Comparative Study of Conventional Steel Building and Pre-Engineered Building

S.B. Bhagate, Guide
Professor, Dr. J. J. Magdum College of Engineering, Jaysingpur

Students
1. Anmol Sawane, Dr. J. J. Magdum College of Engineering, Jaysingpur
2. Govind Taralekar, Dr. J. J. Magdum College of Engineering, Jaysingpur
3. Rahul Patil, Dr. J. J. Magdum College of Engineering, Jaysingpur
4. Rupesh Waghmare, Dr. J. J. Magdum College of Engineering, Jaysingpur

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. This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss. This paper is a comparative study of PEB concept and CSB concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concepts and analysing the designed frames using the structural analysis and design software Staad.Pro.

Introduction: -
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. 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 behavior 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.

Pre Engineered Buildings:
PEB is a rigid jointed plane frame from hot-rolled or cold – rolled sections, supporting the roofing and side cladding via hot-rolled or cold formed purlins and sheeting rails. Pre Engineered Buildings offers many advantages such as more effective use of steel than in simple beams, easy extension at any time in the future and ability to support heavy concentrated loads. PEB frames have a roof slope of from 6 to 12 degree, mainly chosen because of the smaller volume of air involved in heating and cooling the building. Usually, the portal...
frames are composed of tapered stanchions and rafters. Most often, the beam is tapered by providing a slope to the flange for water runoff and keeping the bottom flange horizontal for ceiling applications.

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. 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 is used along with the tapered sections, The use of optimal least section leads to effective saving of steel and cost reduction.

Presently, large column free area is the utmost requirement for any type of industry and with the advent of computer software’s it is now easily possible. With the improvement in technology, computer software’s 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. Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre engineered buildings. Through its origin can be traced back to 1960’s its potential has been felt only during the recent years. This was mainly due to the development in technology, which helped in computerizing the design and design.

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 Indian markets lately in the late 1990’s with the opening up of the economy and a number of multi nationals setting up their projects. The market potential of PEB’s is 1.2 million tons per annum. The current pre engineered steel building manufacturing capacity is 0.35 million tons 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’s is a new concept in India. Beside, in fabrication and other areas of PEB, India is very good. As compared to other countries Indian codes for building design are stringent but safer. IS standards are upgraded continuously. In India, American codes are also followed. Following Figure: 1.1 shows Conventional steel frame and pre-engineered steel frame,

![Pre-Engineered Steel Frame](image1)
![Conventional Steel Frame](image2)

Figure: 1.1 Conventional steel frame and pre-engineered steel frame

1.1.2 Component of a pre-engineered building:

Following Figure: 1.2 shows Component of PEB,
The component of a PEB may be broadly divided into following four parts, namely

a) Main Frame / Primary Members
b) Secondary Frame
c) Wind Bracing
d) Exterior cladding

A) PRIMARY MEMBERS / MAIN FRAMES

Primary members are the main load carrying and support members of a pre-engineered building. The main frame members include columns, rafters and other supporting members. The shape and size of these members vary based on the application and requirements. The frame is erected by bolting the end plates of connecting sections together. All the steel sections and welded plate members are designed in accordance with the applicable sections as per the latest international codes and standards such as AISC, AISI, MBMA and IS to meet all the customer specifications. Moment resisting frames provides lateral stability and transfer the roof and wall load to the foundation through anchor bolts. Main frames are built up tapered or constant depth column and rafters. The tapered profile is based on the moment diagram of the structure, which results in greater economy compare to any other structure. This is the main difference with respect to other structural steel frame building where in straight columns and beams are used. The tapered sections are welded using automatic welding machine to ensure high quality and rapid construction. Flanges are welded to the web by a continuous single side fillet weld. Splices using flange plate are usually provided at the zones of low moment in the frame. Following Figure: 1.3 shows PEB Main Frame,
B) SECONDARY MEMBERS / COLD FORMED MEMBERS

Secondary structural framing refers to purlins, girts, eave struts, wind bracing, flange bracing, base angles, clips and other miscellaneous structural parts. Purlins, girts and eave struts are cold formed steel members which have a minimum yield strength of 345 MPa and will conform to the physical specifications of ASTM 572 (Grade 50) or ASTM A653 (Grade 50) or equivalent. Following Photograph: 1.12 shows cold formed z section and cold formed roof steel sheeting

C) Wind Bracing

Roof and wall cross bracing provide longitudinal stability to the building. It enables effective transfer of wind load acting on building end walls to the foundation. Following figure1.13 shows Wind bracing,

D) Exterior Cladding

Exterior Cladding provides a water tight envelope. It transfers the Structural loads i.e. Wind and Live load to the Secondary Framing. It provides lateral bracing to the Purlin and girt.

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 Span: 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 costs.

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 in future.

Conventional Steel Buildings

Conventional steel buildings (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss. For large pitch, Fink type truss can be used; for medium pitch, Pratt type truss can be used and for small pitch, Howe type truss can be used. Skylight can be provided for day lighting and for more day lighting, quadrangular type truss can be used. The selection criterion of roof truss also includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Several compound and combination type of economical roof trusses can also be selected depending upon the utility. Standard hot-rolled sections are usually used for the truss elements along with gusset plates.

Components of CSB

1. Anchor Bolts: Anchor Bolts are typically set in concrete and used to anchor structural members to the foundation. Anchor bolts can also be drilled and set with epoxy if need be. These bolts are not supplied by MBMI but the concrete contractor will usually provide them.
2. Base Angle: A continuous angle secured to foundation to support wall panels. MBMI supplies a 4x3 angle which is about twice the size most of our competitors supply.

3. Base Plate: A shop-welded, pre-punched plate on that portion of a beam or column which rests on the supporting surface.

4. Batten: A broad, formed strip of metal put over a roof seam for decorative

5. Butt Plate (or Splice Plate): The prepunched end plate of a structural member which usually rests against a matching plate of another member in forming a bolted connection.

6. "C" Section: A member cold-formed from steel coil in the shape of a "C", used primarily in bearing frame endwalls and framed openings.

7. Cap Plate: A plate located at the top of a column or end of a beam for capping the exposed end of the member. Used for pinned conditions.

8. Damper: A baffle used to open or close the throat of ventilators.

9. Deck: The structural surface to which roofing or waterproofing system (including insulation) is applied.

10. Drip Edge: A metal strip placed along the edge of a roof to divert water

11. Eave Strut: A cold-formed structural member at the eave to support roof and wall panels; also transmits forces due to wind on endwall from roof brace rods to wall brace rods.

12. Eave Strut Gusset: A small gusset shop-welded to main frame on RF and BC buildings to support eave struts and afford alignment with by-framed girts.

13. Haunch: Also known as Knee. The deepened portion of a column or rafter, designed to accommodate the high stress where column and rafter intersect and connect. The rigid frame column and rafter come together to form the haunch. The haunch will be the lowest point in the roof of a building.

14. Joist: Joists are supporting open web beams used in the roof or the floor of a mezzanine. Joists are cost effective at carries large loads or spanning large distances.

15. Lip: A flange stiffener.

16. Louver vent: Louver vents provide very economical ventilation for steel buildings. These vents are mounted to the walls of your building and can be combined with ridge vents or turbo vents. Wall louveres will act as intake vents while the roof vents will act like exhaust vents. Vents can be purchased with fixed or adjustable louveres depending on your application. Vents are available in all sizes and come standard with either bird or insect screens to keep your building pest free. Electric fans can be attached to these vents to provide additional air movement. The vents are available in over 20 different colors. The base metal is galvalume, which is a zinc-aluminum coating that provides excellent corrosion resistance. These vents come with a standard 40 year paint warranty.

17. Panel: Steel panels act as the skin of the building. Panels cover the walls and roof our a steel building.

18. Panel Clip: Independent clip used to attach roof panels to substructure.

19. Sag Rod or Sag Angle: Tie rods or angles to support bottom purlin flanges against compression buckling due to special wind force.

20. Sag Strap: A metal strap used to align purlins during erection.

**Objective**

- To minimize the weight of the frame, this results in the cost reduction.
- Detail study of pre-engineered building and conventional steel building.
- Design the industrial Truss.
- Comparison between pre-engineered building and conventional steel building.
Literature Review:


They observed that in the comparison between various configurations of industrial shed using various types of truss type which gave them the suitable shed for the industrial shed and which is more effective in strength and economical point of view. Design of various types of industrial frame by using STAAD-Pro 2007 software gave them the total design and suitability. A truss is essentially a triangulated system of (usually) straight interconnected structural elements; it is sometimes referred as an open web girder. The individual elements are connected at nodes; the connections are often assumed to be nominally pinned. The external forces applied to the system and the reactions at the supports are generally applied at the nodes. When all the members and applied forces are in a same plane, the system is a plane or 2D truss. They had analysed three types of industrial shed using three types of truss which were portal frame type, A-type and saw tooth type by using STAAD-Pro from which they got steel required, strength and economy of different sheds then they compared the respective results obtained found that Saw tooth type industrial shed is 65% more economical than portal and A-type frames which means it is economically good. They also compared Pre-engineered industrial shed with all above three and then went to the conclusion, which one is the best industrial shed economically and strength point of view and that was Pre-engineered industrial shed.


They observed that Pre-engineered Building (PEB) is a suitable Construction technique for developing countries. It is a combination of precast & prefabricated structures. Pre-engineered buildings are generally low rise buildings which are ideal for offices, houses, showrooms, shop fronts etc. PEB will reduce total construction time of the project by at least 50%. This also allows faster occupancy and earlier realization of revenue. Buildings can be supplied with around 80m clear spans. Steel is 100% recyclable and is the most recycled material in the world. Thus, each ton of recycled steel saves 2,500 pounds of iron ore and approximately 1,000 pounds of coal. The application of pre-engineered buildings concept to low rise buildings is very economical and speedy. Buildings can be constructed in less than half the normal time. Although PEB systems are extensively used in industrial and many other non-residential constructions worldwide, it is relatively a new concept in India. They reviewed that PEB structures can be easily designed through simple design procedures in accordance with country standards, which is energy efficient, speedy in construction, saves cost, sustainable and most important it’s reliable as compared to conventional buildings.

Bhojkar Milind and Darade Milind (December 2014) on “Comparison of Pre Engineering Building and Steel Building with Cost and Time Effectiveness”. International Journal of Innovative Science, Engineering & Technology (IJISSET), Vol. 1 Issue 10

They observed that, the Pre-engineered building system is unmatched in its speed and value and that’s why they are said to be economical for modern construction. The erection time of the pre-engineered building is 50% of conventional steel building or less than 8 weeks. Clear spans up to 90 meters wide (could be extended up to 150 m in case of Aircraft hangers) and eave heights as high as 30 meters are possible. The cost may be approximate 30% of Conventional steel Building only. The various types of Main frame for the basic supporting component in the PEB systems; main frames provide the vertical support for longitudinal and lateral stability for the building in its direction while lateral stability in the other direction is could be achieved by application of bracing system. The Pre-engineered buildings could be high rise buildings Conventional steel buildings are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss. For large pitch, Fink type truss can be used; for medium pitch, Pratt type truss can be used and for small pitch, Howe type truss can be used. Skylight can be provided for day lighting and for more day lighting, quadrangular type truss can be used. The selection criterion of roof truss also includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Several compound and combination type of economical roof
trusses can also be selected depending upon the utility. Standard hot-rolled sections are usually used for the truss elements along with gusset plates.


They observed that in recent years, the introduction of Pre Engineered Building concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building 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 8001984, IS 800-2007 and also by referring MBMA-96 and AISC-89. In this study, a structure with length 187m, width 40m, with clear height 8m and having Slope 1:10, is considered to carry out analysis & design for 2D frames (End frame, frame without crane and frame with 3 module cranes). The economy of the structure as they discussed is in terms of its weight comparison, between Indian codes (IS800-1984, IS800-2007) & American code (MBMA-96), & between Indian codes (IS800-1984, IS800-2007).

Proposed Methodology:

STAAD.PRO PROCEDURE

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

Step 1) We will now create the structure in STAAD.Pro. After launching STAAD.Pro, the new model wizard will appear allowing you to create a new file or open recent files. Select Truss as the structure type. Then input a file name for the structure such as “Truss”. You need to select a location to have the file created and saved in. You are advised to save the file in your home area on the network.

Following figure Shows that
Step 2) Select Add Beam to select one of the prototype models already existent in the library of the program. Following Figure Shows that

![Add Beam Image](image)

Step 3) Define supports. First select the Support tab on the left-side on the window. Click on Create so you can add a support to the support list. Following Figure Shows that

![Supports Image](image)

Step 4) Define the properties (cross-sections) of the truss members. First click on the General tab on the left-side on the window. Notice that the Property tab is already selected. Now click on Section Database to define properties of the truss members. Following Figure Shows that

![Section Database Image](image)
Step 5) Define the loads acting at the nodes of the truss. First select the Load tab on the left-side of the window. A window will appear including the “Load Cases Details” option. Click on the Load Cases Details tab, then click on Add, to create a new primary load case. Following Figure Shows that

Step 6) We will now prepare the structure for analysis. First click on the Analysis / Print tab. A window will appear allowing you to select the type of analysis to perform. Make sure the Perform Analysis tab is selected. Select All for the print option. The print option allows you to select optional outputs to print when the analysis is performed. When you are done, click on Add and then on Close. Following Figure Shows that
Step 7) Design the truss by using Stad pro as shown in following figure

Design Procedure Pre-Engineered Building By using Staad-pro
Step 1) Select the make PEBtruss model Following FigureShows that
Step 2) Define supports. First select the Support tab on the left-side on the window. Click on Create so you can add a support to the support list. Following Figure Shows that

Step 3) Define the properties (cross-sections) of the truss members. First click on the General tab on the left-side on the window. Notice that the Property tab is already selected. Now click on Section Database to define properties of the truss members Following Figure Shows that
Step 4) Define the loads acting at the nodes of the truss. First select the Load tab on the left-side of the window. A window will appear including the “Load Cases Details” option. Click on the Load Cases Details tab, then click on Add, to create a new primary load case. Following Figure Shows that

Step 5) We will now prepare the structure for analysis. First click on the Analysis / Print tab. A window will appear allowing you to select the type of analysis to perform. Make sure the Perform Analysis tab is selected. Select All for the print option. The print option allows you to select optional outputs to print when the analysis is performed. When you are done, click on Add and then on Close. Following Figure Shows that
Step 6) A window will appear showing the progress of the analysis. Once the analysis is completed, we can view the results via either View Output File option or Go to Post Processing Mode option. Let’s choose Go to Post Processing Mode to view the results and click on Done. Following Figure Shows that

Step 7) The default results which appear on the screen are Node displacements. Following Figure Shows that
Result: Quantity of steel utilize for the structure 14m X 28m span

Conclusion: PEB system is becoming an eminent segment in pre-engineered construction industry. It has become possible because pre-engineered building encompasses all the characteristics that are compatible to modern demands, namely speed, quality and value of money.
Pre-engineered steel structures building offers low cost, strength, durability, design flexibility, adaptability and recyclability. Steel is the basic material that is used in the materials that are used for Pre-engineered steel building. It negates from regional sources. Infinitely recyclable, steel is the material that reflects the imperatives of sustainable development.

Pre-Engineered Building is more economical as compare to Conventional steel building because of the use of tapered section in pre-engineered building quantity of steel is reduce.

In Conventional Steel building, Inclined Member and bottom members provided because of these quantity of steel is increases

Conventional steel building is not economical as compare to pre-engineered building..

Reference:
[3.] BhojkarMilind and DaradeMilind (December 2014) on “Comparison of Pre Engineering Building and Steel Building with Cost and Time Effectiveness”. International Journal of Innovative Science, Engineering & Technology (IIJSET), Vol. 1 Issue 10