

Cost-effectiveness of Pre-engineered and Conventional Steel frames

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ABSTRACT: Long span, column free structures are the most essential in any type of industrial structures, pre-engineered steel frames fulfil this requirement along with reduced time and cost as compared to conventional steel frames. The present paper presents the comparative study of analysis and design of pre-engineered and conventional steel frames using Staad Pro software. Analysis and design of conventional steel frame has been done in Staad Pro software and then compared with pre-engineered steel frame in terms of amount of steel required and overall cost of structure. In the present work Conventional steel frame of span 30m, length 60m and varying bay spacing and pre-engineered steel frames of same dimensions are analyzed and designed using Staad-Pro software.

KEYWORDS: Conventional steel frame, Pre-engineered steel frame, tapered sections, Staad-Pro software.

I. INTRODUCTION

Conventional steel frames are low rise steel structures with roofing systems of truss with roof coverings. Standard hot-rolled sections are usually used for the truss elements along with gusset plates. This leads to heavy and uneconomical structures. Now a day's pre-engineered steel frames are the best replacement to conventional steel frames.

Pre-engineered steel frames use a combination of built-up sections, hot rolled sections and cold form elements which provide the basic steel framework with a choice of single skin sheeting for roof and wall cladding. Pre-engineered frames can be constructed in less than half the normal time especially when compared with the other engineered subsystems. Pre-engineered steel frames can be easily expanded in length by adding additional bays. Also expansion in width and height is possible by pre designing for future expansion.

A frame lacking lateral stability against wind or earthquake loads will not be standing for long. The most popular pre-engineered structure, rigid frames, relies on its own moment – resisting ability to laterally support to the frame. Other frame systems, such as the familiar post and beam construction, do not possess such as rigidity of their own and absent of any rigid walls, may collapse like a house of cards, if pushed laterally. So nowadays the structural engineers and researchers are accepted the concept of PEB which is effective in strength and rigidity. So here is necessity to required some research work and developments considering all point of views of structural designs regarding with pre-engineered steel frames.

II. RELATED WORK

K.K.Mitra – Gen. Manager Lloyd Insulations (India) Limited (2009)⁽²⁾ studied in detail about the concept of Pre-Engineered Building, its construction system, benefits, applications and various categories of buildings. Pre-Engineered Steel Buildings use a combination of built-up sections, hot rolled sections and cold formed elements which provide the basic steel frame work with a choice of single skin sheeting with added insulation or insulated sandwich panels for roofing and wall cladding. The concept is designed to provide a complete building envelope system which is air tight, energy efficient, optimum in weight and cost and, above all, designed to fit user requirement like a well fitted glove.

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Paul McEntee, S.E., R & D Engineer for Simpson Strong – Tie (2009)⁽³⁾ has carried out the study of steel – frame structures were developed during 19th century in response to the limitations of masonry bearing wall structure were limited to about 10 stories high & allowed for only small openings because of the strength of the masonry materials, while steel frame construction using rigid frames or moment frames provide flexibility in meeting lateral – load demand and allowed for large openings. Combination of systems both vertical and horizontal combinations in same direction, the lowest R factor for calculating seismic loading is used. The challenges of meeting the code beam bracing requirements should be carefully considered when SMF used in light – framed construction. Lower R – factor for OMF results in higher design forces that may increase costs, the advantage is that OMF can be designed without beam bracing. Engineers can use the OMF's instead of SMF's beam bracing based on AISC seismic provision.

Nikhil Agrawal, Achal Kr. Mittal and V.K.Gupta (2009)⁽⁴⁾ have carried out the comparison of wind pressures for different zones of a building, is made using different international design wind codes. The selected building is analyzed for various load combinations. Wind forces were taken from different countries codes but the design of members is carried out as per Indian codes. In the present study, a building having the Howe type truss configuration is analyzed & designed for 15^o, 20^o, 25^o roof slope. For 5^o & 10^o roof slope another truss configuration is used in order to avoid higher forces in the members. The wind codes of countries India, Japan, and Australia/New-Zealand and Hong kong have been considered in the study.

Anbuchejian .A , Dr. Baskar. G (2013)⁽⁵⁾, investigation had been done to study the behavior of cold formed steel 'Z' section purlins. Three members of zinc coated cold formed 'Z' sections and ordinary cold formed Z were tested under gradually applied two points bending with simple support. The results obtained from experiments i.e. the actual deflections, the plastic moment carrying capacities are compared with theoretical values. The following conclusions are made from the experimental study.

1. The elastic moment carrying capacity is directly proportional to the cross section of the member.
2. Comparison of actual deflection at midspan section for various specimen results that, the deflection of the specimen is inversely proportional to the depth of the section and the thickness, i.e., the deflection is small for deeper section and vice versa.
3. The actual deflection for all the specimens linearly varies with the gradually increased load.

III. METHODOLOGY

In this present paper, Conventional steel frames and pre-engineered steel frames of length 60m, span 30m and varying bay spacing 4m, 5m and 6m are analysed and designed using g Staad Pro software. Eaves level for all portals is at 10m from the ground level. The EOT crane is supported at the height of 8m from ground level. Support condition for conventional steel frame and pre-engineered steel frame is pinned. All dead loads, live loads, wind load are confirming to IS: 875-1987. Earthquake loads are confirming to IS: 1893-2002.

Load combinations considered:

- 1) Dead load + Imposed load
- 2) Dead load + Imposed load + Wind load/Earthquake load
- 3) Dead load + Wind load /Earthquake load

The structural analysis and design is performed with the help of **Bentley's STAAD Pro software** which is based on finite element analysis technique, it includes the modules for generation and application of all loads, subsequent code checking of structural elements and joints and capabilities to carryout static analysis.

IV. LOAD CALCULATIONS

3.1 Modelling of conventional and pre-engineered steel frame on Staad-pro software.

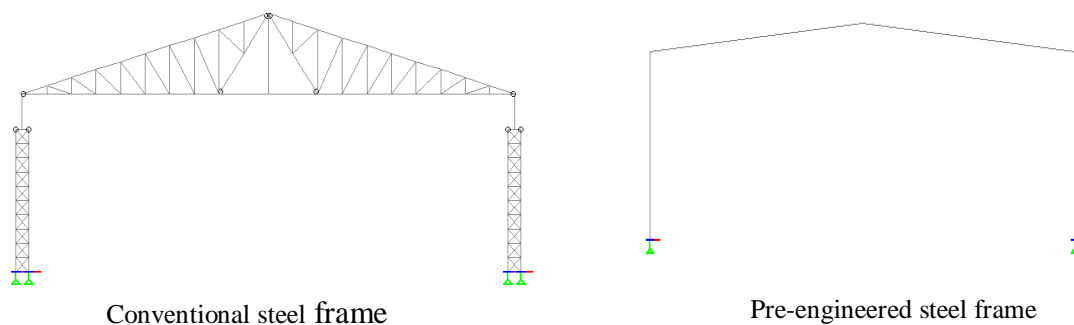


Fig. 1 Conventional and Pre-engineered steel frame in Staad Pro

3.1.1 Dead load

Calculation of dead load according to IS: 875 (Part-1)

Dead load on conventional steel frame

Purlin load – 0.4045 k N/m

Sheeting load – 0.655 kN/m

Dead load on Pre-engineered steel frame

Purlin load – 0.2725 kN/m

Sheeting load – 0.28 kN/m

3.1.2 Live load

Calculation of live load according to IS: 875 (Part 2)

Live load on conventional steel frame

Since the slope of the roof is 16.7° the live load for non accessible roof of 0.75 kN/m^2 is reduce to 0.62 kN/m^2

Intensity of load on rafter = $0.62 \times 5 = 3.1 \text{ kN/m}$

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3.1.3 Wind load

Calculation of wind load according to IS: 875 (Part 3)

Wind load on Conventional steel frame

Wind load is calculated according to IS:875 (Part 3)

Location: Bombay

Risk coefficient (k_1): 1

Structure size factor (k_2): 1.04

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Topography factor (k_3): 1

Basic wind speed (V_b): 44 m/s

Design wind velocity (V_z): $44 \times 1 \times 1.04 \times 1 = 45.8$ m/s

Design wind pressure (P_z): $0.6 \times 45.8^2 = 1.25$ kN/m²

The internal pressure coefficients are taken as +0.2 and -0.2.

Building height ratio (h/w): 0.34 and Building plan ratio (L/w): 2

External pressure coefficients (C_{pe}) for walls of rectangular clad building are taken as +0.7 and -0.25

External pressure coefficients (C_{pe}) for pitch roof of rectangular clad building are taken as -0.64 and -0.4

Wind load on individual members can be calculated by, $F = (C_{pe} - C_{pi}) \times A \times P$

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External pressure coefficients (C_{pe}) for pitch roof of rectangular clad building are taken as -0.96 and -0.4

Wind load on individual members can be calculated by, $F = (C_{pe} - C_{pi}) \times A \times P$

3.1.4 Earthquake load

Calculation of earthquake load according to IS: 1893-2002

Earthquake load on conventional steel frame

Dead load = 0.2119 kN/m²

Live load = 0.155 kN/m² (25% of reduction as per IS 1893-2002)

Total load = DL + LL = 0.367 kN/m²

Bay spacing of frame is 5m

Earthquake load on rafter = $0.367 \times 5 = 1.835$ kN/m²

Earthquake load on conventional steel frame

Dead load = 0.1105 kN/m²

Live load = 0.1875 kN/m² (25% of reduction as per IS 1893-2002)

Total load = DL + LL = 0.298 kN/m²

Bay spacing of frame is 5m

Earthquake load on rafter = $0.298 \times 5 = 1.49$ kN/m

V. RESULTS

4.1 Graphical representation of result comparison of conventional and pre-engineered steel frame of span 30m and bay spacing 4m, 5m and 6m.

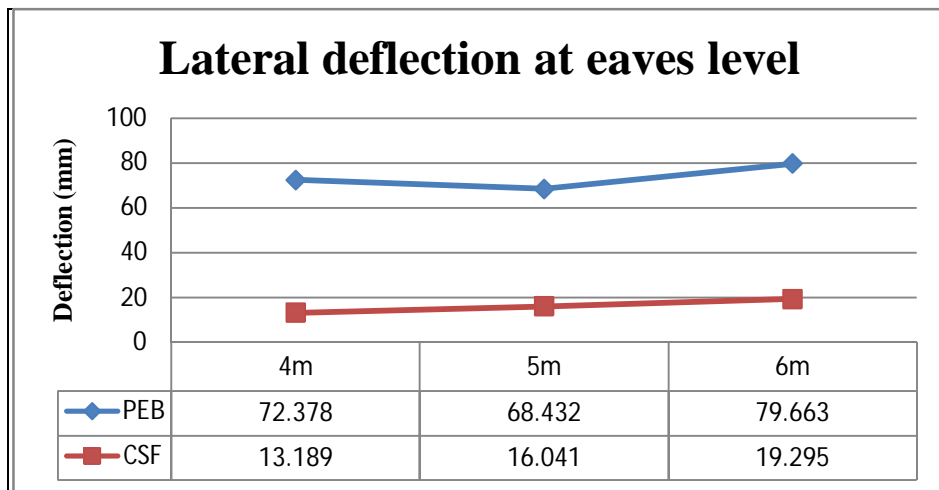


Fig 2. Graphical representation of comparison of lateral deflection at eaves level

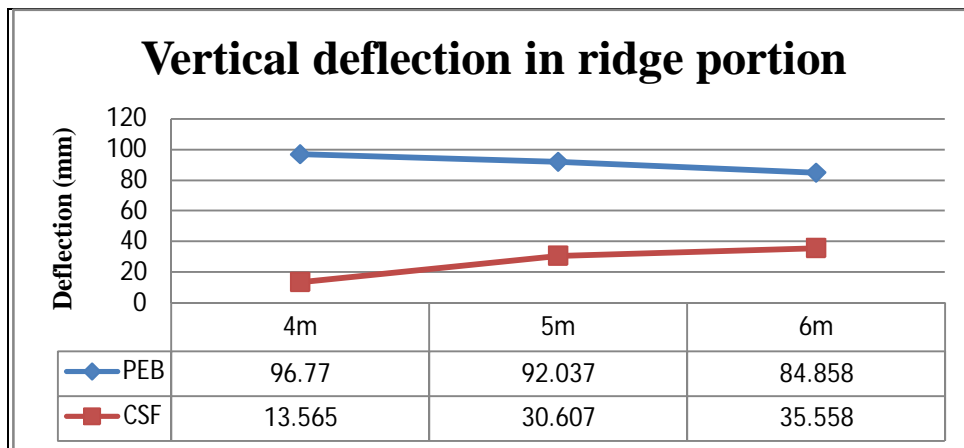


Fig 3. Graphical representation of comparison of Vertical deflection in ridge portion

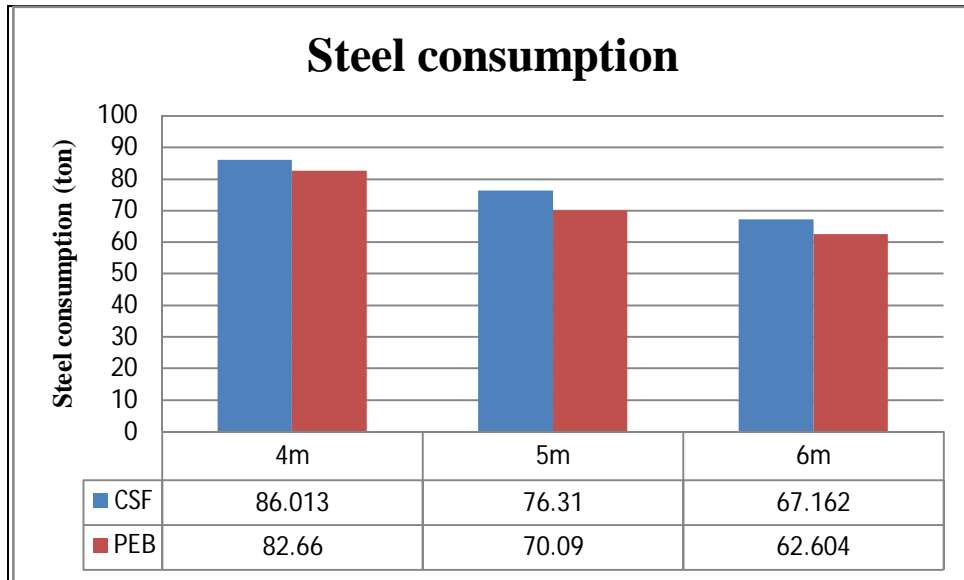


Fig 4. Graphical representation of comparison of steel consumption

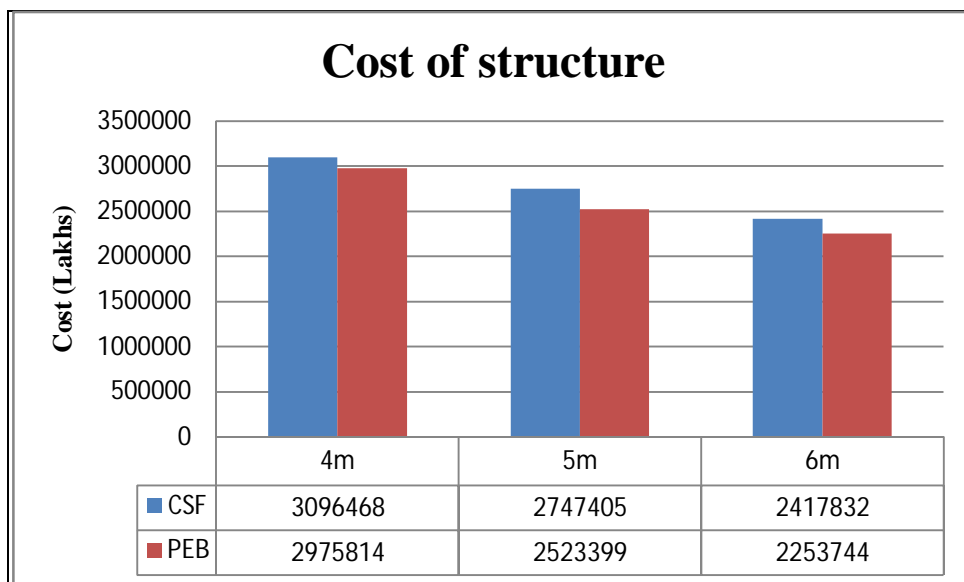


Fig 5. Graphical representation of comparison of cost of structure

VI. CONCLUSION

- Pre-engineered steel structure is almost 15% lighter than conventional steel structure. Also material wastage plays a significant role in reducing steel quantity and cutting the cost of structure as all fabrication work for conventional steel frames are performed at site results in lots of wastage in material.
- Pre-engineered structure cost is 15% lesser than the cost of conventional steel structure. Pre-engineered structure offers low cost, strength, durability and recyclability.
- Steel quantity depends on primary members and purlins. As spacing of frame is increased steel consumption decreased for primary members and increased for secondary members.

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- The comparative study on conventional and pre – engineered portal leads to the conclusion that PEB proves to be relevant and beneficial for warehouses equipped with cranes. Hence pre – engineered frames must be preferred over conventional frames.

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