COMPARATIVE STUDY OF PRE-ENGINEERED BUILDING AND CONVENTIONAL STEEL STRUCTURES

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Abstract - Technological advancement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution in the field of construction industry is the pre-engineered buildings. Pre-Engineered Buildings are custom designed to meet client's requirements. In Conventional steel structure, there has always been an issue of huge steel consumption and higher cost of the structure. This Paper deals to resolve such issues by replacing conventional steel structure with PEBs. The concept and attracting feature of PEB such as members are designed as per the bending moment diagram of the steel frame, in order to make the structure economical in terms of steel consumption and cost. In this paper, various models of PEB span ranging from 10m to 50m i.e. 10m,20m, 30m,40m,50m are compared with another five models of conventional steel structure of span same as that of PEB. Models of both the system are designed using Staad Pro Software and analyzed under Dead , live, wind and Seismic load to find out which system is economical.

Key Words: **Pre-Engineered Building, Loads, Staad pro, Conventional Steel structures, cost of the structure**

1.INTRODUCTION

Buildings & houses are one of the oldest construction practice of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. The present construction methodology for buildings calls for the best aesthetic look, high quality & fast construction, cost-effective & innovative touch. A recent survey by the Metal Building Associations (MBMA) shows that about 60% of the non-residential low rises building in USA are pre-engineered buildings. Although PEB systems are extensively used in industrial and many other non-residential constructions world-wide, it is relatively a new concept in India. These concepts were introduced to the Indian markets lately in the late 1990's with the opening up of the economy and a number of multi nationals setting up their projects. The market potential of PEB's is 1.2 million tons per annum. The current pre-engineered steel building manufacturing capacity is 0.35 million tons per annum. The industry is growing at the compound rate of 25 to 30 %.

1.1 Classification of buildings

1.2.1 Reinforced Cement Concrete Buildings:

Reinforced concrete (RC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement bars having higher tensile strength and ductility to improve overall performance of the concrete. From the earlier time, it has been considered as an economical construction material in one form or another. A large part of its worldwide appeal is due to locally available materials i.e. cement, sand, aggregate, water, and reinforcing bars are widely available and that it is possible to construct a structure using local sources of labor and materials.

1.2.2 Steel Buildings

Steel is one of the important building materials in construction industry. It can be used in many ways for many purposes. Different steel members are manufactured in the factories based on their usage. Rolled steel sections are casted in continuous casting moulds without any joints and these sections are assembled together to get the desired steel structure. Steel building uses the concept of framing system which consist combination of columns and inclined beams (rafter). A structure which is made from organized combination of structural STEEL members designed to carry loads and provide adequate rigidity.

(a) Conventional Steel Buildings

Generally, truss systems are used in conventional steel building system. The Structural members used are hot rolled and are provided as per the IS code which are, in many segments of the members heavier than what is actually required by design, Members have constant cross section regardless of the varying magnitude of the local stresses along the member length. The materials are produced or manufactured in the plant and are shifted to the site. The raw materials are processed in the site for the desired form and requirement and later erected. The modifications can be made during erection by welding and cutting process. Standard hot rolled sections are provided in secondary members which are much heavier.

(b) Pre-Engineered Steel Buildings

Pre-Engineered Steel Buildings are manufactured in the plant itself. The manufacturing of structural members is done as per the customer's requirements. Using steel in an efficient way makes pre-engineered building about 30% lighter than conventional steel structures. Tapered built up sections are provided in primary framing with the smaller depth in areas of lower stress and larger depth in area of higher stress. Light weight cold formed "Z" or "C" shaped sections are provided in secondary members. Possibly no modification can be made at the site at the time of erection such as welding and cutting. No manufacturing process takes place at the customer site.

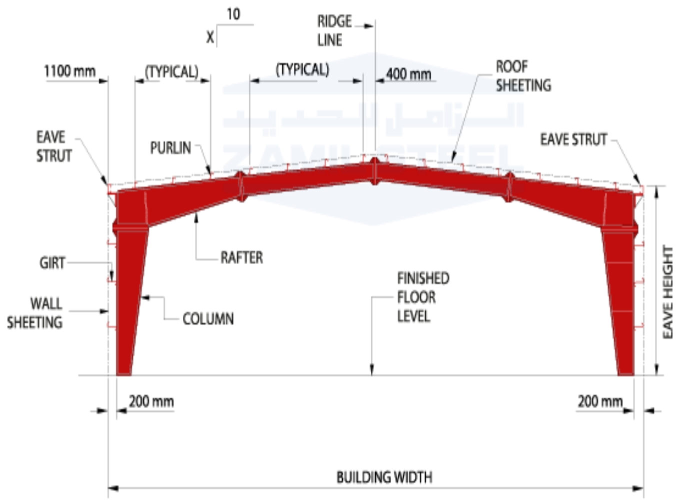

Fig-1 **Typical Pre-engineered building frame**

1.3 OBJECTIVE

The following are the objective of the present study:

1) To design various system for Different types of Loads (Dead, Live etc) and Evaluate the steel consumption in both the system.
2) Reduce the steel Consumption, hence Reducing the Cost of structure.
3) To study comparative costing of various types of system.

2. LITERATURE REVIEW

Neha R.Kolate, Shipa Kewate (july 2015) made a comparative study between pre-engineered building and conventional steel building and observes that PEB has many advantages over CSB such as zero maintenance and superior strength, it is corrosion resistance and features an attractive appearance and it is high level technology innovation and better product over conventional material. PEB system has protection against non-uniform weathering. In this paper, they studied that most of the steel structures are made in a conventional way using conventional sections and this leads to uneconomical and heavy structure and this pushes forward technology to get a better replacement and that is Pre-engineered building having better properties than conventional steel frames.

S.D. Charkha and Latesh S. Sanklecha (June 2014) Observes that constantly increasing cost of steel giving rise to an uneconomical construction practice which needs to be altered using new innovative technology. There are many reason to choose PEB over CSB such as quality design, manufacturing, erection, low maintenance due to pre-painted sections, building can be dismantled and relocated easily and future extension without much hassle is possible due to bolted connection. Along with this PEB proves to be a better system because of its ability to span long distance as many other gable structures are limited to a span of about 100 ft. in cost effective manner. Mainly trusses are provided for longer span but significant design fabrication time is needed. Based on above parameters they concluded that choosing PEB over CSB reduces steel quantity which reduces dead load and hence size of foundation is reduced.

B K Raghu Prasad, Sunil Kumar, Amarnath K (September 2014) observes that reason behind PEB being so high in demand is speed of construction and good control over the quality and when talking about the cost, there are several parameters responsible for it such as span, bay spacing, gable inclination. In this paper, these` Variety of model have been analyzed by varying roof angles, span and bay spacing and keeping the load common for each model i.e. DL, EL, LL, and WL. Pre-engineered buildings are fully factory fabricated and assembles at site using bolted connection unlike welding in conventional steel building. PEB uses hot rolled tapered sections in primary framing as required by the internal stresses hence using the steel in optimum quantity and eliminating wastage of steel which further reduces self-weight of structure.

Jinsha M S, Linda Ann Mathew (July 2016) observes that now a day's column free structures are desirable mainly for industries and Pre-engineered buildings fulfils this requirement. In this study, an attempt is made to achieve the economy in steel quantity in pre-engineered buildings by varying the bay spacing. Observation is done by considering models with different bay spacing designed for wind loads. Analysis and design is performed using the software STAAD Pro V8i. Concept of pre-engineered building is to reduce the quantity of excessive steel as per the internal stress distribution or say bending moment diagram of the frame. Weight of Pre-engineered building depends upon the bay spacing and in this analysis most suitable bay spacing in terms of cost is found by performing the above analysis. As a conclusion of whole study made author aims to achieve a most economical framing system.

C.M. Meera (June2013) studied that Pre-engineered building is a versatile solution to all the single storey industrial building as along with providing a high-quality pre-design structure it is also economical and light weight construction technique. PEB has many advantage over conventional steel structures such as providing a standard fabricated section according to the optimum requirement. In this paper author carried out a comparative study of PEB and CSB on the basis of design and analysis of a typical frame. Design of conventional steel frame include selection of a suitable roof truss built up from standard hot rolled sections. Analysis for both the steel frame using different concept shows that there is about 30% reduction in steel consumption in Pre-engineered building as compared to conventional steel frame, hence PEB are lighter than CSB. In this way PEB proves to be more advantageous from CSB in as it is more economical, quality control, speed in construction, longer span, durability, standard designs, ease in expansion and erection.

3. Proposed Methodology and Discussion

3.1Proposed methodology

The design under discussion is a 30-meter clear span warehouse for grain storage. Design of this warehouse is done using Staad pro V8i software, for proper simulation of the load distribution uniformly in three co-ordinates system i.e. X, Y and Z. In this study five models of PEB of span varying from 10 meters to 50 meters are compared with another five models of CSB of span same as Pre-engineered building. Generally, PEB frames are designed keeping in mind the bending moment diagram of the conventional frame as a result of which sections of Pre-engineered building are tapered according to the internal stress distribution which means larger depth of section in the area of higher stress and lesser depth of section in areas of lower stress. Hence this optimizes the use of steel and makes it more economical.

Load considered while designing the frames for analysis are dead load, Live load, Wind load and seismic load as SL1, SL2, DL1, LL1, WL1, WL2, WL3, WL4 WL5 WL6. The structure has been designed under enclosed as well as open condition for application of wind loads, because of the opening & closing of the large sized warehouse span.

3.2 Warehouse design dimension (Pre-engineered building)

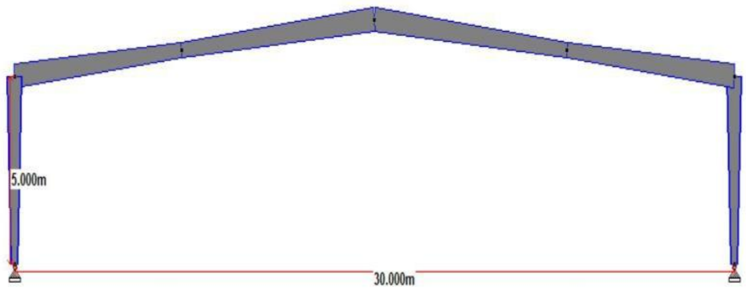

Fig -3.1: Elevation PEB frame

(a) Design dimensions

The parameter considered for warehouse design are
Building Input Data
Width = 30 meters
Length = 30 Meters
Eave Height = 5 Meters
Bay Spacing = 5 Meters
Brick work = 2.5 Meters
Roof Slope = 5.7 degrees

(b) Dead load calculations:

Weight of GI sheet = 0.125 KN/m^2
Weight of purlins = 0.100 KN/m^2
Total dead load = 0.225 KN/m^2
Dead load per meter run on rafter = .225KN/m^2x5m (bay spacing) = 1.125 KN/m

(c) Live load calculations:

Live load as per IS code 875 Part II for flat slopping or curved roof with slope up to 10^o (access not provided) taken as = .75 KN/m^2
Live load per meter run on rafter = .75 KN/m^2x5m (bay spacing) = 3.75 KN/m^2

(d) Wind load calculations:

Wind pressure calculation
Wind Speed Vb = 39 m/sec
Risk coefficient, k1 = 1
Terrain, Ht & size factor, k2 = 0.88 (Category 3 class B)
Topography Factor, k3 = 1
Design Wind Speed,
Vz = Vb x k1 x k2 x k3
= 39 x 1 x 0.88 x 1 = 34.32 m/s Design wind pressure, Pz
=0.6 x $(Vz)^2$ = 0.6 x 34.32^2= 707 KN/m^2 =0.707KN/m^2
Internal Pressure Coefficient (Cpi) = +/-0.2
External Pressure Coefficient for wall from IS 875 III tables (Cpe)
From design dimensions
h/w = 5/30 = 0.16, (h/w< 0.5)
l/w = 30/30 = 1

Table -1: 3.1: External pressure coefficient (Cpe)

Wind angle	Net Coefficient for wall		Wind force	
	(Cpe+Cpi)	(Cpe-Cpi)	(Cpe+Cpi)A Pz	(Cpe-Cpi)APz
0°	0.7+0.2= 0.9	0.7-0.2= 0.5	0.9x5x0.7=3.15	0.5x5x0.7=1.75
	-0.2+0.2= 0	-0.2-0.2= -0.4	0x5x0.7=0	-0.4x5x0.7=-1.4
90°	-0.5+0.2= -0.3	-0.5-0.2= -0.7	-0.3x5x0.7= -1.05	-0.7x5x0.7= -2.45
	-0.5+0.2= -0.3	-0.5-0.2= -0.7	-0.3x5x0.7= -1.05	-0.7x5x0.7= -2.45

Table- 3.2: Wind force in columns are calculated as

For wind angle -0° or 180° and -90° or 270°

Wind angle	External pressure coefficient Cpe			
	A	B	C	D
0°	+0.7	-0.2	-0.5	-0.5
90°	-0.5	-0.5	+0.7	-0.1

3.3.1 Wind force in rafter

Table 3.3: External Pressure Coefficient for roof(Cpe)

Building Height Ratio		Roof Angle α	Wind angle θ 0°		Wind angle θ 90°		Local Coefficients			
		Degrees	EF	GH	EG	FH				
$\frac{h}{w} \le \frac{1}{2}$	W, h	0	-0.8	-0.4	-0.8	-0.4	-2.0	-2.0	-2.0	---
		5	-0.9	-0.4	-0.8	-0.4	-1.4	-1.2	-1.2	-1.0
		10	-1.2	-0.4	-0.8	-0.6	-1.0	-1.4		-1.2
		20	-0.4	-0.4	-0.7	-0.6	-0.8			-1.2
		30	0	-0.4	-0.7	-0.6				-1.1
		45	+0.3	-0.5	-0.7	-0.6				-1.1
		60	+0.7	-0.6	-0.7	-0.6				-1.1
$\frac{1}{2} < \frac{h}{w} \le \frac{3}{2}$	W, h	0	-0.8	-0.6	-1.0	-0.6	-2.0	-2.0	-2.0	---
		5	-0.9	-0.6	-0.9	-0.6	-2.0	-2.0	-1.5	-1.0
		10	-1.1	-0.6	-0.8	-0.6	-2.0	-2.0	-1.5	-1.2
		20	-0.7	-0.5	-0.8	-0.6	-1.5	-1.5	-1.5	-1.0
		30	-0.2	-0.5	-0.8	-0.8	-1.0			-1.0
		45	+0.2	-0.5	-0.8	-0.8				
		60	+0.6	-0.5	-0.8	-0.8				
$\frac{3}{2} < \frac{h}{w} < 6$	W, h	0	-0.7	-0.6	-0.9	-0.7	-2.0	-2.0	-2.0	---
		5	-0.7	-0.6	-0.8	-0.8	-2.0	-2.0	-1.5	-1.0
		10	-0.7	-0.6	-0.8	-0.8	-2.0	-2.0	-1.5	-1.2
		20	-0.8	-0.6	-0.8	-0.8	-1.5	-1.5	-1.5	-1.2
		30	-1.0	-0.5	-0.8	-0.7	-1.5			
		40	-0.2	-0.5	-0.8	-0.7	-1.0			
		50	+0.2	-0.5	-0.8	-0.7				
		60	+0.5	-0.5	-0.8	-0.7				

Table 3.4: External pressure coefficient for roof (Cpe)

Wind angle	External pressure coefficient Cpe	
	EF	GH
0°	-1.4	-0.4
	EG	FH
90°	-0.8	-0.8

Table 3.5: Wind force

Wind angle		Net Coefficient for roof		Wind force	
		(Cpe+Cpi)	(Cpe-Cpi)	$(Cpe+Cpi)AP_z$	$(Cpe-Cpi)AP_z$
0°	EF	-1.4+0.2= -1.2	-1.4-0.2= -1.6	-1.2x5x0.7= -4.2	-1.4x5x0.7= -5.6
	GH	-0.4+0.2= -0.2	-0.4-0.2= -0.6	-0.2x5x0.7=-0.7	-0.6x5x0.7=-2.1
90°	EG	-0.8+0.2= -0.6	-0.8-0.2= -1	-0.6x5x0.7=-2.1	-1x5x0.7=-3.5
	FH	-0.8+0.2= -0.6	-0.8-0.2= -1	-0.6x5x0.7=-2.1	-1x5x0.7=-3.5

Seismic Parameters:

IS 1893 – 2002/2005

BHOPAL comes under zone II

Z = seismic zone coefficient = 0.16 (table 2 of IS 1893 PART 1 -2002)

I = depend upon functional use of the structures = 1(from table 6 of IS 1893)

R = response reduction factor = 4 (table 7 of IS 1893 PART 1 -2002)

These calculated values are then applied to model in staad Pro for analysis.

Steel Take Off

Tapered	Member No:	1	10.00	4.449
Tapered	Member No:	7	30.15	14.624
		TOTAL =		19.073 KN

3.4Bending moment diagram

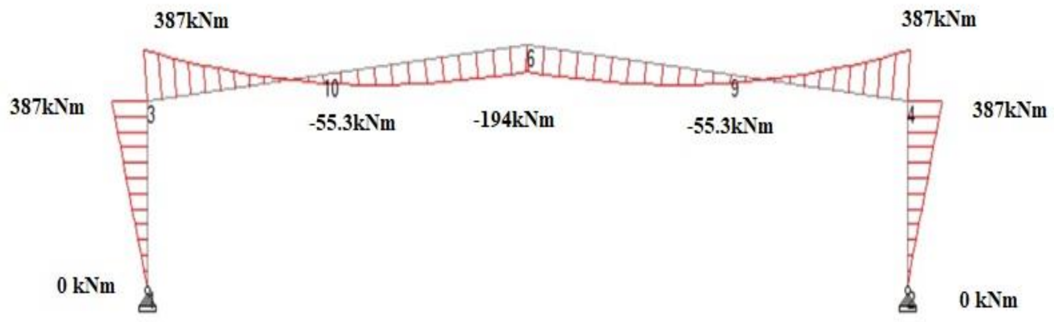

Fig 3.2: Bending moment diagram

3.4 WAREHOUSE DESIGN DIMENSION(CONVENTIONAL STEEL STRUCTURE)

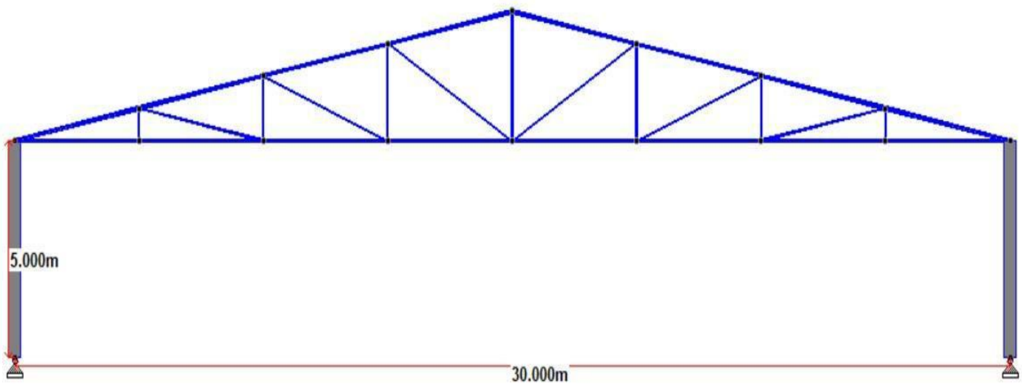

Fig-3.3: Elevation of conventional steel frame

(a)Design dimension Truss type Howe roof truss

The parameter considered for warehouse design are
Building Input Data
Width = 30 meters
Length = 30 Meters
Eave Height = 5 Meters
Bay Spacing = 5 Meters
Brick work = 2.5 Meters
Roof Slope = 11.30 degrees
Rise= 3
Slope= 1/5
Spacing of purlin= 3.8

(b) Dead load calculations:

Weight of GI sheet = 0.125 KN/m^2
Weight of purlins = 0.100 KN/m^2
Total dead load = 0.225 KN/m^2
Dead load on plan area = load x spacing of purlin in plan x bay spacing.

= 0.225 x 3.8 cos(11.30) x 5 =4.19 kN at each node and, 4.19/2 = 2.09 at end node.

(c) Live load calculation:

As per IS 875:1987 part II when slope is greater than ≥10^0 then imposed load on purlin is 750 N/m^2 less 20 N/m^2 for every degree increase in slope in excess of 10^0 but not less than 400 N/m^2.
Live load =750 - 20× (11.30-10) = 724 N/m^2.

In case of sloping roofs with sloping greater than 10^0, members supporting the roof purlins, such as trusses, beams, girders, etc. may be designed for two – thirds of the imposed load on purlins or roofing sheeting.

2/3rd load = 2/3 x 724 = 482.6 N/m^2

Live load on plan area = load x spacing of purlin in plan area x bay spacing.
= 482.6 x 3.8 cos(11.30) x 5 =2366.5 N
= 2.36 kN at each node and,
2.36/2 = 1.18 kN at end nodes.

(d) Wind load calculations:

Wind pressure calculation
Wind Speed Vb = 39 m/sec
Risk coefficient, k1 = 1
Terrain, Ht & size factor, k2 = 0.88 (Category 3 class B)
Topography Factor, k3 = 1
Design Wind Speed, Vz = Vb x k1 x k2 x k3= 39 x 1 x 0.88 x 1 = 34.32 m/s
Design wind pressure, Pz =0.6 x (Vz)^2 = 0.6 x 34.32^2= 707 KN/m^2 =0.707KN/m^2
Internal Pressure Coefficient (Cpi) = +/-0.2
External Pressure Coefficient for wall from *IS 875 III tables (Cpe)*
From design dimensions
h/w = 5/30 = 0.16, (h/w< 0.5)
l/w = 30/30 =1

Table 3.5: External pressure coefficient for wall Cpe

Wind angle	External pressure coefficient Cpe			
	A	B	C	D
0^o	+0.7	-0.2	-0.5	-0.5
90^o	-0.5	-0.5	+0.7	-0.1

Table 3.6: Wind force in columns are calculated as

Wind angle		Net Coefficient for roof		Wind force	
		(Cpe+Cpi)	(Cpe-Cpi)	(Cpe+Cpi)AP$_z$	(Cpe-Cpi)AP$_z$
o·	EF	-1.4+0.2= -1.2	-1.4-0.2= -1.6	-1.2x5x0.7= -4.2	-1.4x5x0.7= -5.6
	GH	-0.4+0.2= -0.2	-0.4-0.2= -0.6	-0.2x5x0.7=-0.7	-0.6x5x0.7=-2.1

90	EG	-0.8+0.2= -0.6	-0.8-0.2= -1	-0.6x5x0.7=-2.1	-1x5x0.7=-3.5
	FH	-0.8+0.2= -0.6	-0.8-0.2= -1	-0.6x5x0.7=-2.1	-1x5x0.7=-3.5

Table 3.7: External pressure coefficient for roof (Cpe)

Wind angle	External pressure coefficient Cpe	
	EF	GH
0°	-1.096	-0.4
	EG	FH
90°	-0.78	-0.78

Table 3.8: Wind force

Wind angle		Net Coefficient for roof		Wind force	
		(Cpe+Cpi)	(Cpe-Cpi)	(Cpe+Cpi)AP_z	(Cpe-Cpi)AP_z
0°	EF	-1.096+0.2= -0.89	-1.096-0.2= -1.2	-1.2x5x0.7= -3.115	-1.2x5x0.7= -4.2
	GH	-0.4+0.2= -0.2	-0.4-0.2= -0.6	-0.2x5x0.7=-0.7	-0.6x5x0.7=-2.1
90°	EG	-0.78+0.2= -0.58	-0.78-0.2= -0.98	-0.58x5x0.7= -2.03	-0.98x5x0.7= -3.43
	FH	-0.78+0.2= -0.58	-0.78-0.2= -0.98	-0.58x5x0.7= -2.03	-0.98x5x0.7= -3.43

Seismic Parameters:

IS 1893 – 2002/2005
BHOPAL comes under zone II
Z = seismic zone coefficient = 0.16 (table 2 of IS 1893 PART 1 -2002)
I = depend upon functional use of the structures = 1(from table 6 of IS 1893)
R = response reduction factor = 4 (table 7 of IS 1893 PART 1 -2002)
These calculated values are then applied to model in staad Pro for analysis Staad Editor
Steel take off
Weight = 27.077 kN

4.EXPERIMENTAL RESULT

It is observed that PEB It is observed that Pre-Engineered building reduced the steel quantity by an average value of 30% than that of required in Conventional steel structures as shown in table 4.1. This is the main reason for cost reduction of the structure. Thus, PEB proves to be a best possible way for material and cost saving. Hence heavier foundation can be avoided in case of PEB and overall cost of structure is reduced due to lighter foundation. A 30-meter span model of both the system is considered here for detailed calculation. Similarly rest of the models are also designed and analyzed in staad pro software and result obtained is shown in table 4.1

Table 4.1 Results obtained from the analysis are:

S.no	Span	Steel consumption (kN)		% Saving in steel consumption
		PEB	CSB	
1	10	6.86	9.62	28.6%
2	20	14	21	33.34%
3	30	19	27	29.62%
4	40	25.3	25.6	1.17%
5	50	36	37	2.7%

COMPARISON OF STEEL CONSUMPTION IN PEB & CSB

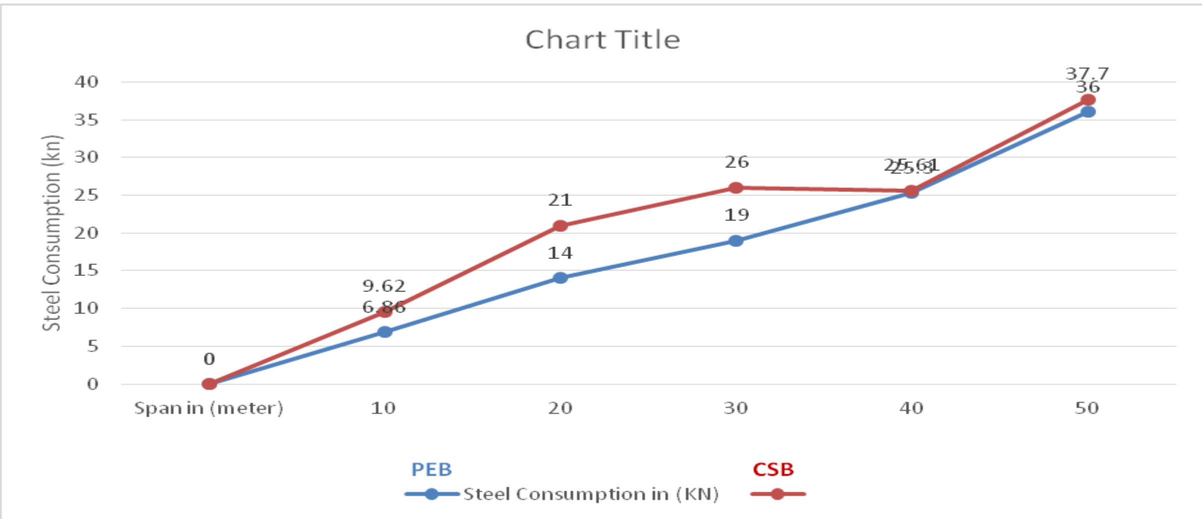

Fig-4.1 Comparison of Steel consumption in PEB & CSB

4.2 Cost of structure

Cost of structure is totally dependent upon quantity of steel, hence lesser the quantity of steel lesser is the cost of structure and this makes pre-engineered building economical than conventional steel structure. Cost comparison of different models of different span of PEB and CSB are shown below:

Table 4.2: Comparison of cost

Cost Of Frame Structure (INR)		
Span in m	Pre-engineered building	Conventional building
10	318272.5	446306
20	649512.5	974155
30	881517	1252706
40	1173809	1187746
50	1670259.5	171666.4

Figures from table 4.2 makes it clear that PEB is more economical than conventional steel structures. In this study, a 30-meter span model is considered for detailed study inclusive of all the calculations made and applied to the model in Staad Pro software. Hence on the basis of above table it can be concluded that PEB is about 30 % economical than conventional steel structure.

PEB Vs CSB quantity of steel is more in case of CSB. Clear span of 10 meters proves to be economical in case of PEB in the same way clear span of 20 and 30 meters are also economical in case of PEB but further increase in span i.e. 40 meters PEB doesn't show any considerable saving in steel quantity, hence up to a clear span of 30 meters PEB is economical in terms of steel quantity and after that steel quantity in both the cases i.e. 40 and 50 meters is almost same. Similarly cost of per meter square of different models shown in fig 4.3 can be calculated which gives brief idea about structure cost without knowing the actual size of the plot. In the field of housing market (whether buying or selling doesn't matter), accurate appraisal of the cost per square meter of the house one wish to sell or buy is paramount. Why? Because if you don't know how large the home or factory one wishes to buy or sell, it is impossible to tell the exact cost, so by calculating the cost per square meter it gets easier.

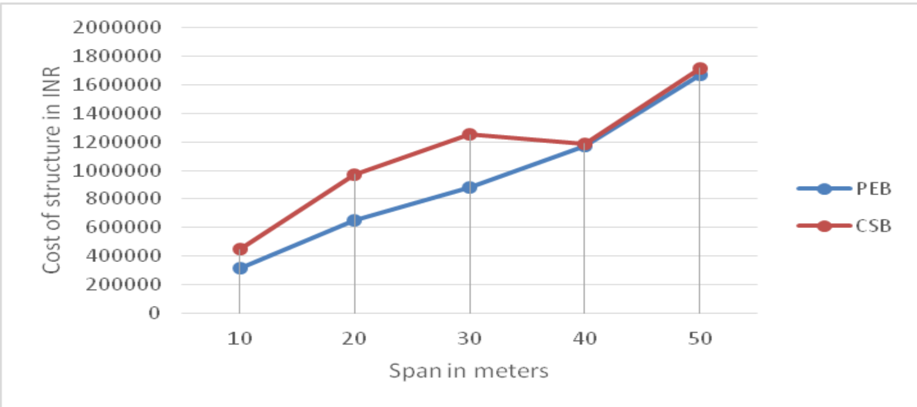

Figure 4.2 COST COMPARISON

Table 4.3 Cost of per square meter for pre-engineered building and conventional steel structure

Span	PEB	CSB
10	1060.9	1487.6
20	1082.5	1623.5
30	979.4	1391.8
40	978.17	989.7
50	1113.5	1144.4

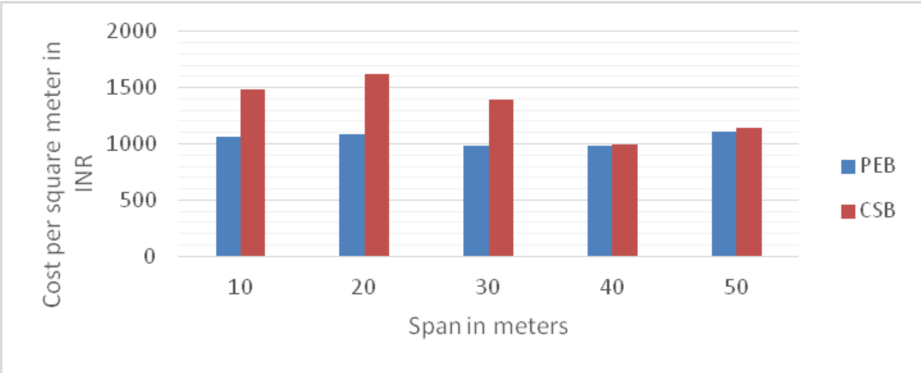

Fig -4.3: Cost of structure per square meter

5. CONCLUSION

Comparative study made on various models of Pre-Engineered building and Conventional steel structure shows that PEB is an economical option and it can be concluded that up to a certain value of clear span Pre-engineered building are most economical option and after a specific span steel quantity in PEB is almost same as that of conventional steel structure. Provision of tapered section in PEB makes it economical and tapering of section is done as per the bending moment diagram. From all the analysis made it can be concluded that steel consumption in PEB is on an average 30% lesser than conventional steel structure. PEB frames are light and more flexible than conventional steel frames and provides higher resistance to seismic forces.

Pre-engineered Metal building concept forms a unique position in the construction industry in view of their being ideally suited to the needs of modern Engineering Industry. It would be the only solution for large industrial enclosures having thermal and acoustical features. The major advantage of metal building is the high speed of design and construction for buildings of various categories.

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