A Comparative Study of Pre-Engineered and Conventional Multi-Span Industrial Building

Jyotsna, shivaraj mangalgi

Abstract: Steel is one of the oldest construction materials and become a popular construction material in late seventeenth and eighteenth century. Environment friendly, rapid construction, easy availability and better fire rating are some of inherent advantages of steel construction. In current modern world, steel structure contributes a highest number of industrial buildings and sheds in the world building inventory. Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. This particular study includes the design of industrial storage structure which is situated in Mangalore. The actual structure is of pre-engineered structure of 90m width of three spans each span 30m width, and running 42m length and of eave height 6m with roof slope 1:10. The analysis and design is carried out by considering the live loads, dead loads, wind loads and earthquake load using relevant IS codes for the given PEB structure. The whole Pre-engineered building and Conventional steel structure is analyzed by using staad pro V8i SS6 software and designed by limit state method as per IS 800-2007. The moment, shear force and axial force decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness. Deformation decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness. Base shear and displacement decreases in PEB structure as compared to CSB structure, due to increase in stiffness. The percentage decrease in weight in PEB structure is 16.28% in comparison to CSB structure, hence cost of PEB structure reduces. Reduction in steel quantity reduces the dead load ultimately reduces the size of the foundation.

Keywords: pre-engineered building, STAAD pro.

I. INTRODUCTION

Structures are one of the most seasoned development exercises of people. The development innovation has progressed since the start from crude development innovation to the present idea of current house structures. The present development technique for structures requires the best stylish look, excellent and quick development, financially saving and creative touch.

Steel Buildings

It is the material of the decision for the outline since it is naturally pliable and adaptable, it flexes under extraordinary loads as opposed to smashing and disintegrating. Auxiliary steels ease, quality, solidness, outline adaptability, flexibility and recyclability keep on making it the material of decision in building development. The present auxiliary steel encircling is bringing beauty, craftsmanship and capacity together in relatively boundless ways and is putting forth new arrangements and chances to make testing structures, which were once thought unthinkable. Steel structures have hold quality; basic "stick" outline in the steel framings enables development to continue quickly from the beginning of erection.

Conventional Steel Buildings

Traditional steel structures are specialist and preservationist. The auxiliary individuals are hot rolled and are utilized as a part of regular structures. The materials are created or made in the plant and are moved to the site. The crude materials are prepared in the site for the coveted from and rose. The changes should be possible amid erection by cut and weld process. Here Truss frameworks are used as a part of ordinary frameworks.

Pre Engineered Steel Buildings

Pre-designed steel structures are fabricated or delivered in the plant. The assembling of auxiliary part is done on client prerequisites. The point by point structure individuals are intended for their separate area and are numbered, which can't be modified; in light of the fact that individuals are fabricated concerning configuration includes these segments are made in particular or totally thumped condition for transportation. These materials are transported to the client site and are raised welding and cutting procedure are not performed at the client site. No assembling procedure happens at the client site.

II. OBJECTIVES

Main objective of the project is to analyze the industrial structure for different load cases. Analysis and design of the structure carried out with STAAD. Pro software using IS codes.

A. To analyze the multi span pre-engineered industrial building for wind and earthquake load.
B. To analyze the multi span conventional industrial building for wind and earthquake load.
C. Comparisons of results between pre-engineered building and conventional steel building using staad pro analysis.

III. REVIEW CRITERIA

1) S.D. Charkha and Latesh S (June 2014)

Observes that, the excess of steel can be reduced by tapering the sections of pre engineering buildings as compared to conventional steel buildings as result of reducing the steel quantity the dead load is also reduced and also size of the foundation can be reduced. Using of PEB increase the Aesthetic view of structure.

2) C.M.Meera(June2013)

Observes that the Pre- Engineered Building (PEB) concept is a new concept especially for single storey industrial building construction. This method is adopted not only for its quality of pre-designing and prefabrication, but also for its light weight and economical in construction.
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The concept includes providing tapered sections for columns and rafters so that excess of steel can be reduced. In this paper the comparisons between PEB and CSB is studied. Pre-Engineered Building concept can be applied including warehouses, metro stations, factories, auditoriums, offices, gas stations, showrooms, vehicle parking sheds, aircraft hangars, workshops, schools, indoor stadium roofs, outdoor stadium canopies, recreational buildings, railway platform shelters, bridges, etc.

IV. METHODOLOGY

This particular study includes the design of industrial storage structure which is situated in Mangalore. The actual structure is of pre-engineered structure of 90m width of three spans each span 30m width, and running 42m length and of eave height 6m with roof slope 1:10. The analysis and design is carried out by considering the live loads, dead loads, wind loads and earthquake load using relevant IS codes for the given PEB structure. The whole Pre-engineered building and Conventional steel structure is analyzed by using staad pro V8i SS6 software and designed by limit state method as per IS 800-2007.

Table 1 Partial Safety Factors for Loads, (Yf), For Limit States

| Load combinations | Partial safety factors for loads,(Yf) , for limit states |
|-------------------|--------------------------------------------------|
|                   | Limit state of strength | Limit state of serviceability (deflection and support reaction) |
|                   | D  | L  | W  | E  | L  | W  | E  | L  | W  | E  |
| DL+L+CL           | 1  | 1.5| 1.05|    | 1  | 1  | 1  |    |    |    |
|                   | DL| Leading | Accompanying | W L/ E | L | DL | Leading | Accompanying | W L/ E |
| DL+L+CL EL+WL(A)  | 1  | 1.2| 1.05| 0  | 6  | 1  | 0.8| 0.8|    |    |
| DL+L+CL EL+WL(B)  | -  | - | 0.53| 1  | 2  | 1  | -  | -  |    |    |
| DL+L EL           | 1  | -  | -  | 1  | 5  | 1  | -  | -  |    |    |

Fig: 1 SECTION OF PROPOSED STRUCTURE

Fig: 2 END VIEW OF A PEB BUILDING

Fig: 3 PLAN OF A PEB BUILDING

Fig: 4 FULL SECTION OF A PEB BUILDING

V. CALCULATION OF WIND PRESSURE:

Steps to be followed for analysis and design:

- Load calculation
- Preparing model
- Assigning materials and material properties
- Assigning loads and load combinations
- Run and analyse the model
- Design the components of structure by using analysis results
Typical Load Combinations

Table 2: Load Combinations Considered

| IS800-2007          |
|---------------------|
| **Limit state of serviceability:** |
| (DL+LL)             |
| (DL+LL+WL/EL)       |
| **Limit state of strength:** |
| 1.5*(DL+LL)         |
| 1.5*(DL+LL+WL/EL)   |

As per clause 5.3 of IS: 875(part 3)-1987, we have

\[ V_z = V_b \times K_1 \times K_2 \times K_3 \]

Where, \( V_z \) = design wind speed at any height
\( V_b \) = basic wind speed at given location
\( K_1 \) = probability factor or risk co-efficient
\( K_2 \) = terrain, height and structure size factor
\( K_3 \) = topography factor

Project location is “MANGALORE”,

Basic wind speed value for mangalore region as per clause 5.2 we have

\( V_b = 39 \text{ m/s} \)

For basic wind speed of 33m/s and for all general buildings and structures as per clause 5.3.1

\( K_1 = 1 \)

The value of topography factor from clause 5.3.3 of IS: 875 (part 3)-1987

\( K_2 = 0.98 \)

Value for wind slope of less than 3° as per clause 5.3.3.1 we have

\( K_3 = 1 \)

Wind pressure \( P_z \) is calculated by using the following formula as per clause 5.4

\[ P_z = 0.6 \times V_z^2 \]

Design wind speed \( (V_z) \) = 38.22 m/s
Design wind pressure \( (P_z) \) = 0.876 kN/m²

| Height(m) | \( K_2 \) | \( V_z \)(m/s) | \( P_z \)(KN/m²) |
|-----------|----------|----------------|-----------------|
| 7.5       | 0.98     | 38.22          | 0.876           |

Fig:6 PROPOSED PEB MODEL BY STAAD.Pro

SEISMIC ANALYSIS:
The analysis of pre engineering building is analyzed by STAAD.Pro software the pre engineering building is studied and which is subjected with seismic force actions under seismic zone III since structure is located in Mangalore.

The following factors to be considered for seismic definition:

1. Response reduction factor \( R = 5 \)
2. Importance factor \( I = 1.0 \) for industrial steel building
3. Soil type \( S = \) medium soil
4. Damping \( D = 5\% \)
5. Load combinations considered as 1.5 (DL+LL) from IS 800-2007

Axial Force, Bending Moment And Displacements Are Shown In Below Diagrams For PEB

Fig:7 Maximum Displacement

Fig:8 Maximum Axial Force
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Axial Force, Bending Moment And Displacements Are Shown In Below Diagrams For Csb

Table 3: Bending Moment, Shear Force, Axial Force and Deflection in Column and Rafter of CSB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|-----------------------------|------------------------|-----------------------|------------------------|
|       | Column | Rafter | Column | Rafter | Column | Rafter | Column | Rafter | Column | Rafter |
| 1     | DL+LL  | 95.68  | 108.27 | 61.256 | 37.26 | 5.024 | 61.27 | 67.59 | 12.237 |
| 2     | DL+LL+WL| 184.73 | 181.87 | 110.56 | 71.24 | 10.006 | 86.06 | 110.18 | 30.412 |
| 3     | DL+LL+EL| 174.35 | 130.76 | 75.83 | 54.87 | 7.958 | 72.55 | 84.23 | 21.144 |

Table 4: Bending Moment, Shear Force, Axial Force and Deflection in Column and Rafter of PEB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|-----------------------------|------------------------|-----------------------|------------------------|
|       | Column | Rafter | Column | Rafter | Column | Rafter | Column | Rafter |
| 1     | DL+LL  | 71.23  | 62.48  | 52.36 | 46.28 | 6.019 | 21.23 | 41.77 | 9.234 |
| 2     | DL+LL+WL| 112.56 | 110.82 | 75.26 | 67.25 | 9.688 | 34.72 | 84.23 | 25.57 |
| 3     | DL+LL+EL| 94.88  | 86.94  | 69.07 | 53.89 | 8.256 | 28.927 | 68.29 | 13.81 |
### Table 5: Bending Moment, Shear Force, Axial Force and Deflection in Purlin and Girt of CSB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|----------------------------|-----------------------|-----------------------|-----------------------|
|       |                  | Purlin | Girt | Purlin | Girt | Purlin | Girt | Purlin | Girt | Purlin | Girt |
| 1     | DL+LL            | 4.78   | 2.15 | 4.44   | 2.71 | 9.06   | 2.01 | 2.87   | 1.94 |
| 2     | DL+LL+WL        | 9.67   | 4.63 | 6.84   | 4.37 | 15.10  | 6.08 | 6.44   | 3.71 |
| 3     | DL+LL+EL        | 7.96   | 3.84 | 5.08   | 3.34 | 12.14  | 4.98 | 5.83   | 3.10 |

### Table 6: Bending Moment, Shear Force, Axial Force and Deflection in Purlin and Girt of PEB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|----------------------------|-----------------------|-----------------------|-----------------------|
|       |                  | Purlin | Girt | Purlin | Girt | Purlin | Girt | Purlin | Girt | Purlin | Girt |
| 1     | DL+LL            | 4.83   | 1.18 | 1.93   | 1.03 | 9.84   | 3.93 | 1.57   | 0.97 |
| 2     | DL+LL+WL        | 6.93   | 3.34 | 3.72   | 2.98 | 12.03  | 5.75 | 3.67   | 2.82 |
| 3     | DL+LL+EL        | 5.45   | 2.75 | 2.24   | 1.76 | 11.05  | 4.84 | 2.33   | 1.54 |

### Table 7: Bending Moment, Shear Force, Axial Force and Deflection in Base Plate and Bracing of CSB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|----------------------------|-----------------------|-----------------------|-----------------------|
|       |                  | Base plate | Bracing | Base plate | Bracing | Base plate | Bracing | Base plate | Bracing |
| 1     | DL+LL            | 47        | 32      | 16        | 6       | 6.89     | 6.12    | 37.86    | 11.75   |
| 2     | DL+LL+WL        | 65        | 54      | 35        | 12      | 10.28    | 9.28    | 53.23    | 16.24   |
| 3     | DL+LL+EL        | 58        | 44      | 28        | 10      | 9.06     | 8.74    | 45.55    | 15.02   |

### Table 8: Bending Moment, Shear Force, Axial Force and Deflection in Base Plate and Bracing of PEB Structure

| SI NO | Load Combination | Max. Bending Moment in KN-m | Max. Shear Force in KN | Max. Deflection in mm | Max. Axial Force in KN |
|-------|------------------|----------------------------|-----------------------|-----------------------|-----------------------|
|       |                  | Base plate | Bracing | Base plate | Bracing | Base plate | Bracing | Base plate | Bracing |
| 1     | DL+LL            | 32.94     | 19.88   | 15.95     | 4.45    | 6.67     | 3.97    | 20.05    | 6.24    |
| 2     | DL+LL+WL        | 54.08     | 36.28   | 27.22     | 7.25    | 10.27    | 5.04    | 41.97    | 10.93   |
| 3     | DL+LL+EL        | 45.92     | 29.17   | 21.78     | 6.98    | 8.75     | 4.66    | 34.82    | 9.82    |

### Table 9: Design Forces for CSB

| Components | Moment in KN-m | Axial Force in KN | Shear Force in KN | Deflection in mm |
|------------|----------------|-------------------|-------------------|------------------|
| Column     | 184.048        | 110.18            |                   |                  |
| Rafter     | 45.483         | 30.412            |                   |                  |
| Purlin     | 9.67           |                   | 6.84              | 15.1             |
| Girt       | 4.63           |                   | 4.37              | 6.08             |
| Base plate | 65             | 53.23             | 35                |                  |
| Bracings   | 16.24          |                   | 12                |                  |
### Table 10: Design Forces for PEB

| Components   | Moment in KN-m | Axial Force in KN | Shear Force in KN | Deflection in mm |
|--------------|----------------|------------------|------------------|------------------|
| Column       | 112.56         | 84.23            |                  |                  |
| Rafter       | 110.82         | 25.57            |                  |                  |
| Purlin       | 6.93           |                  | 3.72             | 12.03            |
| Girt         | 3.34           |                  | 2.98             | 5.75             |
| Base plate   | 54.08          | 41.97            | 27.22            |                  |
| Bracings     | 10.93          |                  |                  | 7.25             |

### Comparison of bending moment (KN-m) in various components of CSB and PEB

#### Comparison of Axial force (KN) in various components of CSB and PEB
Comparison of Shear force (KN) in various components of CSB and PEB

| Component     | CSB | PEB |
|---------------|-----|-----|
| Column        |     |     |
| Rafter        |     |     |
| Purlin        |     |     |
| Girt          |     |     |
| Base Plate    |     |     |
| Bracing       |     |     |

Comparison of deflection (mm) in various components of CSB and PEB

| Component     | CSB | PEB |
|---------------|-----|-----|
| Column        |     |     |
| Rafter        |     |     |
| Purlin        |     |     |
| Girt          |     |     |
| Base Plate    |     |     |
| Bracing       |     |     |

Table 11: Displacement

| Seismic Zone | Height (m) | Displacement (cm) for PEB | Displacement (cm) for CSB |
|--------------|------------|---------------------------|---------------------------|
| ZONE III     | 0          | 0                         | 0                         |
| ZONE III     | 3          | 0.0586                    | 0.0612                    |
| ZONE III     | 6          | 0.0618                    | 0.0724                    |
| ZONE III     | 7.5        | 0.0915                    | 0.0995                    |

Table 12: Base shear

| Structure | Zone | Z | Time (sec), T=0.085h0.75 IS 1893:2016 | Sa/g | Ah | Weight of structure (kN) | Base Shear, VB=Ah x W(kN) |
|-----------|------|---|-------------------------------------|------|----|-------------------------|---------------------------|
| CSB       | 11   | 0.16 | 0.365                              | 2.5  | 0.04 | 94000                   | 3760                      |
| PEB       | 11   | 0.16 | 0.365                              | 2.5  | 0.04 | 78900                   | 3156                      |
VI. RESULT AND DISCUSSION

1. The both structural components of CSB and PEB are analysed and designed by STAAD.Pro vi software.

2. The section of structural components used in CSB are
   - RAFTER: ISMB450
   - COLUMN: ISMB300
   - PURLIN and GIRTS: ISMC 150
   - BRACINGS (side and roof bracings): 60x60x8mm

3. The section of structural components used in PEB(TAPERED) are
   - F1: Depth of section at start node
     - COLUMN: F1=0.35m, F3=0.7m
     - RAFTER: F1=0.35m, F3=0.35m
   - PURLIN and GIRTS: Z 200mmX1.5mm
   - BRACINGS (side and roof bracings): RD-60mm

4. From table 3 and 4, it seen that the moment, Axial Force, deflection and shear force in Column in case of CSB and PEB are 184.73KN-m, 110.18KN, 10.006mm and 110.56KN and 112.56KN-m, 84.23KN, 9.688mm and 75.26KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 39.06%, 23.55%, 3.18% and 31.92% respectively in comparison to CSB structure.

5. From table 3 and 4, it seen that the moment, Axial Force, deflection and shear force in Rafter in case of CSB and PEB are 181.87KN-m, 30.412KN, 86.06mm and 71.24KN and 110.82KN-m, 25.57KN, 34.72mm and 67.25KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 39.06%, 15.92%, 59.65% and 5.6% respectively in comparison to CSB structure.

6. From table 5 and 6, it seen that the moment, Axial Force, deflection and shear force in Purlin in case of CSB and PEB are 9.67KN-m, 6.44KN, 15.10mm and 6.84KN and 6.93KN-m, 3.67KN, 12.03mm and 3.72KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 28.33%, 43.01%, 20.33% and 45.61% respectively in comparison to CSB structure.

7. From table 5 and 6, it seen that the moment, Axial Force, deflection and shear force in Girt in case of CSB and PEB are 4.63KN-m, 3.71KN, 6.08mm and 4.37KN and 3.34KN-m, 2.82KN, 5.75mm and 2.98KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 27.86%, 24.59%, 5.43% and 31.8% respectively in comparison to CSB structure.

8. From table 7 and 8, it seen that the moment, Axial Force, deflection and shear force in Base plate in case of CSB and PEB are 65KN-m, 53.23KN, 10.28mm and 35KN and 54.08KN-m, 41.97KN, 10.27mm and 27.22KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 16.8%, 21.15%, 0.1% and 22.23% respectively in comparison to CSB structure.

9. From table 7 and 8, it seen that the moment, Axial Force, deflection and shear force in Bracing in case of CSB and PEB are 54KN-m, 16.24KN, 9.82mm and 12KN and 36.28KN-m, 10.93KN, 5.04mm and 7.25KN respectively. The percentage decrease in moment, Axial Force, deflection and shear force in PEB structure is 32.81%, 32.67%, 48.67% and 39.58% respectively in comparison to CSB structure.

10. From table 11, it seen that the average displacement in case of CSB and PEB are 0.0995cm and 0.0915cm respectively. The percentage decrease in average displacement in PEB structure is 8.04% in comparison to CSB structure.

11. From table 12, it seen that the Base shear in case of CSB and PEB are 3760KN and 3156KN respectively. The percentage decrease in Base shear in PEB structure is 16.06% in comparison to CSB structure.

12. From table 13, it seen that the weight of structure in case of CSB and PEB are 94000KN and 78691KN respectively. The percentage decrease in weight in PEB structure is 16.28% in comparison to CSB structure.

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VII. CONCLUSION

- The bending moment, shear force and axial force decreases in various components of pre-engineered multi-span industrial structure(PEB) as compared to conventional multi-span industrial structure(CSB), due to increase in stiffness.
- Displacement decreases in PEB structure in various components as compared to CSB structure, due to increase in stiffness.
• PEB structure subjected to seismic loading, base shear and displacement decreases in comparison to CSB structure.
• The percentage decrease in weight in PEB structure is 16.28% in comparison to CSB structure, hence cost of PEB structure reduces.
• Reduction in steel quantity reduces the dead load ultimately reduces the size of the foundation.

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AUTHORS PROFILE

JYOTSNA, a PG scholar currently studying in final year(2019-20), pursuing master of technology in structural engineering from civil engineering department, P.D.A College of Engineering. She has completed her Bachelor degree in civil engineering from P.D.A College of Engineering kalaburagi in 2018.

PROF. SHIVARAJ MANGALGI, Associate professor in the Department of Civil Engineering, PDA College of Engineering, Kalaburagi, Karnataka, India. He has an experience of 30 years in the field of teaching, guided more than 35 M-Tech students and published nearly 30 papers in the various journals.