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Design and Analysis of a Pre-Engineered Warehouse Building Considering Lateral Load Using ETABS A Review

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ABSTRACT

Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing design. Steel is the basic material that is used in the Materials that are used for Pre-engineered steel building. The latest version of the Code of Practice for general construction in steel IS 800:2007 is based on Limit State Method of 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 and Pre Engineered Buildings (PEB) fulfills this requirement along with reduced time and cost as compared to conventional structures. PEB methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. In this study, an industrial structure (Ware House) is analyzed and designed according to the Indian standard, IS 800-2007. The study of Pre Engineering Building with Conventional Steel Building has been carried out and the observations made based on this study are very much useful to the practicing structural engineers. In this paper we are presenting review of literatures.

Keywords- Steel Structure, Conventional Steel Building (CSB), Pre Engineered Building (PEB), Bracing Systems, Wind Analysis, Cross Bracing, Diagonal Bracing, K-Bracing.

I. INTRODUCTION

- Steel structures are considered as most durable and fast setup structure around the world, these structures are more advantageous than general RCC structures. These structures are used not only in industrial or commercials places but even in residential projects.
- Buildings with long spans, arch building and for proper elevations where high strength is required steel structures are utilized. Pre-engineering building currently most preferred structure where steel sections are assigned together to setup a proper building structure.
- Ware houses, industrials buildings with gantry crane setups and other high load bearing structures need such setups. In Pre-engineered

structure came into existence in 1960's. It had roof, floor, outline and so forth These parts were assembled to make the entire structure. This made development simpler.

- Steel structures are utilized in a wide range of uses and their interest is expanding. There are basically two classifications in steel structures

Conventional-Steel Building [C.S.B]

Pre-Engineered Building [P.E.B]

the research done from numerous authors in relation to similar topics where different techniques were used to study the analysis of pre-engineered building or any steel part of structure. Seismic loads are primarily evaluated in the analysis of the structure and the summarized report of such authors is described below.

Seena Somasekharan and Vasugi K (2021) in the research paper, the truss chord members were designed for different sections such as ISLC/ISA, UB/UC and SHS using SAP 2000-18. The most economic truss chord sections were utilised for the design of the industrial building, the industrial buildings are thus designed to carry out wind analysis with different bracings such as X- bracing, diagonal bracing and k- bracing. Therefore, the most optimised structure was compared with the PEB structure for the same parameters.

Economic and technical analysis of the PEB and CSB with span 42m and bay spacing 6m, when carried out wind analysis for the Chennai zone, results stated PEB with diagonal bracing gives the best suited based on the economical feasibility and the structural safety. Using of PEB instead of CSB reduces the steel quantity. Reduction in the steel quantity definitely reducing the dead load. Reduction in the dead load reducing the size of the Foundation. Using of PEB increase the Aesthetic view of the structure.

Muhammad Umair Saleem and Hisham Jahangir Qureshi (2020) research paper focused on the optimization of steel building costs with the use of pre-engineered building construction technology. Construction of conventional steel buildings (CSB) incorporates the use of hot-rolled sections, which have uniform cross-sections throughout the length. However, pre-engineered steel buildings (PEB) utilize steel sections, which are tailored and profiled based on the required loading effects. The performance of PEB steel frames in terms of optimum use of steel sections and its comparison with the conventional steel building was presented. A series of PEB and CSB steel frames were selected and subjected to various loading conditions. Frames were analyzed using a Finite Element Based analysis tool and design was performed using American Institute of Steel Construction design specifications. Comparison of the frames was established in terms of frame weights, lateral displacements (sway) and vertical displacements (deflection) of the frames.

The results stated that the size of the foundation will be minimized due to the reduction in dead load. An overall reduction of 30–40% in steel weight was observed in the mainframes, which spanned between 30 and 50 m. For bigger frame spans (40 m, 45 m and 50 m), a higher percentage reduction in frame weight was found as compared to smaller frame span.The seismic forces has no significant effect on the frame weights (both CSB and PEB) because of the lesser weight and lighter roofing of the building. The PEB steel frames have shown lesser lateral and vertical displacements compared to conventional hot-rolled steel frames because of the better control over the cross-sectional sizes and tapering technology of steel sections. Hence, conclusion indicated that PEB steel frames are not only the most economical solution due to lesser weight of construction but also have shown better performance compared to CSB frames.

Jinsha M S and Linda Ann Mathew (2019) in the research paper, Pre-Engineered Building of 25m width & 6m Eave Height have been analyzed and designed by using STAAD Pro.2007 to understand the

behaviour of Pre –Engineered structure & to check in which case it achieve the economy in steel quantity by varying bay spacing as 6m, 8m, 10m, & 12m. Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings fulfils this requirement along with reduced time and cost as compared to conventional structures. In the present work, Pre Engineered Buildings (PEB) is designed for wind forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987.Static loads i.e., Dead loads and Live load was considered as per IS 875 (Part I) – 1987 & IS 875 (Part II) – 1987 and Dynamic loads i.e. Wind loads was considered as per IS 875 (Part III) - 1987 respectively.

The results concluded that 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. Pre engineered building with bay spacing 8m is found to be most economical Steel quantity is primarily depending on primary members and purlins. As bay spacing is increased steel consumption is decreased for primary members & Steel consumption is increased for secondary member.

Nitin K. Dewani and Sanjay Bhadke (2018) research paper conducted analysis of an industrial structure (Ware House) and designed according to the Indian standard, IS 800-2007, Pre Engineering Building with Conventional Steel Building. The planning of an Industrial building is based on functional requirements i.e. on the operations to be performed inside the building. In the planning of an Industrial building, due consideration should be given to factors such as wide area of primary frames, large height, large doors and openings, large span of primary frames , consistent to give minimum weight of primary frames, purlins, girts, eave struts etc. and lighting and sanitary arrangement.

Results stated that by increasing the area of Industrial building material and cost of the building is minimized in case of PEIB while in case of Convention building the material and cost is not optimized if theirs an increase in area of building.

Darshan Kalantri et al (2017) in the research paper, an industrial structure was analyzed and designed according to the Indian standards. One model each for PEB and CSB is considered and parametric study is carried out to access the performance of the models. Comparison is made in terms of weight, cost and time of construction. The models of the Conventional Steel Building (CSB) and Pre-Engineered Building (PEB) was analyzed and designed using STAAD.Pro software.

The study of Self-Weight of the models showed that the Self-Weight for PEB was lower than CSB for the same geometry. With reduction in Self-Weight, the loads and hence the forces on the PEB will be relatively lesser, which decreases the effective sizes of the structural members. The study of Cost of Construction of the models showed that PEB structures are economical since the effective sizes of the structural members in PEB structures are lesser than CSB structures. Hence, the quantity of steel required for PEB structures will be lower than the CSB structures. It was seen that there was about 35% saving in cost for PEB compared to CSB. The study of Time of Construction of the models showed that PEB structures can be constructed in a lesser time compared to the CSB structures for the same geometry. On an average, the PEB structures can be constructed in about 35% lesser time duration than CSB structures. Also, PEB technology can be adopted for the bigger sized structures more effectively than the smaller sized structures.

Tabish Izhar et al (2017) the research paper involved the comparative study of pre Engineered Buildings (PEB) in RCC and general RCC structure. Ware house structure of 20m width and 24m length& single story was analyzed and designed using STAAD Pro.2007 in ordinary RCC and PEB RCC to understand the behavior of Pre –Engineered structure. Pre Engineered Buildings fulfils requirement along with

reduced time and cost as compared to conventional structures where the building was deisnged for both seismic and wind loads.

The conclusion stated that PEB RCC structures are more advantageous than general RCC structures in terms of maximum bending moment, shear force, support reaction. Savings in cost for PEB can be done in many ways such as savings in material, providing lighter foundation etc., quality control speed in construction. The weight of dead load can be reduced to 24.5% for the building, providing lesser dead load which in turn offers higher resistance to seismic forces.

B.Meena Sai Lakshmi et al (2015) in the reserch paper, Pre Engineered Steel Buildings (PEB) and Conventional Steel Buildings was designed for static and dynamic forces, which include wind forces and seismic forces. An industrial building of 60m length, 30m width and 10m eave height is located at Vijayawada and with different roof slopes like 5.71° & 7.125° as PreEngineered Steel Building and Conventional steel Buildings with 5.71° slope of roof is analysed and designed by using STAAD Pro V8i. Dead load is taken according to IS: 875 (Part 1)-1987. Live load is taken according to IS: 875(Part 2)-1987.Wind analysis has been done as per IS 875 (Part 3) -1987, seismic analysis was carried out as per IS 1893 (2002) and cold formed sections and designed as per IS 801-1975.

Steel take-off is more for PEB with flat roof compared to PEB with steep roof. The total steel take-off for PEB with slope 5.71˚ is more than the total steel take-off for PEB with slope 7.125˚. The axial forces for both haunch and ridge portions are less in PEB with slope 5.71˚ when compared to CSB with slope 5.71˚ & PEB with slope 7.125˚ at both end and middle frames. 5. The shear forces for both haunch and ridge portion are more in PEB with slope 5.71˚ when compared to CSB with slope 5.71˚ at both end and middle frames. The axial forces in columns are less in PEB with slope 5.71˚ when compared to CSB with slope 5.71˚ & PEB with slope 7.125˚ at both end and middle frames.

G. Durga Rama Naidu et al (2014) the research paper involved the comparative study and design of Pre Engineered Buildings (PEB) and Conventional steel frames. Design of the structure was being done in Staad Pro software and the same was 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 was done in two examples and in the third example, Pre Engineered Building structure with increased bay space is taken for the study. Pre Engineered Buildings (PEB) and Conventional steel frames structure was designed for wind forces and wind analysis was done manually as per IS 875 (Part III) – 1987.

The results concluded 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. “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”.

Swati Wakchaure and N.C.Dubey (2016) an industrial structure PEB Frame & CSB Frame was analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007 in the resarch paper. A structure with length 80m, width 60m,with clear height 11.4m and having R-Slope 5.71 Degree for PEB & 18 Degree for CSB was considered to carry out analysis& design for 2D frames . The economy of the structure was discussed in terms of its weight comparison, between Indian codes (IS800-1984, IS800-2007) & in between PEB & CSB building structure.

Results stated that PEB Structure was 30% lighter than the conventional building structure. As per IS Code 800-2007 Table 2, the section is classified as Plastic, Compact and semi-compact, slender cross section. The slender section are not design as per IS 800-2007.So in PEB design the slender section are not

design as per IS 800-2007 code and IS 800-1984 code design the slender section and reducing the weight of structure. The deflection limits are higher in IS 800-1984 compared to IS 800-2007. PEB structure reduces the dead load & hence it reduces the size of foundation. Pre-engineering building structure increases the aesthetic view of structure.

Rakesh Dumaru et al (2018) the research paper aimed to evaluate the seismic performance of the existing non- and pre-engineered buildings, and later employed retroft measures that are commonly practised in the region.The four existing buildings were selected, representing two each for non- and pre-engineered design buildings that were recorded as damaged and undamaged during the Gorkha earthquake. The entire case study buildings were located in Bhaktapur, Nepal. The non-engineered buildings were provided with a constant slab thickness of 100 mm and pre-engineered buildings with 125 mm thickness. Two types of unreinforced solid masonry infll walls were provided, such as external infll wall of 230 mm thickness mostly located in the periphery of the building and internal infll wall of 110 mm thickness functioning as the partition walls. In some cases, a wall thickness of 110 mm was found to be used as the external infll wall.

The analytical results revealed that the selected buildings were seismically deficient and are most likely to undergo extensive damage to collapse states, at 0.3 g PGA. It was found that the retrofit measure significantly enhances the stiffness, maximum strength and ductility in the existing buildings. The pushover curves indicated that the steel bracing highly increased the stiffness, strength and ductility capacity in all case study buildings. The steel-braced building was recorded to have increased the maximum base shear capacity by almost ten times for the soft-storey MRT1 building. Similarly, the retrofit measures also eliminated the potential single storey drift concentration recorded in the original building, such that a uniform inter-storey drift profile can be attained throughout. The conditional probability of collapse for the case study buildings, at 0.3 g PGA, ranges from 13.5 to 42% and could be minimized below 4% in the worst-case scenario for the shear wall. All the numerical results demonstrated that steel bracing was much more effective in enhancing the seismic performance of the existing buildings.

Aijaz Ahmad Zende et al (2013) research paper involved 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 was done in two examples and in the third example, longer span Pre Engineered Building structure was considered in the investigation. Pre Engineered Buildings (PEB) and Conventional steel frames structure is designed for dynamic forces, which includes wind forces and seismic forces. Wind analysis was done manually as per IS 875 (Part III) – 1987 and seismic analysis has been carried out as per IS 1893 (2002).

Results stated that 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 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. 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.

Apurv Rajendra Thorat and Santosh K. Patil (2017) in the research paper, Pre-engineered Buildings were designed and investigated in accordance with Kirby Technical Specification which is based on ASCE-07. Two examples have been taken for the study. Comparison of Pre Engineered Buildings (PEB) with bracings and Pre Engineered Buildings (PEB) without bracings was done in two examples. Later Pre Engineered Buildings (PEB) was analyzed for Dynamic loads using El-centro specified ground motion.

Results stated that Displacement along X-direction of Pre Engineered building with bracings is observed 34% less than the Pre Engineered Building without bracings along the longitudinal direction. Displacement along Y-direction is observed 13% less than the Pre Engineered Building without bracings but it is permissible in both cases hence no extra bracings are required for specified ground motion. Displacement along Z-direction is observed 23% less than the Pre Engineered Building without bracings. Acceleration at time period 3.02 seconds observed 609m/s2 and 492 m/s2 for with and without bracings respectively which is very severe and need to be controlled for current structural configuration.

Subodh.S.Patil et al (2017) the research paper presented a comparative study 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. Comparison of Pre Engineered Buildings (PEB) and Conventional steel frames is done in two examples and in the third example, Pre Engineered Building structure with increased bay space was considered in the investigation. Pre Engineered Buildings (PEB) and Conventional steel frames structure is designed for wind forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987.

Results stated that 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.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. 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 labor requirement.

Shraddha P. Raut et al (2017) the research paper presented comparative study of resource management of pre-engineering industrial building and conventional industrial building.“ Pre Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures.The actual structure was proposed as a Pre-Engineered Building with four spans of 21 meters length and an eave height of 7 meters. Typical PEB frame of 21 meter span was taken into account and the design was carried out by considering wind load as the critical load for the structure. CSB frame was also designed for the same span considering an economical roof truss configuration. Both the designs are then compared to find out the economical output. The designs were carried out in accordance with the Indian Standards and by the help of the structural analysis and design software Staad.Pro.

Results stated that PEB structures are more advantageous than CSB structures in terms of cost

effectiveness, quality control speed in construction and simplicity in erection. Pre-engineered steel structures building offers low cost, strength, durability, design flexibility, adaptability and recyclability. PEB building cost is 38.89% lesser than the cost of CSB structure. The cost of the material industrial shed can be reducing using PEB as per this study 57.72% saving in the cost of steel material. By comparison 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.

L. Maria Subashini and Shamini Valentina (2015) research paper presented 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 methodology was versatile not only due to its quality pre-designing and prefabrication, but also due to its lightweight and economical construction.

Conclusion 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 onventional Steel Building. In secondary members, lightweight "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. Lightweight 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 uers a much more economical and better solution for long span structures where large column free areas are needed.

T D Mythili (2017) the research paper comparative study of conventional and Pre-engineered steel structures which is a truss of span 30m carrying a crane of 10 tonne, 15t and 20t. Further research aimed at comparison of conventional steel building with Pre-Engineered steel buildings for industrial warehouses equipped with Electrical Overhead Travelling (EOT) cranes. The basic frame for conventional steel building is a built up column with truss as a roofing system and the basic frame for pre-engineered steel building is a pitched roof portal with tapered columns. The span to be used for the portal is 30m. Spacing of portal is 5m c/c. Inclination angle for PEB portal is 6° with respect to horizontal. The Crane of capacity of 10t is used on each frame under consideration.

Results stated that use of PEB instead of CSB may be reducing the steel quantity. Reduction in the steel quantity definitely reducing the dead load. Reduction in the dead load reducing the size of Foundation. Using of PEB increase the Aesthetic view of structure.

Hemant Sharma (2017) the research paper have analyzed, designed and compared the pre-engineered industrial building with the conventional building by mainly comparing the bending moments at different sections considering different components of the pre-engineered steel building. To design and analysis the PEB and CSB, Staad pro v.8 as per Indian standard codes was used. Two structures in terms of Economy and Time saving of construction were compared and many truss systems for cladding and roofing system was purposed. For the design Dead Load, Live Load and Wind Load for the location of Vadodara, Gujarat was considered as per IS Code consideration.

37% overall material saving & cost reduction in PEB compared to CSB was observed in detailed analysis of PEB and CSB.

II. CONCLUSION

No detailed study on suitability of Inclined building and related technique has been done in past researches were conducted on different materials including RCC, flyash cement concrete and panels (glass and aluminum) however information on techno economic feasibility of materials to be used in steel structures

i. This study will provide a suitability criteria for long span industrial buildings.
ii. This study will provide a reference to designer for providing suitability and lateral load resisting technique using steel structure and Pre-engineering building.

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