, and re-roofing.

The IS: 875 (Part 1) – 1987 Code of Practice for design loads (other than earthquake) for buildings and structures suggest the following typical values:

1. Ceilings: 0.25 to 0.74 kN /m2
2. Metal Sheeting: 0.052 to 0.131 kN /m2
3. Service pipes: 0.014 to 0.105 kN /m2
4. Thermal insulations: 1.45 to 2.95 kN /m3.

2 Live Load

Live load refers to the weight of building occupants, furniture, storage items, portable equipment, and partitions Owing to the fact that live load is relatively short-term, not easily predictable or quantifiable, it carries large factors of safety (uncertainty, really) in the ultimate design methods. Other sources of live load arise during construction, repair, or maintenance of the building, and these are even more difficult to predict and quantify. To deal with this uncertainty, building codes have enacted conservative values for live loads the framing must be designed to resist the loads which might occur only once or twice in the lifetime of the structure, if at all. For example, office buildings are normally designed for the live load of 2.5 to 4 kN/m2 as per IS : 875 (Part 2) – 1987 Code of Practice for design loads (other than earthquake) for buildings and structures, while the actual weight of all the people and furniture in a typical office probably does not exceed this load. It is quite probable that the design live load will occur in a relatively small area of the building at some time or another; it is much less probable that the whole floor will ever see that load.

3 Wind Load

To design wind-resisting structures, the engineers need to know how to quantify the wind loading and distribute it among various building elements. IS : 875 (Part 3) – 1987 Code of Practice for design loads (other than earthquake) for buildings and structures gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds have been worked out for a 50 year return period. By using the code – provided formulas it is possible to translate the basic wind speed into a corresponding Design wind speed in m/s by applying probability, terrain and topography factor. From the design wind speed design wind pressure on the building as a whole can be determined**.**

4 Earthquake Load

The first classic theory holds that the majority of earthquakes originate when two segments of the earth crust collide or move relative to each other. The movement generates seismic waves in the surrounding soil that are perceived by humans as ground shaking; the waves diminish with the distance from the earthquake epicenter. The wave analogy explains why earthquakes are cyclical and repetitive in nature. The second seismic axiom states that, unlike wind, earthquake forces are not externally applied. Instead, these forces are caused by inertia of the structure that tries to resist ground motions. As the earth starts to literally shift away from the building, it carries the building base with it, but inertia keeps the rest of the building in place for a short while. From Newton’s first law, the movement between two parts of the building creates a force equal to the ground acceleration times the mass of the structure. The heavier the building, the larger the seismic force that acts on it.

Factors affecting the magnitude of earthquake forces on the building include the type of soil, since certain soils tend to amplify seismic waves or even turn to a liquid like consistency (the liquefaction phenomenon). The degree of the building’s rigidity is also important. In general terms, the design seismic force is inversely related to the fundamental period of vibration; the force is also affected by the type of the building’s lateral load-resisting system. Most building codes agree that the structures designed in accordance with their seismic code provisions should resist minor earthquakes without damage, moderate earthquakes without structural damage, but with some non-structural damage, and major ones without collapse. Since the magnitude of the actual earthquake forces is highly unpredictable, the goal of collapse avoidance requires the structure to deform but not to break under repeated major overload. The structure should be able to stretch well past its elastic region in order to dissipate the earthquake-generated energy.

5 Industrial structures design criteria (IS 1893: part IV, 2005)

To perform well in an earthquake, the industrial structure should possess adequate strength, stiffness, and ductility. Generally structures have large capacities of energy absorption in its inelastic region. Structures which are detailed as per IS 13920 or SP 6 (6) and equipment which are made of ductile materials art withstand earthquakes many fold higher than the design spectra without collapse; and damage in such cases is restricted to cracking only.

Structures are classified into the following four categories:

a) Category 1: Structures whose failure can cause conditions that -can lead directly or indirectly to extensive 10ssof life/property to population at large in the areas adjacent to the plant complex.
b) Category 2: Structures whose failure can cause conditions that can lead directly or indirectly to serious fire hazard/extensive damage within the plant complex
c) Category 3: Structures, which are required to handle emergencies immediately after an earthquake, are also included.
d) Category 4: Structures whose failure, although expensive, does not lead to serious hazard within the plant complex.

IV. MODELLING

4.1 GENERAL

The present study deals with comparative analysis of PEB industrial sheds with conventional design. In first stage an industrial shed is validated by comparing support reaction and axial force of each member.

For comparative purpose following models are proposed:

Model No.1	CST industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.2	CST industrial sheds with 9 bays (each bay of 8m and span 12m)
Model No.3	PEB industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.4	PEB industrial sheds with 9 bays (each bay of 8m and span 12m)
Model No.5	PEB industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.6	PEB industrial sheds with 3 bays (each bay of 8m and span 12m) with cross

4.1.1 Analysis, design and validation of an industrial truss

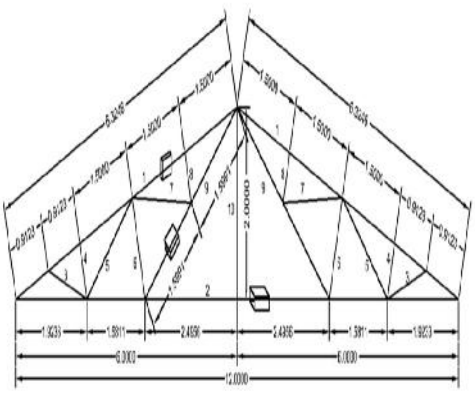


Fig 2 Elevation of the Truss

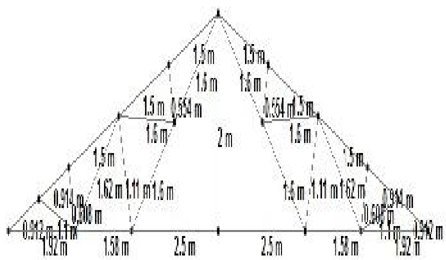


Fig 3 Dimension in STAAD-Pro

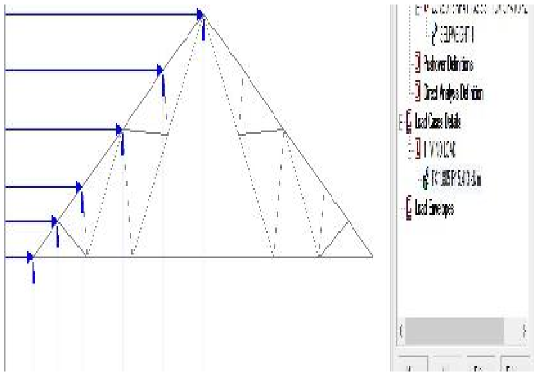


Fig 4 Wind word Side

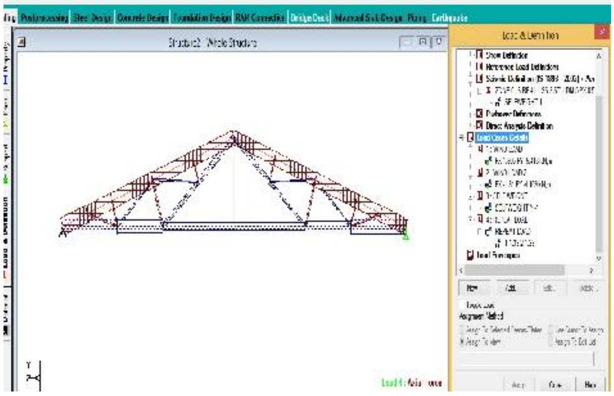


Fig 5 Axial Force

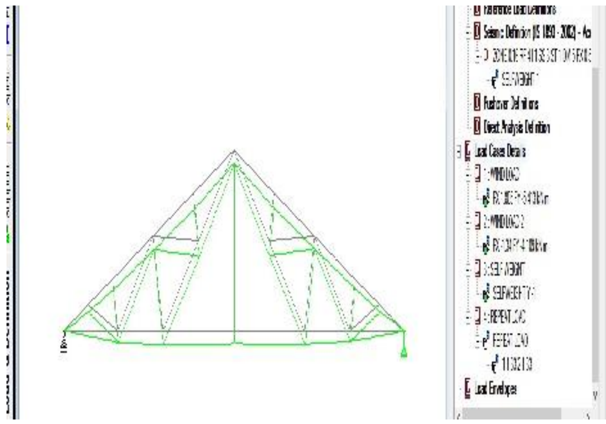


Fig 6 Deflection

Staad Pro Generated Frames

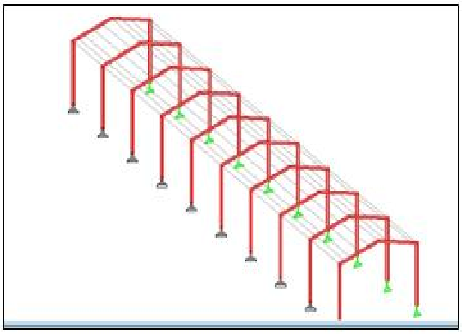


Fig: 7 Staad Pro Generated PEB with 9 bays.

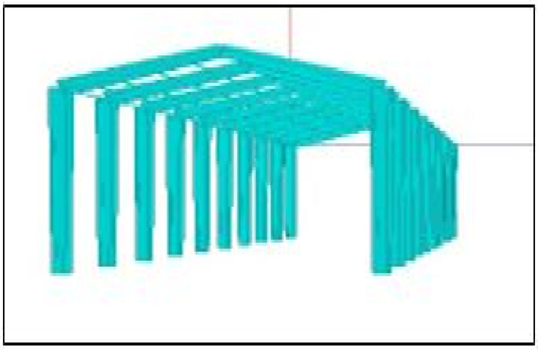


Fig: 8 Staad Pro Generated Pre-Engineered Building(Rendered)

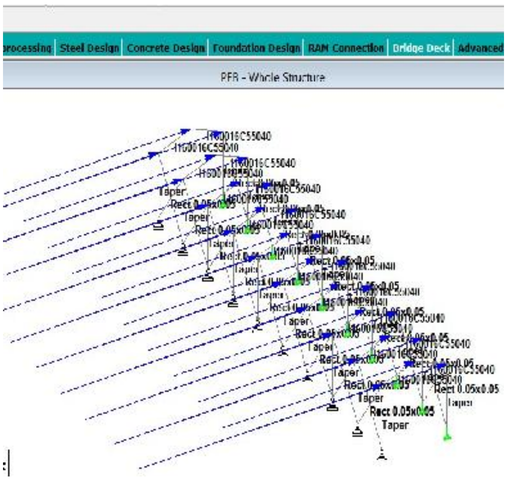


Fig: 9 Staad Pro Generated Conventional Steel Building.

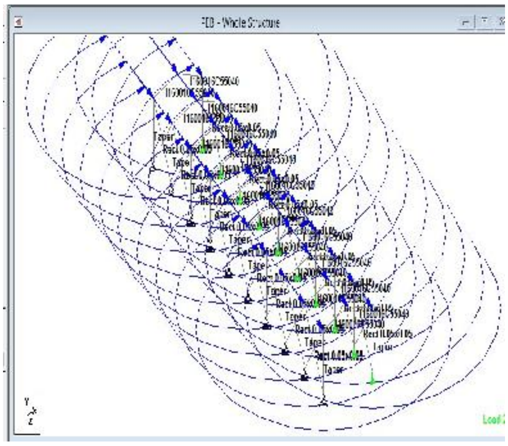
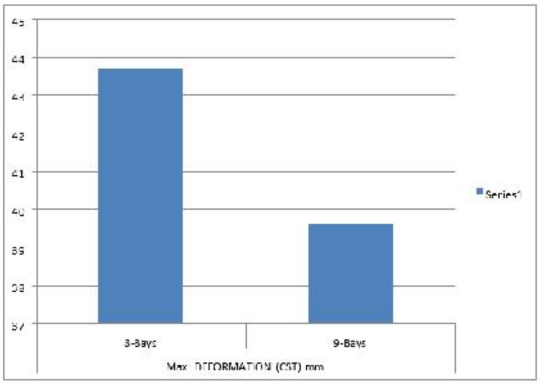


Fig. 10 PEB frames with accidental load

V. RESULT AND DISCUSSION

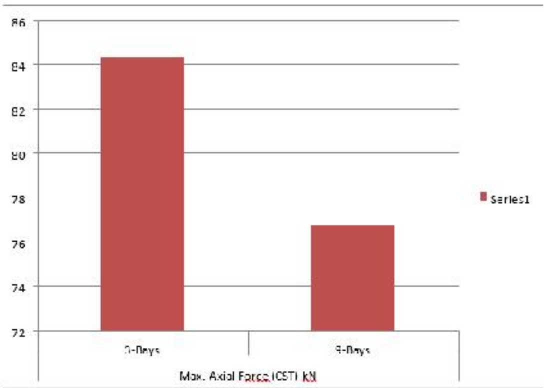
Max. DEFORMATION (CST) mm	
3-Bays	**9-Bays**
43.7	39.6



Graph No.1 Maximum deformation of CST of 3-Bays and 9-Bays

Above graph shows maximum deformation of conventional steel building of 3 bays and 9 bays. 3 bays structure has the maximum deformation.

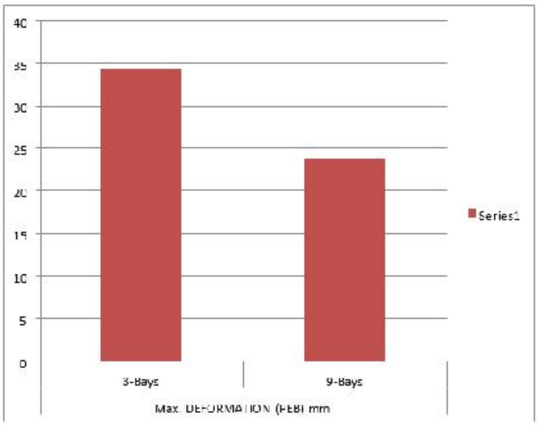
Max. Axial Force (CST) kN	
3-Bays	**9-Bays**
84.3	76.7



Graph No.2 Maximum Axial Force of CST of 3-Bays and 9-Bays

Above graph shows Maximum Axial Force of conventional steel building of 3 bays and 9 bays. 3 bays structure has the Maximum Axial Force.

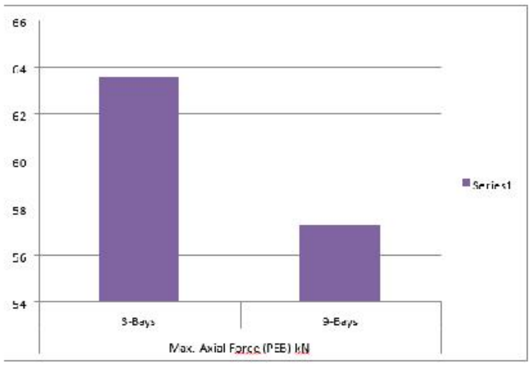
Max. DEFORMATION (PEB) mm	
3-Bays	**9-Bays**
34.3	23.7



Graph No.3 Maximum deformation of PEB 3-Bays and 9-Bays

Above graph shows maximum deformation of PEB structure of 3 bays and 9 bays. 3 bays structure has the maximum deformation.

Max. Axial Force (PEB) kN	
3-Bays	**9-Bays**
63.58	57.23



Graph No.4 Maximum Axial force of PEB 3-Bays and 9-Bays

Above graph shows Maximum Axial force of PEB structure of 3 bays and 9 bays. 3 bays structure has the Maximum Axial force.

VI. CONCLUSION

- In the first stage of study industrial shed model of Staad-Pro is validated for axial forces and support reactions which were calculated by joint method
- As it is seen in the present work, the weight of steel can be reduced to 27% for the PEB, providing lesser dead load which in turn offers higher resistance to accidential loads. Comparison in the second example showed that even though PEB structures provides clear span, it weighs 10% lesser than that of Conventional Buildings.
- As number bays of CST and PEB are compared it is observed that axial deformation is decresed by 10-15% as number of bays are increased for accidental load, also displacements along longitudinal direction is also reduced by 10%
- For longer span structures, Conventional buildings are not suitable with clear spans. Pre-engineered building is 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 72 m. 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.

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