

# Economizing Steel building using Pre-Engineered Steel Sections

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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) fulfil this requirement along with reduced time and cost as compared to conventional structures. 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 present work presents the comparative study and design of conventional steel frames and pre-engineered buildings (PEB). In this work, industrial frames of length 60m and width 30m with roofing system as conventional steel truss and pre-engineered steel truss analyzed and designed by using STAAD Pro V8i.

**Keywords:** Pre-engineered steel frames, Staad.Pro, Tapered section.

## 1. INTRODUCTION

India has the second fastest growing economy in the world and a lot of it, is attributed to its construction industry which figures just next to agriculture in its economic contribution to the nation. In its steadfast development, the construction industry has discovered, invented and developed a number of technologies, systems and products, one of them being the concept of Pre-engineered buildings (PEBs). As opposed to being on-site fabricated, PEBs are delivered as a complete finished product to the site from a single supplier with a basic structural steel framework with attached factory finished cladding and roofing components. The structure is erected on the site by bolting the various building components together as per specifications. PEBs are developed using potential design software. The onset of technological advancement enabling 3d modeling and detailing of the proposed structure and coordination has revolutionized conventional building construction. A pre-engineered building (PEB) is the future for India. Most of the Indian business community is just started to realize the benefits of PEB's. Where you have been building with concrete for as long as anyone can remember, it is difficult to change. However India's most

progressive companies are seeing the benefits of PEB's.

## 2. HISTORICAL DEVELOPMENT

**K.K.Mitra – Gen. Manager Lloyd Insulations (India) Limited** (2009)<sup>(1)</sup> 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.

**Nikhil Agrawal, Achal Kr. Mittal and V.K.Gupta (2009)**<sup>(3)</sup> 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<sup>0</sup>, 20<sup>0</sup>, 25<sup>0</sup> roof slope. For 5<sup>0</sup> & 10<sup>0</sup> 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.

**Dr. S.K. Dubey, Prakash Sangamnerkar and Prabhat Soni (2012)**<sup>(4)</sup>, studied the behavior of steel roof truss under normal permeability condition. The main purpose of study presented in paper is to analyze the steel roof truss under the normal permeability condition of wind according to Indian standard code IS :875 (Part 3) – 1987; in which intensity of wind load is calculated considering different conditions of class of structure. Terrain, height & structure size factor, topography factor, permeability conditions & compared the results which were obtained with the calculations made in SP – 38 (S & T) 1987. In present paper, A type of truss had been analyzed. The study in present paper concluded that Terrain category 1 & 2, as per SP 38: 1987 & Terrain category 3 & 4 calculated wind forces are lesser than values as per SP 38:1987. The study in paper concluded that analysis made in SP 38:1987 cannot be followed without considering various conditions of class of structures, risk coefficients, terrain conditions, topography factor & permeability conditions.

**Anbuhezian .A, Dr. Baskar. G (2013)**<sup>(7)</sup>, 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

### 3. ADVANTAGES OF PRE-ENGINEERED STEEL FRAMES

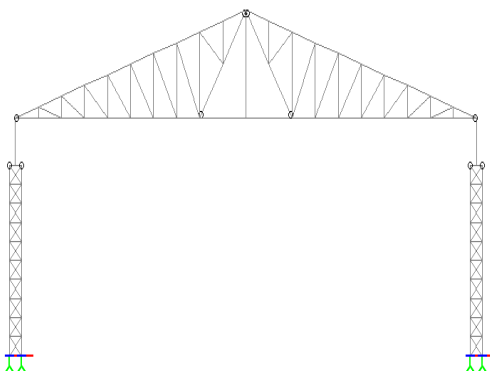
1. PEB system is zero maintenance and superior in strength
2. It is corrosion resistance & feature an attractive appearance
3. Steel arriving at the site is dry with no residual oil on the surface
4. PEB system is excellent resistant in transit to corrosion and storage strain
5. This system reduces energy loads on buildings due to long term bright surface that helps to retain heat reflectivity.

### 4. METHODOLOGY

In the present study an industrial steel structure with conventional steel structure with steel columns and Pre-engineered steel structure are considered for the analysis and design using Staad.Pro V8i. Conventional steel frame of length 60m and span 30m. Bay lengths are maintained at an interval of 4m, 5m and 6m along length. Slope of the roof is  $16.7^\circ$  and covered with GI sheets. 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. Pre-engineered steel frames of length 60m and span 30m. Bay lengths are maintained at an interval of 4m, 5m and 6m. For this structure from general practice slope of the roof is taken as  $6^\circ$ . The spacing of the purlins is maintained at 1.57m. 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.

### 4. LOAD CALCULATIONS

#### 4.1 Model of conventional steel frame on Staad. Pro V8i



**Fig 1 : Model of conventional steel frame on Staad. Pro V8i**

#### 4.1.1 DEAD LOAD ON CONVENTIONAL STEEL FRAME

Dead load is calculated according to IS:875 (Part 1).

a) Purlin load

Assumed Channel Section ISMC 125

Wt = 12.7 kg/m

Spacing of purlin = 1.57m

Load per square meter =  $12.7/1.57 = 0.0809 \text{ kN/m}^2$

Bay spacing is 5m c/c

Intensity of load on rafter = 0.4045 kN/m

Hence purlin load = 0.4045 kN/m

b) Sheetting load

Galvanized sheetting (1.6mm thk) =  $0.131 \text{ kN/m}^2$  (from IS 875 – 1987 Part 1)

Intensity of load on rafter =  $5 \times 0.131 = 0.655 \text{ kN/m}$

#### 4.1.2 CRANE LOAD CALCULATION FOR CONVENTIONAL STEEL FRAME

**Summary of crane load:**

Dead load on column A and B = 75.6 kN

Live load on column A = 72.82 kN

Live load on column B = 2.19 kN

Horizontal thrust = 6 kN

#### 4.1.3 LIVE LOAD CALCULATION

The slope of the roof is  $6^\circ$  the live load for non accessible roof of  $0.75 \text{ kN/m}^2$  is adopted. With the Bay spacing of 5m.

Intensity of load on the rafter =  $5 \times 0.75 = 3.75 \text{ kN/m}$

#### 4.1.3 WIND LOAD CALCULATION

Terrain: Category 1 Class: B

Risk coefficient ( $k_1$ ): 1

Structure size factor ( $k_2$ ): 1.04

Topography factor ( $k_3$ ): 1

Basic wind speed ( $V_b$ ): 44 m/s

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

Design wind pressure ( $P_z$ ):  $0.6 \times 45.8^2 = 1.25 \text{ kN/m}^2$

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

Building height ratio ( $h/w$ ): 0.34 and Building plan ratio ( $L/w$ ): 1.34

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 -0.96 and -0.4

Roof angle -  $6^\circ$

Wind load on individual members are then calculated by

$$F = (C_{pe} - C_{pi}) \times A \times P_z$$

#### 4.1.4 EARTHQUAKE LOAD CALCULATION

Seismic zone: 3

Seismic intensity: Moderate

Zone factor (Z): 0.16

Importance factor (I): 1

Response reduction factor (R): 3  
 Type of soil: Medium  
 Damping: 2%  
 Method of calculation: Seismic coefficient method  
 Load combination for seismic load: DL + 0.25LL  
 Total Dead load = 226.44 kN  
 Total Live load = 97.09 kN  
 Seismic weight (W) = 226.44 + (97.09 x 0.25)  
 = 250.71 kN  
 Fundamental Natural Period ( $T_a$ ) = 0.085 h<sup>0.75</sup>  
 = 0.6316 seconds

**4.2 MODEL OF PRE-ENGINEERED STEEL FRAME ON STAAD. PRO V8i**

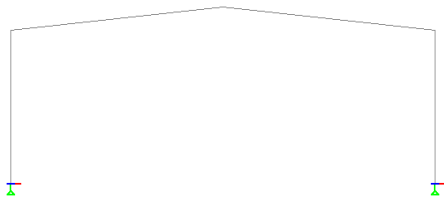


Fig 2: Model of pre-engineered steel frame on Staad. Pro V8i

**4.2.1 DEAD LOAD ON PRE-ENGINEERED STEEL FRAME**

a) Purlin load  
 Assumed Z - section with clips 200x60x20x3.15  
 Wt = 8.23 kg/m  
 Spacing of purlin = 1.51m  
 Load per square meter = 8.23/1.51 = 0.0545 kN/m<sup>2</sup>  
 Bay spacing is 5m c/c  
 Intensity of load on rafter = 5 x 0.0545 = 0.29 kN/m  
 Hence purlin load = 0.2725 kN/m  
 b) Sheeting load  
 Galvanized sheeting (0.63mm thk) = 0.056 kN/m<sup>2</sup> (from IS 875 - 1987 Part 1)  
 Intensity of load on rafter = 5 x 0.056 = 0.28 kN/m

**4.2.2 CRANE LOAD CALCULATION FOR PRE-ENGINEERED STEEL FRAME**

Crane load calculations are same as that for conventional portal hence refer (4.1.2 load calculation for crane load)  
 Summary of crane load:  
 Dead load on column A and B = 75.6 kN  
 Live load on column A = 72.82 kN  
 Live load on column B = 2.19 kN  
 Horizontal thrust = 6 kN

**4.2.3 WIND LOAD CALCULATION**

Location: Bombay  
 Terrain: Category 1 Class: B  
 Risk coefficient (k<sub>1</sub>): 1  
 Structure size factor (k<sub>2</sub>): 1.04  
 Topography factor (k<sub>3</sub>): 1  
 Basic wind speed (V<sub>b</sub>): 44 m/s  
 Design wind velocity (V<sub>z</sub>): 44 x 1 x 1.04 x 1 = 45.8 m/s  
 Design wind pressure (P<sub>z</sub>): 0.6 x 45.8<sup>2</sup> = 1.25 kN/m<sup>2</sup>

The internal coefficients are taken as +0.2 and -0.2.  
 Building height ratio (h/w): 0.34 and Building plan ratio (L/w): 1.34  
 External pressure coefficients (C<sub>pe</sub>) for walls of rectangular clad building are taken as +0.7 and -0.25  
 External pressure coefficients (C<sub>pe</sub>) for pitch roof of rectangular clad building are taken as -0.96 and -0.4  
 Roof angle - 6°  
 Wind load on individual members are then calculated by  
 F = (C<sub>pe</sub> - C<sub>pi</sub>) x A x P<sub>z</sub>

**4.2.4 EARTHQUAKE LOAD CALCULATION**

Seismic zone: 3  
 Seismic intensity: Moderate  
 Zone factor (Z): 0.16  
 Importance factor (I): 1  
 Response reduction factor (R): 3  
 Type of soil: Medium  
 Damping: 2%  
 Method of calculation: Seismic coefficient method  
 Load combination for seismic load: DL + 0.25LL  
 Total Dead load = 226.44 kN  
 Total Live load = 97.09 kN  
 Seismic weight (W) = 226.44 + (97.09 x 0.25)  
 = 250.71 kN  
 Fundamental Natural Period ( $T_a$ ) = 0.085 h<sup>0.75</sup>  
 = 0.6316 seconds

**5. RESULTS AND DISCUSSIONS**

**5.1 RESULT COMPARISON OF LATERAL DEFLECTION FOR STRUCTURES OF SPAN 30M**

Table 5.1 Result comparison of lateral deflection of structures for wind zone 2

	4 m	5 m	6 m
CSF	16.774 mm	12.757 mm	18.395 mm
PEB	66.028 mm	77.659 mm	75.153 mm

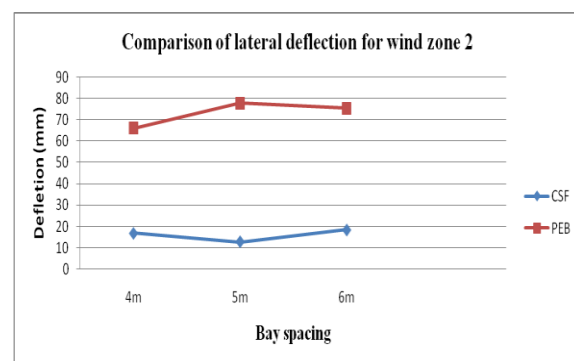


Fig. 5.1 Comparison of lateral deflection for wind zone 2

Table 5.2 Result comparison of lateral deflection of structures for wind zone 3

	4 m	5 m	6 m
CSF	16.775 mm	13.154 mm	17.97 mm
PEB	77.659 mm	77.722 mm	75.28 mm

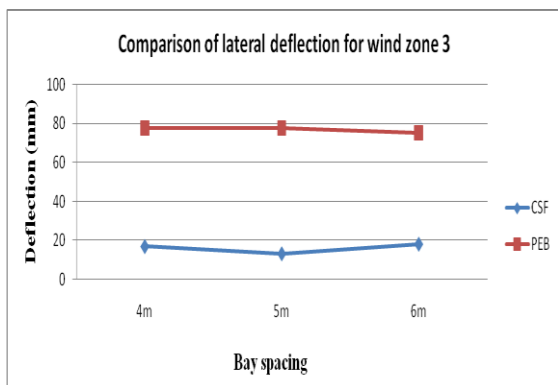


Fig. 5.2 Comparison of lateral deflection for wind zone 3

Table 5.3 Result comparison of lateral deflections of structures for wind zone 4

	4 m	5 m	6 m
<b>CSF</b>	13.068 mm	14.583 mm	16.089 mm
<b>PEB</b>	69.508 mm	65.254 mm	50.328 mm

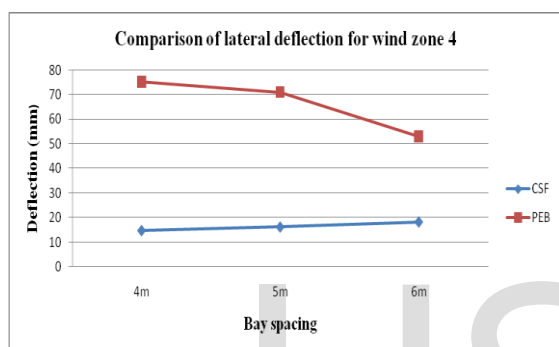


Fig. 5.3 Comparison of lateral deflection for wind zone 4

Table 5.4 Result comparison of lateral deflections of structures for wind zone 5

	4 m	5 m	6 m
<b>CSF</b>	13.068 mm	14.583 mm	16.08 mm
<b>PEB</b>	69.508 mm	65.254 mm	50.32 mm

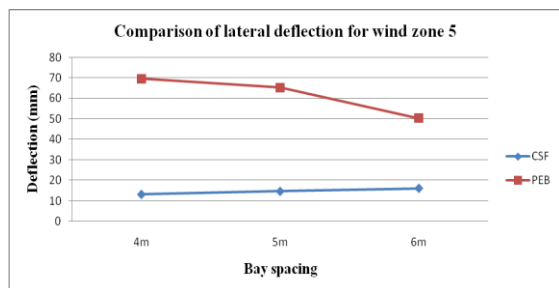


Fig. 5.4 Comparison of lateral deflection for wind zone 5

## 5.2 RESULT COMPARISON OF VERTICAL DEFLECTION FOR STRUCTURES OF SPAN 30M

Table 5.5 Result comparison of vertical deflection of structures for wind zone 2

	4 m	5 m	6 m
<b>CSF</b>	30.357 mm	30.063 mm	35.56 mm
<b>PEB</b>	99.663 mm	98.66 mm	99.77 mm

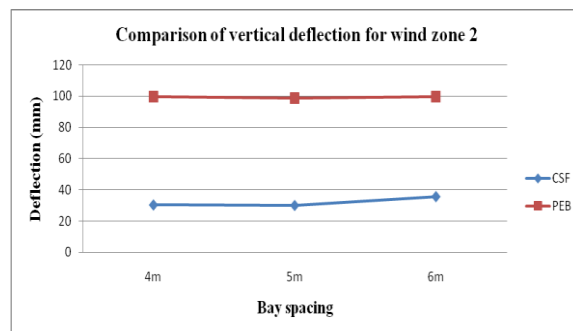


Fig. 5.5 Comparison of vertical deflection for wind zone 2

Table 5.6 Result comparison of vertical deflection of structures for wind zone 3

	4 m	5 m	6 m
<b>CSF</b>	30.357 mm	30.063 mm	35.568 mm
<b>PEB</b>	99.663 mm	98.66 mm	99.77 mm

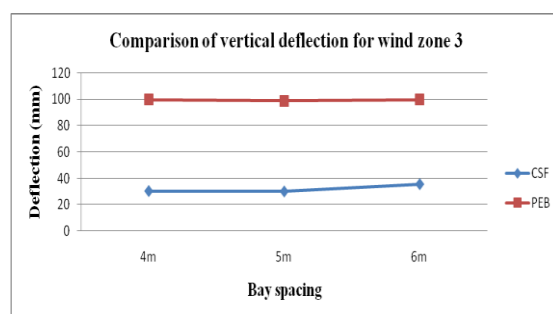


Fig. 5.6 Comparison of vertical deflection for wind zone 3

Table 5.7 Result comparison of vertical deflection of structures for wind zone 4

	4 m	5 m	6 m
<b>CSF</b>	25.11 mm	30.062 mm	30.852 mm
<b>PEB</b>	83.84 mm	93.925 mm	66.601 mm

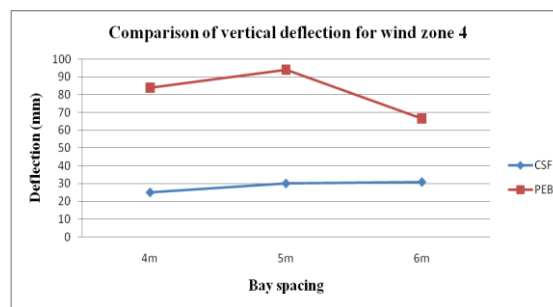


Fig. 5.7 Comparison of vertical deflection for wind zone 4

Table 5.8 Result comparison of vertical deflection of structures for wind zone 5

	4 m	5 m	6 m
<b>CSF</b>	29.942 mm	31.112 mm	30.643 mm
<b>PEB</b>	78.14 mm	83.919 mm	65.542 mm

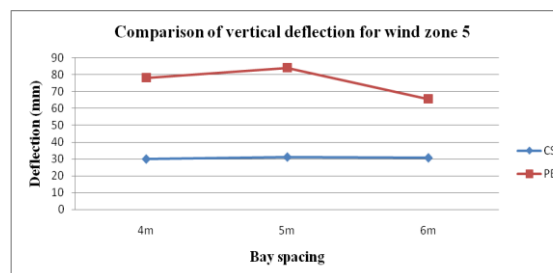
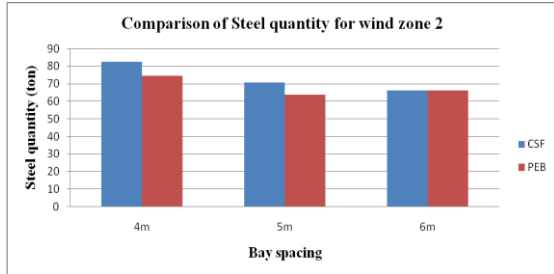


Fig. 5.8 Comparison of vertical deflection for wind zone 5

### 5.3 RESULT COMPARISON OF STEEL QUANTITY FOR STRUCTURES OF SPAN 30M

**Table 5.9** Result comparison of steel quantity of structures for wind zone 2

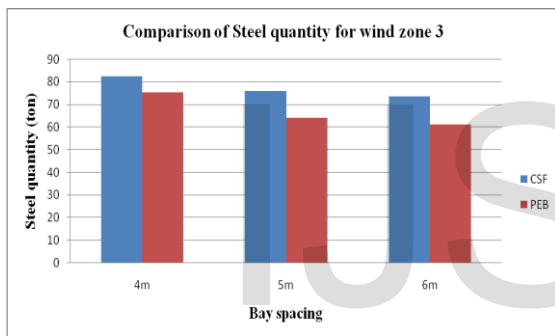
	4 m	5 m	6 m
<b>CSF</b>	82.326 ton	70.7 ton	66.066 ton
<b>PEB</b>	74.383 ton	63.82 ton	66.04 ton



**Fig. 5.9** Comparison of steel quantity for wind zone 2

**Table 5.10** Result comparison of steel quantity of structures for wind zone 3

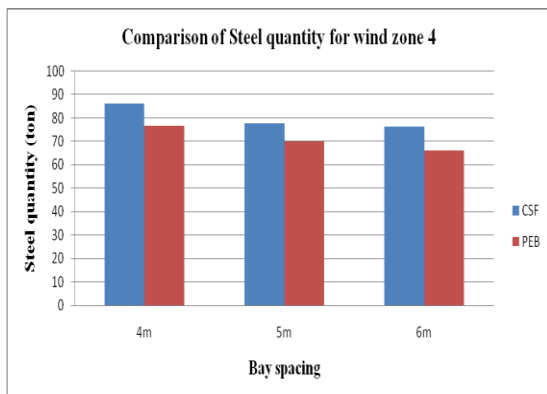
	4 m	5 m	6 m
<b>CSF</b>	82.326 ton	75.92 ton	73.54 ton
<b>PEB</b>	75.21 ton	64.109 ton	61.144 ton



**Fig. 5.10** Comparison of steel quantity for wind zone 3

**Table 5.11** Result comparison of steel quantity of structures for wind zone 4

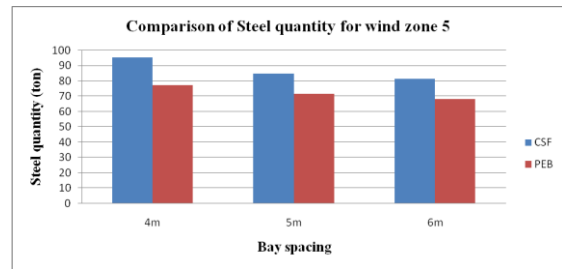
	4 m	5 m	6 m
<b>CSF</b>	86.025 ton	77.37 ton	76 ton
<b>PEB</b>	76.39 ton	69.97 ton	65.87 ton



**Fig. 5.11** Comparison of steel quantity for wind zone 4

**Table 5.12** Result comparison of steel quantity of structures for wind zone 4

	4 m	5 m	6 m
<b>CSF</b>	94.95 ton	84.55 ton	81.039 ton
<b>PEB</b>	77.22 ton	71.48 ton	68.119 ton

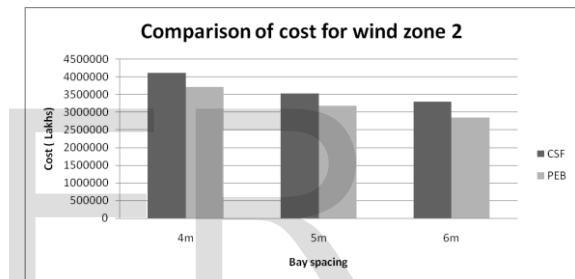


**Fig. 5.12** Comparison of steel quantity for wind zone 4

### 5.4 RESULT COMPARISON OF COST FOR STRUCTURES OF SPAN 30M

**Table 5.13** Result comparison of cost of structures for wind zone 2

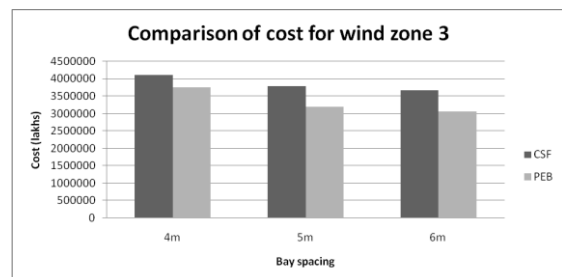
	4 m	5 m	6 m
<b>CSF</b>	4116300	3535020	3303300
<b>PEB</b>	3719150	3191220	2845100



**Fig. 5.13** Comparison of cost for wind zone 2

**Table 5.14** Result comparison of cost of structures for wind zone 3

	4 m	5 m	6 m
<b>CSF</b>	4116300	3796100	3677000
<b>PEB</b>	3760475	3205440	3057200



**Fig. 5.14** Comparison of vertical deflection for wind zone 3

**Table 5.15** Result comparison of cost of structures for wind zone 4

	4 m	5 m	6 m
<b>CSF</b>	4301250	3818600	3800350
<b>PEB</b>	3819500	3498540	3293350

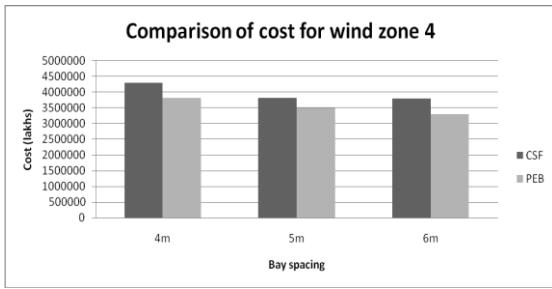


Fig. 5.15 Comparison of cost for wind zone 4

Table 5.16 Result comparison of cost of structures for wind zone 5

	4 m	5 m	6 m
<b>CSF</b>	4747275	4227920	4051950
<b>PEB</b>	3860825	3574080	3405950

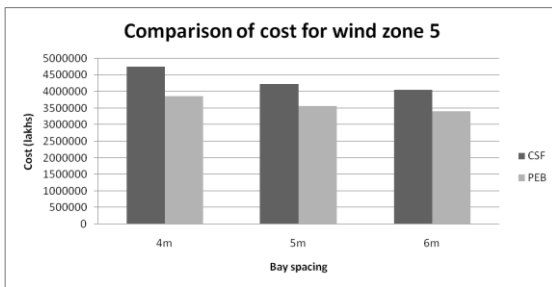


Fig. 5.16 Comparison of cost for wind zone 5

## CONCLUSION

1. Pre-engineered steel structure is almost 23% 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.
2. Pre-engineered structure cost is 18% lesser than the cost of conventional steel structure. Pre-engineered structure offers low cost, strength, durability and recyclability.
3. As wind intensity on frame is increased steel consumption is also increased for primary and secondary (purlin) members.
4. 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.
5. Conventionally steel frames are generally used for smaller spans but pre-engineered steel frames can be used to around 90m clear spans, this is the most important benefit of pre-engineered steel frame giving column free space.
6. 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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