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ALTERNATIVE DESIGNS FOR GABLE INDUSTRIAL STRUCTURE

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ABSTRACT - *The Introduction of new alternatives for Gable frame Industrial structures has helped to optimize structural designs. The structures have been economized based on their span, height and spacing and with possible alternative roofing systems. In this study Alternative structural layouts for Industrial gable frames of long span light roof structures like Industries, Warehouses etc are been proposed. The Alternatives considered are Conventional Frame with Truss, Pre-engineered Frame and Lattice Girder Frame and they have been Analyzed and Designed as per IS 800-2007. The Finite Element software STAAD Pro-v8i has to be employed for this purpose. In this present study, an Industrial structure with plan dimensions of 22.5m x 48m having a eave height of 12m and with practically possible roof slopes is considered for Analysis and Design for 2-D frames (Gable End frame, Intermediate frame) and also a complete 3-D Analysis and Design with the addition of secondary members . By maintaining the same height and width of the frame for all the alternative designs the Economy of the Industrial building with the best suitable alternative roofing system is proposed in terms of its tonnage, in the case of 2-D frames and also Tonnage comparison in the case of 3-D building.*

Keywords – P.E.B-Pre Engineered Building, C.S.B-Conventional Steel Building, Lattice Girder Building, 2-D-Two dimensional ,3-D Three dimensional.

1. INTRODUCTION

Any structure worn by the industry to stock crude materials or for assembling products of the manufacturing is known as an Industrial Structure. Modern single story industrial structures might be divided as Normal Industrial structures and Special Industrial structures. Typical kind of gable industrial structures is shed or warehouse type of structures with a basic type of rooftop. These structures are utilized for workshop, stockrooms and other assembling forms. These structures require enormous and clear column-free area. The huge floor territory gives enough flexibility and office in the later stages, if any adjustment in the production format without significant structural modifications. The modern single story structures are developed with sufficient headroom for moving the overhead crane. The objective of Gable Industrial building percept the degree of elegance.

The structural steel outlines the following choices for a Gable Industrial Structure, they are:

a) Pre-Engineered Building Frame (P.E.B)

These PEBs are equipped with the combined usage of different sections they are Hot Rolled standard sections, Tapered sections and the elements of Cold formed sections. The components of PEB may be generally classified as follows: Main or Primary Frame, Secondary Frame, Material for Sheeting and Cladding and Other Accessories.

The construction of these structures as shown in figure 1.1 below

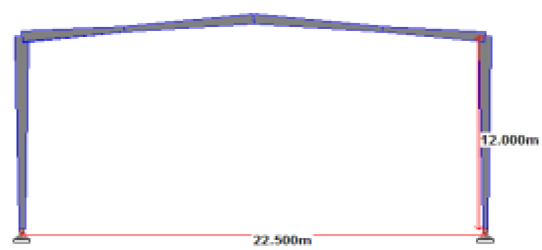

Fig.1.1. Pre-Engineered Building Frame

These type of structures are for the most rigidly jointed structure frames worked from hot rolled and cold formed areas, the rooftops, and side cladding is supported by purlins, sheeting rails. For the selection of rooftop slope in case of P.E.B is chosen between 5 to 12 degree with reference to the practical applications , on account of least volume of air involved during warming and cooling of the structure and also for the drainage point of view.

b) Conventional Steel Building Frame with Truss (C.S.M):

Steel structures are single-story buildings with different types of Truss systems of roofing with roof coverings are termed as Conventional Steel Buildings. As shown below in figure 1.2. for these kind of structures the type of truss used is pitched Pratt type truss. As per the angle or pitch of truss, the diverse type of roofing system can be utilized.

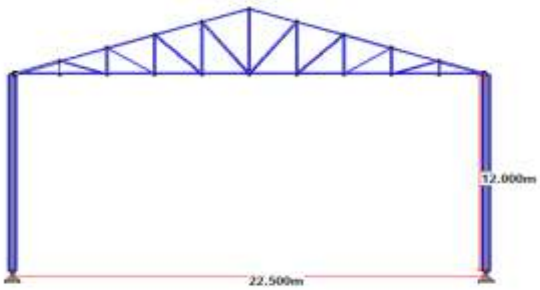

Fig.1.2 Conventional Steel Building Frame with Truss

c) Lattice Girder Building Frame:

Lattice Girder frames are supported on steel as well as R.C.C columns they are usually costlier than Steel portal or gable frames for lesser spans. Though they give the great framing possibilities for an enormous range of span more than 30m. For the service amenities needing space or machinery or cranes suspended from the roofing area, or where deflection criterion is predominantly critical (in case of using corrugated cement roofing sheet) such type of lattice frames are preferably used.

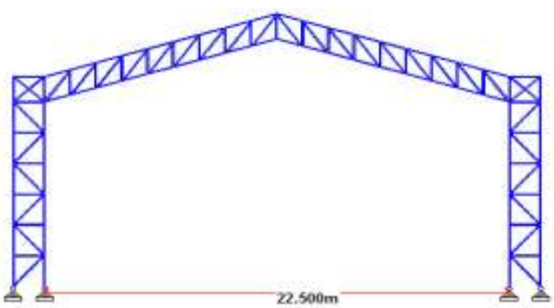

Fig.1.3 Lattice girder building frame.

2. LITERATURE REVIEW

Mahen Mahendran and Costin Moor (1999) observed that the practical strength, deflection of industrial or commercial single storey steel portal frames are accepted only if the problem of the stiffness of both profiled steel covers or perforated steel cladding and end frames is incorporated. The ordinary or traditional steel plans dismiss these kinds of impacts and, are for the most part rely upon normalized behavior of 2D frames. When a portal steel frame was considered and complete tests were done under most of the load cases as per the design, point out that the practical bending moments and deflections in the frame were generally not quite the same as those obtained from a 2-D analysis ignoring these impacts. Three-dimensional analysis of the exceptionally same structure, comprehensive of the impacts of the end bay frame and covering, which were done and the outcomes have concurred with a full-scale and complete set of test results. To study and record the true structural performance of portal frame buildings the need for such an analysis and testing is required as indicated by the results. It is knowing that such a three-dimensional analysis and design will demonstrate the best approach to lighter, efficient steel frames as the maximum deflection and moments are diminished.

Syed Firoz, Sarath Chandra Kumar (2012) observed that PEB and its creation and maintenance is done in actual time using a software package called as staad pro and it is used for complete engineering and designs. The connection between primary structural steel members is taken care of by secondary members. Other than supporting the roof, wall loads these secondary members carry other exterior loads on to the fundamental main framing system and secondary members also help in flange bracing also. This paper mainly discusses PEB and its particular components one by one and also how to proceed with the design of such a building and also the comparison between PEB and the conventional building was done. He has wrapped up by saying that PEB is more economical than conventional building for different spans.

Aijaz Ahmad Zende (2013) observed that structural steel is the material which can be possibly reused number of times and maintains the sustainability of materials used. PEB is the structures that provide a large number of spans and are comparatively less weight than other conventional buildings. In the current work, an industrial single storey structure was taken into the consideration of spanning about 88m. By using software to design, the number of possibilities of design solutions is more. The PEB is more economical because the material can be saved on the low moment areas of the primary and fundamental members which are not possible in conventional buildings. Especially for buildings of height up to 30 m and spanning up to 90m. He also said that PEB is costly for smaller spans. Finally, he has concluded that the PEB gives more convincible solution than conventional.

Meera (2013) observed that the PEB methodology is a special and versatile concept of an industrial building. This pre-engineering methodology is special and unique, due to the less weight also its pre-design and also its economical construction. This PEB concept includes providing the sections up to its best requirements. This paperwork is a relative understanding between Conventional Building concept and pre-engineering building concept. This PEB concept can be designed for structures which can be relocated. For the modelling and construction of a single storey steel industrial structures, hot-rolled sections, steel rods and cold-formed sections, and other members are used. In this work first the methods adopted are been discussed and a brief preamble to Pre Engineering Building and Conventional Building with a detailed case study has been provided. And further load and its combination are defined and explained and also about the software staad pro and its importance and other literature studies are depicted. The work in this paper mainly aims at establishing and developing an approach to the design and advanced concepts of Pre-engineering single storey building structures and its preference over Conventional Building structures. It is observed from the paper that PEB costs 30 % less than CSB frame for the certain span and eave height as discussed in this work which concludes that PEB is more beneficial than Conventional Steel Building.

Jatin Thakar, Patel (2013) sees that PEB structure are steel building wherein the surrounding individuals and different parts are completely planned and produced in the plants and passed on to the site for assembling, predominantly by nut-screws, in this manner coming about into a steel structure of high gauge and precision. In customary steel improvement, we have site welding included, which isn't the circumstance in P.E.B utilizing the mechanism of nut and bolt. For primary framing, these structures use hot rolled tapered sections and for secondary framing, these structures use cold form sections (considered Z and Channel sections) as per internal pressure necessities, in this manner reducing wastage of steel and dead load of the structure and in this way leads to lighter foundations.

In this journal PEB structure warehouse of 25m, 30 m, 40 m with 6m eave tallness have been investigated and planned by utilizing staad pro and conduct is studied. And furthermore, it has been looked at to discover in which case it will achieve economy in steel tonnage by changing the different bay spacing of frames and the outcomes have been graphically plotted to dependent on various comparisons and it is clearly noticeable that PEB relies upon the different parameter changes in itself.

3. OBJECTIVES

The objective of the study is to improve the design of a Industrial Gable Warehouse Building.

1. To prepare 2-D models of Pre-engineering building frame, Conventional building frame with Pratt truss, Lattice Girder frame for 2-D analysis using STAAD pro v8i software.
2. According to Indian standards Manually calculate the Dead load, Live load, wind load and assign the same loads accordingly onto the Models prepared in the software.
3. To Design sections for sidewall Girts and rafter Purlins manually and use the same sections to the 3-D models prepared using the above 2-D models with a suitable frame to frame spacing.
4. Comparison between 2-D models of P.E.B, Conventional, Lattice girder frame for steel tonnage separately for Intermediate frame and End frame.
5. Comparison between 3-D completed models of P.E.B, Conventional, Lattice girder building for steel tonnage.
6. Propose an Economical and Feasible Industrial Gable frame considering above comparisons.

4. METHODOLOGY

1. All the necessary information such as Building plans, Length, Height and Span of P.E.B, Conventional building and Lattice Girder type building is decided based upon the most common industrial building construction practices in India.
2. A detailed study and investigation of the behaviour of P.E.B, Conventional pitched Pratt truss type building frame and Lattice girder type building frame by keeping the Span and Height constant for all types of alternatives along with wind forces as critical load condition, are main parameters of the study.
3. The Dead load and Live load and Wind load will be calculated using Indian standards 875.
4. The Designing of different type of frames considered is performed using Indian Standard code 800-2007 (Limit State Design).
5. The steel Mainframes are Analyzed and Designed by using F.E.M based software STAAD PRO.
6. The steel frame is subjected to different load combination and frame sections are optimized by using the technique of bending moment profile in P.E.B and in constant continuous sections for the other two types of frames.

7. Manual designs of purlins and girts will be done accordingly and will be checked with the software results.
8. The present study mainly will be concentrated on the comparison between P.E.B, Conventional steel truss building and Lattice girder frames for steel Take-off or tonnage.

5. NUMERICAL EXAMPLE

5.1 CONVENTIONAL STEEL BUILDING WITH PITCHED PRATT TRUSS

1) Plan Dimensions: **22.5m x 48 m**

Width= **22.5m** Length= **48m**

2) Place of Construction: **Bengaluru**

3) Eave Height: **12m**

4) Bay Spacing: **6 m**

5)Roof Angle: **19°**

6) Percentage of Openings in the building: **5%-20% (medium openings)**

7) Roof Type: **PITCH ROOF**

Dead Load Calculation

Intermediate Nodal point Dead Load = 54.675/10= **5.467 kN**

End Nodal Dead Load= 5.467/2= **2.73 kN**

Live Load Calculation

Intermediate Nodal Live Load = 76.95/10= **7.695 kN**

End Nodal Live Load = 7.695/2= **3.847 kN**

Design Wind Pressure

Vz = Vb x k1 x k2 x k3 x k4 = 33 x 0.94 x 0.934 x 1.0 = **28.97m/s**

Design wind pressure(pz) = 0.6 Vz^2 = 0.6 x 28.97^2 = **0.504 kN /m²**

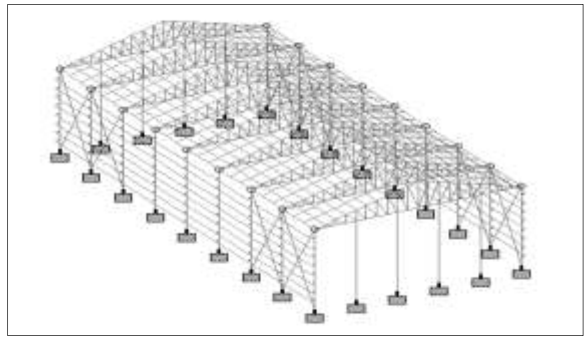

fig 5.1 A 3-D view of Industrial building with Pratt truss

5.2 PRE ENGINEERED BUILDING

1) Plan Dimensions: **22.5m x 48 m**

Width= **22.5m** Length= **48m**

2) Place of construction: **Bengaluru**

3) Eave Height : **12m**

4) Bay Spacing : **6 m**

5)Roof Angle : **1:10 = 5.71°**

6) Percentage of Openings in the building **: 5%-20%**

7) Roof Type**: PITCH ROOF**

8) Intensity of Live Load: **0.75 kN/m²**

Dead Load Calculation

Total Dead Load Including Purlin **= 0.364 kN/m**

Live Load Calculation

Live Load Per meter Length of Purlins = 0.75 x 1.4 = **1.05 kN/m**

Design Wind Pressure

Design wind pressure(pz) = 0.6 Vz^2 = 0.6 x 28.97^2 = **0.504 kN /m²**

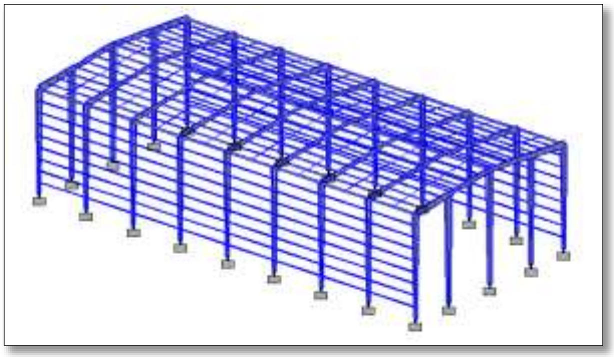

fig 5.2 A 3-D view of Industrial building with Pratt truss

5.3 LATTICE GIRDER FRAME BUILDING

1) Plan Dimensions: **22.5m x 48 m**

Width= 22.5m Length= 48m

2) Place Of Construction: **Bengaluru**

3) Eave Height : **12m**

4) Bay Spacing : **6 m**

5)Roof Angle : **= 10°**

6) Percentage of Openings **: 5%-20%**

7) Roof Type**: PITCH ROOF**

8) Intensity of Live Load : **0.75 kN/m2**

Dead Load Calculation

Total amount of Dead Load Including Purlin **= 0.343 kN/m**

Live Load Calculation

Live Load Per Meter Length of Purlins = 0.75 x 1.3 = **0.975 kN/m**

Design Wind Pressure

Design wind pressure(pz) = 0.6 Vz2 = 0.6 x 28.972 = **0.504 kN /m2**

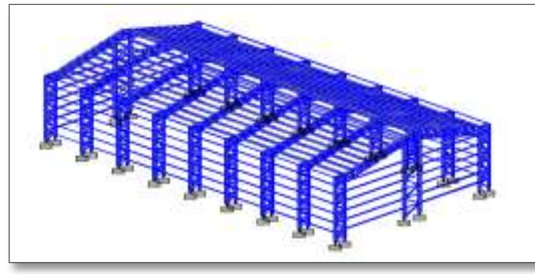

fig 5.3 A 3-D view of Industrial building with Pratt truss

6. RESULTS AND DISCUSSION

Lattice girder, Pre-engineered buildings are compared and consumption of steel quantity in terms of tonnage is brought out.

a) Graphical Representation of Steel Tonnage Comparison for different types of Gable Industrial 2-D intermediate frames as shown in fig 6.1 below.

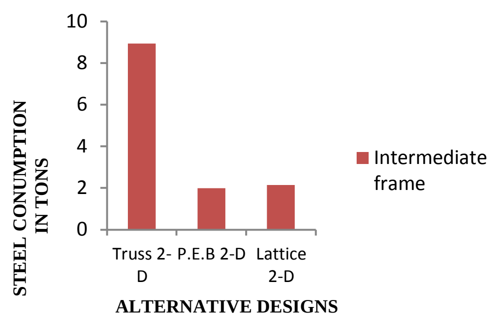

Fig 6.1 Steel Tonnage Comparison For Different Types of Gable Industrial 2-D Intermediate Frames

b) Graphical Representation of Steel Tonnage Comparison for different types of Gable Industrial 2-D End frames as shown in fig 6.2 below.

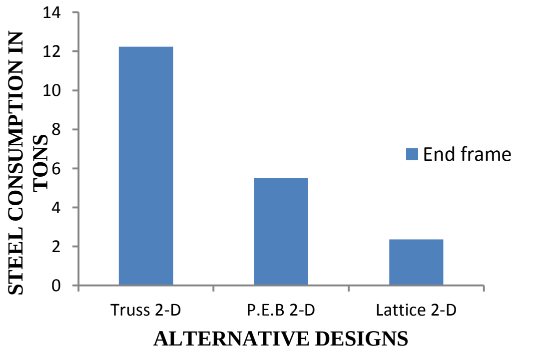

Fig 6.2 Steel Tonnage Comparison For Different Types of Gable Industrial 2-D End Frames

c) Graphical Representation of side by side Steel Tonnage Comparison for different types of gable industrial 2-D Intermediate and Gable End Frames as shown in fig 6.3.

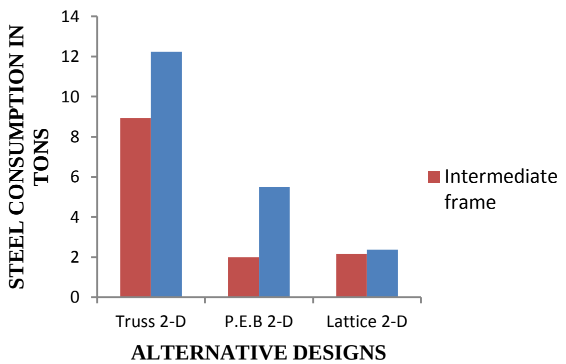

Fig 6.3 Steel Tonnage comparison for different Designs of Gable Industrial 2D frames

d) Graphical Representation of Steel Tonnage Comparison for different types of Gable Industrial 3-D structures as shown in fig 6.4.

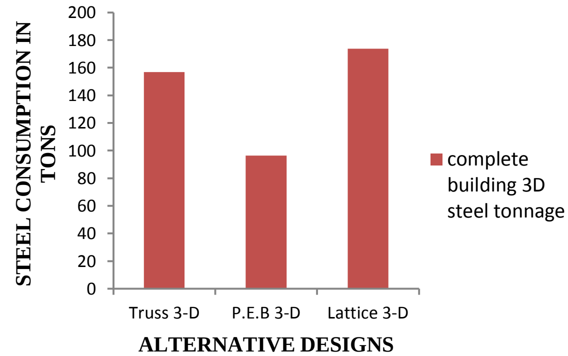

Fig 6.4 Steel Tonnage comparison for different types of gable industrial 3-D structures.

7. CONCLUSIONS

In the 2-D and 3-D Analysis of conventional Pratt truss frame, Pre engineered building frame, Lattice Girder frame the following conclusions can be made in terms of percentage of steel savings.

a) 2-D Analysis of Intermediate Frames

Steel consumption in Intermediate frames for the case of Conventional Pratt truss type Industrial frame is **77%** more than that of Pre engineered building and **75%** more than Lattice girder frame .So, by this we can conclude that Pre engineered building is more economical than Conventional and Lattice girder type building but from the Fig 6.1 we can also suggest that Lattice girder frame is nearly economical as that of pre engineered building.

b) 2-D Analysis of End Frames

Steel consumption in End frames for the case of Conventional Pratt truss type Industrial frame is **55%** more than that of Pre engineered building and **80%** more than Lattice girder frame .So, by this we can conclude that Lattice Girder type frame is more economical than Conventional and Pre engineered building. The reason for P.E.B not being economical option in the case of End frame is because of more number of Intermediate columns between the main columns. Whereas in Lattice girder End frame, the end frame is taken care by one single Lattice column connecting to ridge point.

c) 3-D Analysis

Steel consumption in case of Lattice girder building is **44%** more than Pre engineered building and **9%** more than that of Conventional Pratt truss type building and also Pre engineered building consumes **38%** less steel than that of Conventional Pratt truss type building with this we can suggest and conclude that Pre Engineered Building is more economical in terms of steel consumption than other two alternative designs.

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