DESIGN AND ANALYSIS OF PRE-ENGINEERED STEEL FRAME

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Abstract:- 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. The present work involves the analysis and design of Pre Engineered Buildings (PEB). Examples have been taken for the study. Wind analysis has been done manually as per IS 875 (Part III) – 1987.

Keywords:- Pre-Engineered-Buildings; Staad Pro; Steel Take-off; Tapered Sections.

Typical PEB Steel structure
I. 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 (PEB). 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 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 behaviour 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 in future. In this paper we will discuss the various advantages of pre-engineered buildings and also, with the help of three examples, a comparison will be made between pre-engineered buildings and conventional steel structures.

- **Pre Engineered Buildings**

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.

- **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 Spans**: 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 coats.

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 labor requirement.

From the numerous advantages of Pre-engineered building, in the present study, the point b is considered for the study, i.e. to save the steel and reducing cost.

II. Design Criteria

DESIGN METHOD: Allowable stress design method is used as per the INDIAN specifications.

DEFLECTIONS: Unless otherwise specified, the deflections as per INDIAN criteria and standard industry practices.

PRIMARY FRAMING: Moment resisting frames with pinned or fixed bases.

SECONDARY FRAMING: Cold formed Z sections or C sections for purlins or girts designed as continuous beams spanning over rafters and columns with laps.

LONGITUDANAL STABILITY: Wind load on building end walls is transferred through roof purlins to braced bays and carried to the foundations through diagonal bracing.

DESIGN SOFTWARE: The latest software that is used for design is STAAD 2007 & MBS Software.

ANALYSIS AND DESIGN OF PEB

In this present work, Staad Pro software has been used in order to analyze and design Pre-engineered building structure. In the below example, a 2D plane frame of length 50 m, width 38.1m and bay spacing 6.25 m has been designed and weight of steel is shown.

Structural Analysis and Design

STAAD Pro software can be used for analyzing and designing of the pre-engineered buildings. It gives the Bending Moment, Axial Forces, Shear Forces, Torsion, Beam Stresses of a steel structure so that the design can be done using tapered sections and check for the safety.

Static Analysis

In the present work, using the Staad Pro software. All the components of Pre-engineered building are tapered using the in-built option of the Software. The software provides options for hinged, fixed, and spring supports with releases so as to analyze as per our requirement. Herein this work, Pinned supports are assigned to the structures. It also facilitates Linear, P-Delta Analysis, and Non-Linear Analysis with automatic load. Multiple analyses can also be done simultaneously which reduces the time. It also has an option of assigning members as tension-only members and compression-only members for truss structures.

Dynamic Analysis

Dynamic analysis has been done in the present work taking wind loads into consideration. The software provides automatic load generation for wind forces, however, the wind loads are calculated manually for the present work as per IS codes. The software also provides Loading for Joints, Members/Elements including concentrated, Uniform, Linear, Trapezoidal, Temperature, Strain, Support Displacement, Pre-stressed and Fixed - end Loads. It also provides the facility of combination of Dynamic forces with Static loading for subsequent design.

EXAMPLE 1- INDUSTRIAL SHED

Statement of the Problem

In this Example a comparison of 2D Plane Frame is made for both pre-engineered building and conventional type. The plane frame is having width 38.1 m and bay spacing 6.25 m and eave height 8.2 m, subjected to wind load. A typical 2D PEB frame is shown in Fig 1.
Design Data:

Main Frame-
Frame Type - Clear Span, Rigid Frame.
Support- Pinned
Building Width (W) – 38.10 m (C/C Steel Columns)
Building Length (L) – 50 m (C/C Steel Columns)
Bay Spacing- 6.25 @ 8 m
Clear height- 7.2 m
Roof Slope- 1 in 10

Grits Type-
Sidewall grits- Continuous
End wall grits- Continuous

Purlin Type-
Roof Purlin- Continuous
Spacing- 1.5m c/c

Panel Type-
Roof- Galvanized sheet.

LOAD CALCULATIONS

Calculation of static loads:

Dead loads are considered as per Table-2 of IS 875 (Part-1) – 1987
Weight of the G.I sheeting = 0.05 kN/m2 (class 1 G.I sheeting, thickness 0.5 mm)
Self-weight of section = 0.05 kN/m2
Total weight = 0.10 kN/m2
Spacing of purlin = 1.5 m
Bay spacing = 6.25 m
Total weight on frame = 0.10 x 6.25 = 0.625 kN/m

Live load are considered as per Table-2 of IS 875 (Part-2) – 1987
Live load on the sloping roof = 0.75 kN/m2
Live load on rafter = 0.75 x 6.25 = 4.69 kN/m

Calculation of Wind Loads:
Wind loads are calculated as per IS 875 Part III (1987), in this example. For the Present work, the basic wind speed (Vb) is assumed as 50 m/s and the building is considered to be open terrain with well scattered obstructions having height less than 10m with maximum dimension more than 50m and accordingly factors K1, K2, K3 have been calculated as per IS 875 Part III (1987). Terrain Category- 2, Class- C K1- Probability factor- 1.0
K2- Terrain, height and size factor- 0.93
K3- Topography factor- 1

Design wind speed, Vz = Vb (K1 x K2 x K3) Vz = 46.50 m/s
Design pressure, P= 0.6 Vz² = 1.29 kN/m²
Ratio- H/W=0.19, L/W= 0.98

**WIND LOADS**

*Wind Coefficient*

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<th>Length (m)</th>
<th>Weight (t)</th>
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Profile Length (m) Weight (t)

LOAD 6 WL2
MEMBER LOAD
1 2 UNI GX 11.35
6 8 10 12 UNI Y 1.95
7 9 11 13 UNI Y -2.43
3 4 UNI GX -3.65

LOAD 7 WR1
MEMBER LOAD
7 9 11 13 UNI GY 13.29

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250 – 255
Weight of the steel for the PEB with primary frame spacing 6.25 m

In order to calculate steel weight of PEB of primary frame spacing 6.25 m the following member properties are used (Table 8). For columns and rafters Tapered “I” sections are assigned. For the purlins and girts cold formed “Z” sections are used. For bracings Indian standard angle sections are used. Now using the above parameters the lengths and weights are calculated accordingly.

Table 8 Steel take-off for the PEB with primary frame spacing 6.25 m

| LOAD 8 WR2 | MEMBER LOAD | 3 4 UNI GX -11.35 | 7 9 11 13 UNI Y 1.95 | 6 8 10 12 UNI Y -2.43 | 1 2 UNI GX 3.65 |
| LOAD 9 LW1 | MEMBER LOAD | 1 2 UNI GX -9.73 | 6 8 10 12 UNI Y 12.16 | 7 9 11 13 UNI Y 12.16 | 3 4 UNI GX 9.73 |
| LOAD 10 LW2 | MEMBER LOAD | 1 2 UNI GX 1.62 | 6 8 10 12 UNI Y 0.81 | 7 9 11 13 UNI Y 0.81 | 3 4 UNI GX -1.62 |

Total = 36.818

1. APPLICATIONS

- Industrial Buildings
- Warehouses
- Commercial Complexes
- Showrooms
- Offices
- Schools
- Indoor Stadiums
- Outdoor Stadiums with canopies
- Gas Stations
- Metro Stations, Bus Terminals, Parking Lots
- Primary Health Centers, And many more…

CONCLUSION

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. Based on the analytical and design results thereon of conventional and pre-engineered steel buildings, the following conclusions are drawn.

It is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces and further increase makes the weight heavier.

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 areas are needed”.

REFERENCES

