A Review on Pre-Engineered Building design of an Industrial Warehouse

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***Abstract*: 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 pre-designing and prefabrication, but also due to its light weight and economical construction. The concept includes the technique of providing the best possible section according to the optimum requirement. The concept has many advantages over the Conventional Steel Building (CBS) concept of Building with roof truss. This paper is a comparative study of PEB concept and CBS concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concepts and analyzing the designed frame using the structural analysis and design software Staad Pro.**

***Keyword*: Pre-Engineered Building, Conventional steel building, Staad Pro.**

I.INTRODUCTION

The scientific-sounding term pre-engineered building came into being in the 1960s. Typically, a Pre-building is a metal building that consists of light gauge metal standing seam roof panels on steels purlins spanning between rigid frames it has a much greater vertical and horizontal rise building which are ideals for offices, houses, showrooms, shop fronts etc. One may think about its possibility, but it's a fact many people are not aware about Pre Engineered Building. If we go for regular steel structure, time frame will be more, and also cost will be more, and both together i.e. tie and cost, makes it uneconomical. Thus in pre engineered building, the total design is done in the factory and as per the design, members are pre fabricated and then transported to the site where that are erected in a tie less than 6 to 8 weeks.

The first rigid-frame building introduced in the late 1940s could span only 40ft. In a few years, 50-60-and 70fts building became possible. By the late 1950s, rigid frames with 100-ft spans were made ribbed metal panels became available allowing the building to look different from the old tired corrugated appearance. Third collared panels were introduced by Strand-Steel Corp. in the early 1960s. permitting some design individuality.

At about the same time, continuous span cold-formed Z purlins were invented (also by Strand-Steel), the first factory panels were developed by Butler, and the first UL- approved metal roof appeared on the market. 1st. And last, but not least, the first computer-designed metal building also made their debut in the early 1960s. with the advent of computerization the design possibilities became almost limitless. All these factors combined to produce a new metal-building boom in the late 1950s and early 1960s. As lng as purchaser could be restricted to standard design , the building could be properly called pre-engineered.

II.Literature Review

2.1 Syed Firoz, et. al; (2012) observed that, The pre-engineered steel building system construction has great advantages to the single storey building, practical and efficient alternative to conventional buildings, the system representing one central model within multiple disciplines. Pre-engineered building creates and maintain in real time support is currently being implemented by Staad Pro Choosing steel to design a Pre engineered steel structures building is to choose a material which offers low cost, Strength, durability, design flexibility, adaptability and recyclability. Steel is the basic material that is used in the materials that are use for Pre- engineered steel building. It negates from regional sources. It also means choosing reliable industrial products which come in a huge range of shapes and colors, it means rapid site installation and less energy consumption. It means choosing to commit to the principles of sustainability. Infinitely recyclable, steel is the material that reflects the imperatives of sustainable development.

A tall steel building is not more in the total number of tall steel structures that are built around the world. A large steel structures that are built are only single storey building for industrials purpose. Secondary structural members span the distance between the primary building frames of metal building systems. They play a complex role that extends beyond supporting roof and wall covering and carrying exterior loads to main frame. Secondary structural, as these members are sometimes called, may serve as flange bracing for primary framing and may function as a part of the building's lateral load-resisting system. Roof secondary members, known as purlins, often form an essential part of horizontal roof diaphragms; wall secondary members, known as girts, are frequently found in wall bracing assemblies. The majority of steel structures being built are only low rise building are normally used for steel plants, automobiles industries, light, utility and process industries, thermal power station, warehouses, assembly plants, storages, garages small scale industries, etc. these building requires large column free areas. Hence interior columns, wall and partition are often eliminated or kept to a minimum. Most of these building may require adequate headroom purlins, or eave girt, acts as part purlins and part girts top flange support roof panels, its web part siding. Girts, purlins, and eave struts exihibits similar structural behavior. Since most secondary members normally encountered in metal building system are made of cold-formed steel our discussion starts with some relevant issues in design of cold-formed steel structures.

2.2 C.M. Meera (2013) , has carried out a comparative study of PEB and CSB concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concept and analyzing the designed frames using the structural analysis and design software Staad Pro. The designing of industrial warehouse includes designing of the structural element including principal rafter or roof truss, column and column base, purlins, sag rods, tie rods, gantry girder, bracing, etc. A combination of standard hot-rolled sections, cold-framed Industrial building can be categorized as Pre-Engineered Building (PEB) and Conventional Steel Building (CSB), according to the design concepts. The paper starts with the discussion of methods adopted in the study. Loads and the load combination 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 concept of PEB structures and its advantages over CBS structure.

2.3 Sagar Wankhede et.al; (2014) has given a review paper on comparisons of Conventional Steel Building and Pre-Engineered Building. The paper starts with discussion of various element of industrial building such as Purlins, sag rod, Principal rafters, Roof Truss, Gantry Girders, Brackets, Column and Column Base, Girt Rods, Bracing. Further carried by study load and load combination as per IS 875-1987. Then he has given an overview of concepts of Pre engineering Building by stating its advantages, effective use and about its frame. The final portion consist of describing about the component of Pre Engineered Building that are, Main Frame, Secondary frame, wind Bracing And Exterior Cladding. He has also shown us Comparisons between PEB and CSB. And finally concluded that PEB structures are more advantageous than CSB structures in term of cost effectiveness, quality control speed in speed in construction and simplicity in erection..

2.4 Shrunkhal V. Bhagatkar et. al;(2015), has shown a study on Pre Engineered Building with review of various authors of papers on Pre Engineered Building. The paper aimed to assess from the past advancement, the use of PEB is implemented and continuously increasing, its usage is not throughout the construction industry. It is reviewed that PEB structures can be easily designed by simple design procedures in accordance with country standards, it is energy efficient, speedy in construction, saves cost, sustainable and most important its reliable as compared to conventional buildings. Thus PEB methodology must be implemented and researched for more outputs.

2.5 Prof. P. S. Lande et. al;(2015) analyze and design of Conventional Steel Building and Pre-Engineered Building has been carried out and conclude that PEB structure can be easily designed by simple design procedures in accordance with country standards. Low weight Flexible frames of PEB offers higher resistance to wind load. Cold Formed steel section over hot rolled section as purlin is almost lighter than 32%. Pre Engineered Building weight is 35% lesser than weight of conventional steel building. Pre-Engineered Building construction gives end users a much more economical and better solution for long span structures where column free areas are needed. The study is achieved by designing 3D frame of a Industrial Warehouse building using both the concept and analyzing the frame using the Staad Pro software. The economy of structure is discussed in terms of its weight comparisons.

2.6 Jinsha M. S. et. al; (2015), observes that Pre Engineered Building are nothing but steel building in which excess is avoided by tapering the section as per the bending moment's requirement. If we go for regular steel time frame will be more and also cost will be more, both together i.e. time cost makes it uneconomical. Thus in engineered building the total design is done in the factory, and as per the design members are erected and then transported to the site where they are erected in a time less than 6 to 8 weeks. In this study single storey pre engineered building having 25m width, 0.6m Eave Height bay spacing as 6m, 8m, 10m & 12m and 60m length is selected for analysis. In this paper, Static load i.e., Dead loads and Live loads are considered as per IS 875 (Part I) – 1987 & IS 875 (Part II) – 1987 and Dynamics loads i.e. Wind loads are considered as per IS 875 (Part III) – 1987 respectively. It has seen in this paper that the weight of PEB depends upon the bay spacing, with the increase in bay spacing of 8m spacing, the weight reduces and further increase makes it heavier. The authors finally concluded that Steel quantity is primarily depending on primary and purlins. As bay spacing increased steel consumption is decreased for primary members & Steel consumption is increased for secondary member.

2.7 D Rakesh et. al; (2016) studied comparison of displacement and steel quantity is done in conventional type and pre engineered structure. In this study pre engineered structure shows less displacement in column and less consumption of steel. Pre-engineered steel structure building offers low cost, strength, durability, design flexibility. Based on the analytical design results theorem of conventional and pre engineered steel building. The total steel take-off for PEB with primary frame spacing of 5m is 60% of the conventional steel building. It is also seen that the weight of PEB 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 area are needed. In this study the displacements are more in conventional building compared to the Pre Engineered building and the axial force are more in Pre Engineered building compared to the conventional steel building. Hence authors propose Pre – Engineered Building Construction are more cost effective and economical when compared to conventional steel building and construction time and cost also reduces.

2.8 Apruv Rajendra Thorat et. al; (2017) observes that Pre Engineered Building are those that are totally invented within the industrial plant once planning, shipped in CKD (Completely Knocked Down) condition and all parts are assembled and erected at a site with nut-bolts and thereby reducing the time completion. The structural analysis and design is done for Static analysis, Dynamic analysis, Secondary analysis and El-Centro data is used for Time History Analysis. All the dead load, live load, accidental load will by confirming to IS 875-1987. Earthquakes loads will be confirming to IS 1893-2002 part-IV. Load combination considered as Self Weight of structure, Weight of Purlins, Wind Force in X direction, Wind Force in Z direction, Negative Wind Pressure in X direction, Negative Wind pressure in Z direction, Ground motion in X and Z direction. In this paper dynamic load action on Pre Engineered Building is observed and checked for El-Centro Data using Time History Analysis. Two parametric models of Pre Engineered Buildings of 21m span with and without bracing.1. Displacement along X-direction of Pre-Engineered building with bracings is observed 34% less than the Pre Engineered Building without bracings along longitudinal direction. 2. 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 bracing required for specified ground motion. 3. Displacement along Z direction is observed 23% less than the Pre Engineered Building without bracing 4. Acceleration at time period 3.02 seconds observed 609 m/s and 492 m/s for with and without bracings respectively which is very serve and need to be controlled for current structural configuration.

III. PRE ENGINEERED BUILDING

Pre-Engineered Building concept involves the steel building system which are predesigned prefabricated. The basis of the PEB concept lies in providing the section at a location only according to the requirement at that spot. The section can be varying throughout the length according to the bending moment diagram. This lead to the utilization of non-prismatic rigid frames with slender elements. Tapered I section made with built up thin plates are used to achieve this configuration. Standard hot-rolled, cold-formed section, profiled roofing sheets, etc. is also used along with the tapered section. The use of optimal least section leads to effective saving of steel and cost reduction. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure.

IV. COMPONENTS OF PEB

A typically assembly of a simple metal building system is shown below to illustrate the Synergy between the various building as described below:

Primary component

Secondary Component

Sheeting (or) cladding

Accessories

4.1. Primary Component

4.1.1. Main Framing

Main framing basically includes the rigid steel frames of the building. The PEB rigid frame comprises of tapered columns and tapered rafters (the fabricated tapered section are referred to as built-up members.) The tapered section are fabricated using the site of art technology wherein the flanges are welded to the web. Splices plates are welded to the ends of the tapered sections. The frame is erected by bolting the splice plates of connecting sections together. All rigid frames shall be welded built-up “I” section or hot-rolled section. The columns and the rafter may be either uniform depth or tapered. Flanges shall be connected to webs by means of a connection fillets weld on one side. All end wall roof beams and end wall columns shall be cold-formed “C” sections, mill-rolled section or built-up “I” section depending on design requirement. Plates Stiffeners, etc. All base plates splice plates, cap plates and stiffeners shall be factory welded into place on the structural member’s. Built-up I section to build primary structural framing members (Columns and Rafters).

4.1.2. Columns

The main purpose of the column is to transfer the vertical loads to the foundation. However apart of the horizontal actions (wind action) is also transferred through the column. Basically in pre-engineered building column are made up of column I section consists of flanges and web which are made from plates by welding.

4.1.2. Rafter

A rafter is one of a series of sloped structural members (beams) that ended from the ridge or hip to the wall plates down slope perimeter or eave, and that are designed to support the roof deck and its associated loads.

4.2. Secondary Components

Purlins, Girts and Eave struts are secondary structural members used as support to wall and roof panels. Purlins are used on the roof. Girts are used on the wall and Eave struts are used at the interaction of the sidewall and the roof. They are supplied with minimum yield strength of 34.5KN/m. Secondary members act as struts that help in resisting part of the longitudinal loads that are applied on the building such as wind and earthquakes loads and provide lateral bracing to the compression flanges of the main frame members for increasing frame capacity. Purlins, Girts and Eave Struts are available in high grade steel conforming to ASTM 607 Grade 50 or equivalent, available in 1.5mm, 1.75mm, 2.0mm, 2.25mm, 2.5mm and 3.0mm thickness. They come with a pre-galvanized finish or factory painted with a minimum of 35 microns (DFT) of corrosion protection primer. Purlins and girt shall be cold-formed “Z” section with stiffened flanges. Flange stiffeners shall be sized to comply with the requirements of the latest edition of AISI.

4.3. Sheeting and Cladding

The used in the construction of pre-engineered building are composed of the following. Base metal of either galvalume coated steel conforming to ASTM A 792M Grade 345B or aluminum conforming to ASTM B 209M. Galvalume coating is 55% Aluminium and about 45% Zinc by weight. An exterior surface coating on painted sheets of 25 microns of epoxy primer with a highly durable polyester finish. An interior surface coating on painted sheets of 12 microns of epoxy primer and modified polyester or foam. The sheeting material is cold-rolled steel, high tensile 550 MPA yield stress, with hot dip metallic coating of Galvalume sheet.

4.4. Accessories

4.4.1. Anchor bolts

Bolts used to anchor the structural member to the concrete floor, foundation or other support. This usally refers to the bolts at the bottom of all columns. Anchor bolts are manufactured with circular steel rods having threading portion at the top for bending and bent up at the bottom for Foundation.

4.4.2. Louvers

Standard Louvers shall have a 26 gauge galvanized steel frame painted with 26 gauge blades. Heavy Duty Louver frames shall be 18 gauge galvanized steel frame painted with 20 gauge blades. Both Standard and Heavy Duty louvers shall be self-framing and self flashing. They shall equipped with adjustable or fixed blades as specified. Nominal sizes shall be 2-0” X 20” X 2’-0”, 3’-0” X 3’-0”, 4’-0” X 3’-0” and 3’-0” X 4’-0”.

4.4.3. Fasteners

Standard fasteners shall be self drilling screws with metal and neoprene washers. All screws shall have hex heads and are zinc plated.

4.4.4. Gantry Girder

In mills and heavy industrial building such as factories and workshop, gantry girder supported by columns and carrying cranes are used to handle and transport heavy goods equipment etc. there are several types of cranes; Overhead travelling under-slung, jib, gantry, and monorail are among are among the most common. A building may have one or several of these, either singly or in combinations. Hand operated overhead cranes have lifting capacities of in to 50 KN and electrically operated overhead cranes, called EOT cranes can have capacities in the range of 10-3000 KN.

V. ADVANTAGES OF PEB

PEB is a suitable Construction technique for developing countries for the following reasons:

5.1. Reduced construction time

Building are typically delivered in just a few weeks after approval of drawings. Foundation and anchor bolts are cast parallel with finished, ready for site bolting. PEB will reduces total construction time of the project by at least 50%. This also allows faster occupancy and earlier realization of revenue.

5.2. Lower cost

Due to the system approach, there is a significant saving in design, manufacturing and on site erection cost. The secondary members and cladding nest together reducing transportation cost. Steel buildings that are properly insulated save natural resources, energy and money.

5.3. Flexibility of expansion

Building can be easily expanded in length by adding additional bays. Also expansion I width and height is possible by pre designing for future expansion.

5.4. Large clear spans

Building can be supplied to around 80M clear spans.

As building are manufactured completely in the factory under controlled conditions the quality is assured

5.6. Sustainability

Steel is 100% recyclable and is the most recycled material in the world.

VI. APPLICATION OF PEB

The most application of Pre Engineered Building are as follows:

6.1. Industrial

Factories, Workshops, Warehouses, Cold stores, Car parking sheds, Slaughter houses, Bulk product storage.

6.2. Commercial

Showrooms, Distribution centers, Supermarkets, Fast food restaurants, Offices, Labor camps, Service station, Shopping centers, Schools, Exhibition halls, Hospitals, Theatres/auditorium, Sports halls.

6.3. Institutional

Schools, Exhibition halls, Hospitals, Theatres, Sport halls.

6.4. Recreational

Gymnasium, swimming pool enclosures, Indoor tennis courts.

6.5.Aviation & Military

Aircraft hangers, Administration buildings, Residential barracks.

VII. CONCLUSION

From the past advancement, the use of PEB is implemented and continuously increasing but its usage is not throughout the construction industry. It is reviewed that PEB structure can be easily designed by simple design procedures in accordance with country standards, it is energy efficient, speedy in construction, saves cost, susutainable and most important its reliable as compared to conventional to conventional buildings. Thus PEB methodology mist be implemented and researched for mire outputs.

REFERENCES

1. C. M. Meera, “Pre=Engineered Building Design of an Industrial Warehouse”, International journal of Engineering Sciences and Engineering Technologies, Volume 5, Issue 2, June-2013, pp:75-82.
2. Syed Firoz, Sarath Chandra Kumar B, S. Kankambara Rao, “Design concept of Pre Engineered Building”, International Journal of Engineering Research and Application, Volume 2, April 2012,pp.267-272.
3. Shrunkala V Bhagatkar, Farman Iqbal Shaikh, Bhanu Prakash Gupta and Deepak Kharta, “ A study on Pre-Engineered Building- A Construction Technique”, International Journal of Engineering Research, Volume 4, Issue 2,2016, pp 802-805.
4. Prof. P. S. Lande, Vivek V. Kucheriya, “ Comparative Study of Pre- Engineered Building with Conventional Steel Building”, International Journal of Pure and Applied Research In Engineering and Technology, Volume 3, April 2015, pp 28-39.
5. D. Rakesh, V. Sanjay Gokul, G. Amar, “ Design and Analysis of Conventional and Pre-Engineered Building (RCC and Steel)”, International Journal of Engineering Development and Research, Volume 4,Issue 2, 2016, pp 802-805.
6. Apruv Rajendra Thorat, Santosh K. Patil. “ A study of performance of Pre-Engineered Building of an Industrial Warehous for Dynamic Load”, International Research Journal of Engineering and Technology, Volume 4, Issue 6, June -2017, pp 2240-2246.
7. Jinsha M. S., Linda Ann Mathew, “ Analysis of Pre-Engineered Buildings”, International Journal of Science and Research, Volume 5, Issue 7, July 2016, pp 1049-1051.
8. Sagar Wankhade & P. S. Pajgade, “ Review Paper on Construction of Conventional Steel Building & Pre-Engineered Building”, International of Research in Advent Technology, Volume 2, Issue 5, May 2014, pp 271-276.