Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 01, January-2022

Comparative Study of Pre-engineered Building and Conventional Steel Building

Swetha Pantheeradi
PG Scholar, Department of Civil Engineering
Sree Narayana Guru College of Engineering & Technology
Payyannur, India

Dr.Susan Abraham
Associate Professor, Department of Civil Engineering
Sree Narayana Guru College of Engineering & Technology
Payyannur, India

Abstract— **Pre-Engineered Building (PEB) concept is a new conception of single storey industrial building construction. 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 concept includes the technique of providing the best possible section according to the optimum requirement. This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss. This paper mainly focuses on PEB concept and CSB concept and how we can choose the concepts for practical application. The study is achieved by designing a Warehouse building as PEB and as CSB with the help of Staad Pro.**

Keywords—Pre-Engineered Building, Conventional Steel Building, Tappered sections, Wind load, Staad Pro.

I. INTRODUCTION

Steel-concrete composite structures are gaining significant importance all over the world in the recent past. Steel-concrete composite construction technique offers number of advantages like increased load carrying capacity and stiffness, saving in weight of steel, reduction in cost of foundation and most importantly a large saving in construction time. Composite construction also leads to a reduction in the overall weight of the structure, which is a pre requisite for earthquake resistant structures. With the increased demand on strength, safety and reliability in all types of structural systems, it has become imperative for developing countries like India, to adopt steel concrete composite construction technique in large scale.

A. Conventional Steel Building (CSB)

Conventional steel buildings (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss. For large pitch, Fink type truss can be used; for medium pitch, Pratt type truss can be used and for small pitch, Howe type truss can be used. Skylight can be provided for day lighting and for more day lighting, quadrangular type truss can be used. The selection criterion of roof truss also includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. Several compound and combination type of economical roof trusses can also be selected depending upon the utility. Standard hot-rolled sections are usually used for the truss elements along with gusset plates.

B. Pre-Enineered Building (PEB)

Technological improvement over the year has contributed immensely to the enhancement in quality of life through various new products and services. One such revolution is Pre-engineered building (PEB). PEB means a part of fabrication, cutting and welding is completed at factory, then it just delivers and erects at the site without doing any fabrication work. Pre engineered steel buildings are manufactured by companies such as IETC, Mabani steel, Interarch Buildings Product Ltd, EPS buildings and PEB steel.

PEB systems are extensively used in industrial and much other non-residential construction worldwide. This concept was introduced to the Indian markets in the late 1990's with the opening up of the economy and a number of multi-nationals settings up their project. Various analysts forecast the pre-engineered building (PEB) market in India to grow at a CAGR of 16.15% during the period 2016-2020[4]. Pre-engineered steel building can be fitted with different structural accessories including mezzanine floors, canopies, fascias, interior partitions etc. and the building is made water proof by use of special mastic beads, filler strips and trims. This is a very versatile building system, and can be finished internally to serve any functions and accessories externally to achieve attractive and unique designing styles. It is very advantageous over the conventional buildings and is really helpful in the low rise building design. PEB are generally low rise building, however the maximum eve height goes up to 25 to 30m. The applications of PEB concept to low- rise buildings are very economical and speedy. Buildings can be constructed in less than half the normal time, especially when completed with the other engineered sub systems.

C. Applications

Pre-Engineered Building concept have wide applications including warehouses, factories, offices, workshops, gas stations, showrooms, vehicle parking sheds, aircraft hangars, metro stations, schools, recreational buildings, indoor stadium roofs, outdoor stadium canopies, railway platform shelters, bridges, auditoriums, etc. PEB structures can also be designed as re-locatable structures.

Conventional steel building applications include multi-story buildings, heavy-loaded industrial facilities, or special shapes for architectural features etc.

D. Objective of the Study

- To design a ware house building for Food products (24m X 48m) as,
  Type I: Pre-engineered Building (PEB)
  Type II: Conventional Steel Building (CSB)

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- Comparative study of PEB and CSB in terms of Quantity of materials, Axial forces and Moments

II. METHODOLOGY

Present study focuses on the concept of Pre engineered buildings and Conventional steel buildings. A ware house for the manufacturing and storage of food products is considered and designed as PEB and as CSB, designated as Type I and Type II.

Type I is Pre-engineered Steel Building of length 48 m and span 24m. Bay lengths are maintained at an interval of 6 m along the length. The eve height of building is taken as 7.8m. The slope of roof is taken as 11˚and covered with roofing sheet. The spacing of purlins is maintained as 1.42 m.

Type II is Conventional Steel Building of length 48m and span 24m. Bay lengths are maintained at an interval of 6m along the length. The eve height of building is taken as 7.8m. The slope of roof is taken as 11˚and covered with roofing sheet. The spacing of purlins is maintained as 1.42 m.

A. Functional Requirements

The functional requirements of the proposed ware house are,

- Size of warehouse : 24 m X 48 m
- Slope of the roof : 11°
- Single bay length : 6m
- Eave height : 7.8 m
- IS 2062 material with a minimum yield strength of 340 N/mm^2 will be used for main frames of PEB
- GI – z purlins of minimum 3.2mm thick will be used as purlins and girts
- Bare galvalium sheets 0.63mm thick (trough shape) will be used as roofing sheets.
- 0.63mm thick pre painted galvalium sheets (PPGA) will be used for side and cladding.
- Walls will be 3m high and 0.20m thick laterite masonry in cement mortar of 1:3 and finished with cement concrete copping of 50mm thick
- Masonry will be supported on plinth beams spanning between the pedestals
- Foundation will be based on the SBC of soil and the expected pull out force due to wind. (in this case Isolated footing)

B. Loads

1) Dead Load (DL):

Dead loads include the weight of all permanent construction. For example, in a building weight of roofs, floors, floor finishes, wall, beams, column, footing, architectural finishing materials etc. constitute dead load. These loads may be assessed by estimating the quantity of each material and then multiplying it with unit weight as per IS 875(part 1):1987

2) Live Load (LL)/ Impose Load(IL):

The loads which keep on changing from time to time are called live loads. Common examples of such loads in a building are the weight of the person, weight of movable partition, dust loads and weight of furniture. These loads are to be suitably assumed by the designer. It is one of the major loads in the design. The minimum values to be assumed are given in IS 875 (part 2):1987. It depends upon the intended use of the building.

3) Wind Load(WL):

The force exerted by the horizontal component of wind is to be considered in the design of buildings, towers etc. The wind force depends upon the velocity of wind, shape, size & location of buildings. A complete detail of calculating wind loads on structure is given in IS 875(part 3):2015. Brief idea is given below;

- Using colour code, the basic wind velocity ‘V_b’ is shown in a map of India. Designer can pick up the value of V_b depending upon the location of the structure
- To get the design wind velocity V_z ,the following expression shall be used;

$$V_z = k_1 k_2 k_3 k_4 V_b \qquad \text{Eq.(1)}$$

Where,
k_1 = Risk coefficient
k_2 = Coefficient based on terrain, height and structure size
k_3 = Topography factor
k_4 = Importance factor for cyclonic regions

The design wind pressure is given by,

$$p_d = k_d k_a k_c p_z \qquad \text{Eq.(2)}$$

Where,

$$p_z = 0.6\, V_z^2 \qquad \text{Eq.(3)}$$

p_d = design wind pressure
p_z = wind pressure at height z
k_d = wind directionality factor
k_a = area averaging factor
k_c = combination factor

Wind loading on individual structural members such as roofs, walls, and individual cladding units and their fittings as per IS875 (part 3):2015,

$$F = (C_{pe} - C_{pi}) * A p_d \qquad \text{Eq.(4)}$$

Where,
C_{pe} = external pressure coefficient,
C_{pi} = internal pressure coefficient,
A = surface area of structural element or cladding unit

C. Load Calculations

1) Dead Load for type 1:

As per IS 875(part 1):1987, item no. 39, class A for 0.63mm thick metal sheeting the maximum load is equal to 0.056 kN/m^2

Weight on frame due to roofing sheet = 0.336 kN/m

As per IS 875(Part I): 1987, table 1, item no. 49, for unbounded rock and slag wool the maximum load between 11.30 kN/m^3 to 19.60 kN/m^3

For 25mm per length of sheet take 15 kN/m^3

Then load = 15 × 0.025
= 0.375 kN/m^2

Weight on frame due to insulations = 2.25 kN/m

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Assuming Z –purlin of CZ 220×30, Flange 74mm with unit weight of 9.05 kg/m

Weight of purlin on frame = 0.380 kN/m
Total weight on frame = 2.966 kN/m
Add 10% for sag rods, bracings etc.
Therefore total weight on frame = 3.262 kN/m
Vertical load on frame = 3.323 kN/m

2) Dead Load for Type 2:

As per IS 875(part 1):1987, item no. 39, class A for 0.63mm thick metal sheeting the maximum load is equal to 0.056 kN/m^2

Weight on frame due to roofing sheet = 0.336 kN/m

As per IS 875(Part I): 1987, table 1, item no. 49, for unbounded rock and slag wool the maximum load between 11.30 kN/m^3 to 19.60 kN/m^3

For 25mm per length of sheet take 15 kN/m^3
Then load = 15 × 0.025
= 0.375 kN/m^2
Weight on frame due to insulations = 2.25 kN/m
Assuming purlin to be ISMC150, unit weight 16.8 kg/m
Weight of purlin on frame = 0.710 kN/m
Total weight on frame = 3.296 kN/m
Add 10% for sag rods, bracings etc.
Therefore total weight on frame = 3.626 kN/m
Vertical load on frame = 3.694 kN/m

3) Impose Load :

As per IS 875(part 2):1987, section 4, table 2,Imposed load intensity is equal to 0.75kN/m^2, for slope up to 10° and for every 1° rise in slope deducts 0.02 from this load intensity value. Hence for 11°,

Imposed load intensity = 0.73 kN/m^2

As per clause 4.5.1 of IS 875(part II):1987, If slope is more than 10° the imposed load on frames or whichever is supporting the purlins be designed for 2/3rd of the imposed load

Intensity of imposed load on frames = 2/3 × 0.73
= 0.487 kN/m
Imposed load on frame (vertical) = 2.868 kN/m

4) Wind Load:

As per IS 875 (part 3):2015,

Location: Kannur
Basic wind speed,V_b = 39 m/s

Risk coefficient factor (k_1) = 1.06
Terrain and height facto (k_2) = 1.0013
Topography factor (k_3) = 1
Importance factor for cyclonic regions (k_4) = 1.15
Design wind speed Vz = $k_1k_2k_3\ k_4V_b$
= 1.06 x 1.0013x 1 x 1.15 x 39
= 47.60 m/s
Wind pressure at height z, p_z = 0.6 V_z^2
= 0.6 x 47.60^2
= 1.36kN/m^2
Wind directionality factor (k_d) = 0.90
Area averaging factor (k_a) = 0.80
Combination factor (k_c) = 0.90
Design wind pressure, p_d = $k_dk_ak_cp_z$
= 0.90 x 0.80 x 0.90 x 1.36
= 0.881kN/m^2

As per IS 875 (part 3):2015, cl.7.3.1,

$$F = [C_{Pe} - C_{Pi}]\ AP_d$$
$$F = 1.42 \times 0.881\ [C_{Pe} - C_{Pi}]\ KN/m$$

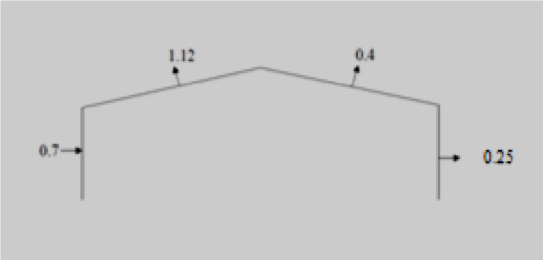

Fig. 1. External pressure coefficient diagram (Cp_{e1})

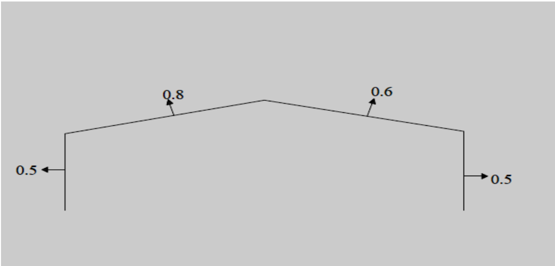

Fig. 2. External pressure coefficient diagram (Cp_{e2})

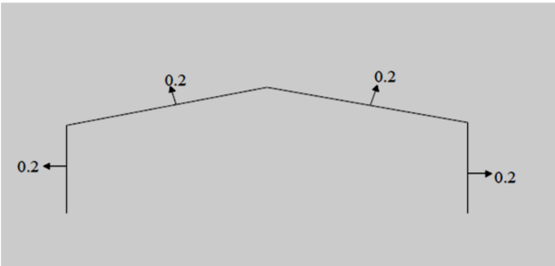

Fig. 3. Internal pressure coefficient diagram (Cp_{i1})

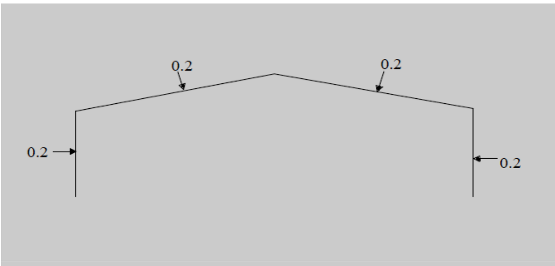

Fig. 4. Internal pressure coefficient diagram (Cp_{i2})

Case 1 = $C_{Pe1} + C_{Pi1}$

Case 2= $C_{Pe1} + C_{Pi2}$

Case 3= $C_{Pe2} + C_{Pi1}$

Case 4= $C_{Pe2} + C_{Pi2}$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 01, January-2022

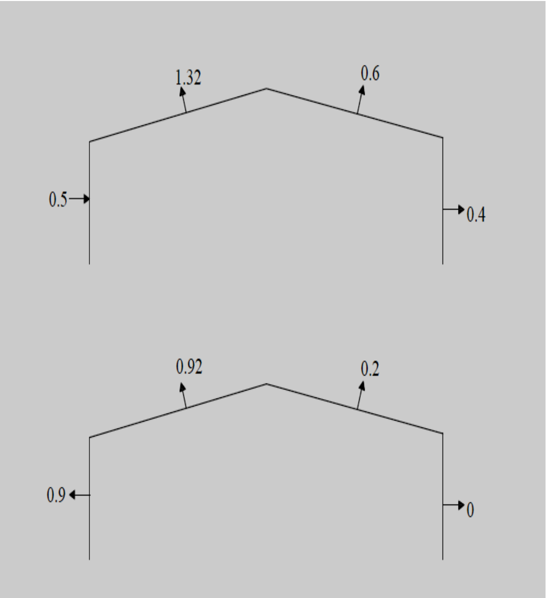

Fig. 5. Combination diagram (Case 1 and Case 2)

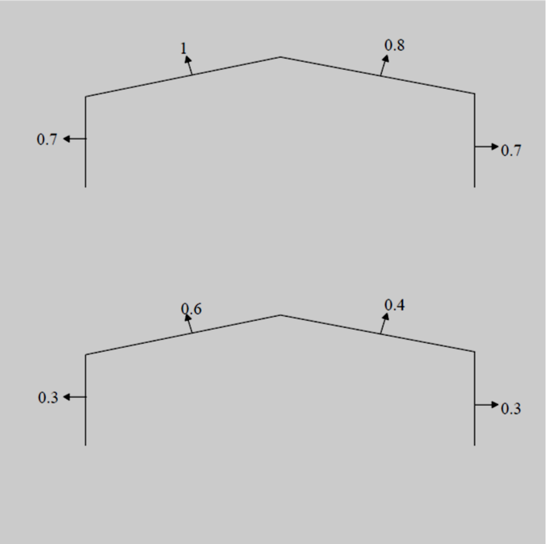

Fig. 6. Combination diagram (Case 3 and Case 4)

D. Final Loads

1) For Type 1

Dead Load (DL) = 3.323 kN/m
Imposed load (IL) = 2.868 kN/m

TABLE I. WIND LOAD FOR TYPE 1

Wind load cases	Windward (kN/m)	Leeward (kN/m)
WL1	7.297	3.317
WLC1	2.643	2.379
WL2	5.086	1.106
WLC2	4.757	0.264
WL3	5.528	4.422
WLC3	3.7	3.7
WL4	3.317	2.211
WLC4	1.586	1.586

2) For Type 2

Dead Load (DL) = 3.694 kN/m
Imposed load (IL) = 2.868 kN/m

TABLE II. WIND LOAD FOR TYPE 2

Wind load cases	Windward (kN/m)	Leeward (kN/m)
WL1	7.297	3.317
WLC1	2.643	2.379
WL2	5.086	1.106
WLC2	4.757	0.264
WL3	5.528	4.422
WLC3	3.7	3.7
WL4	3.317	2.211
WLC4	1.586	1.586

III. ANALYSIS AND DESIGN

Type 1 building is analyzed using Staad Pro. V8i. The Axial force, Shear force and Bending moment at the three joints were noted down (at A, B, C)

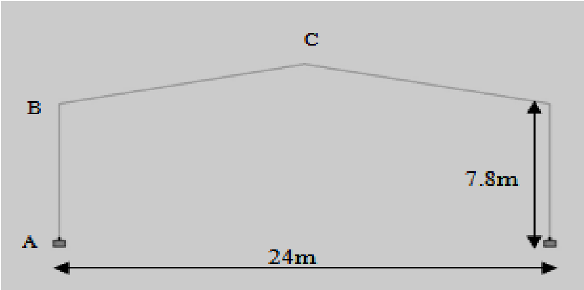

Fig. 7. Elevation of Pre-engineered building with slope 11°

The frame section is designed using Pre Engineered I-Section software.

At A	IS 250×200
At B	IS 400×200
At C	IS 200×200

Type 2 building is analyzed and designed using Staad Pro. V8i.

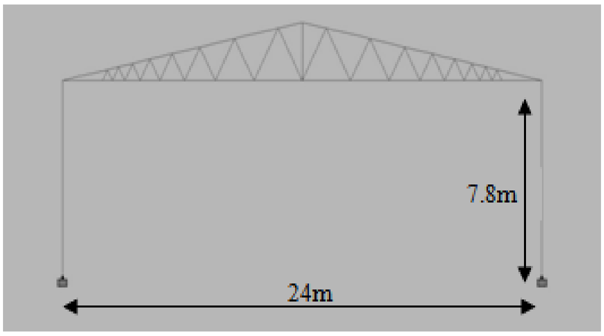

Fig. 8. Elevation of Conventional steel building with slope 11°

IV. RESULTS AND DISCUSSION

The weights of conventional steel building and pre-engineered building are calculated after the design. For conventional steel building the weight of the section is given in Table III and that for pre-engineered building is given in Table IV.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 01, January-2022

A. Weight of the steel for Conventional Steel Building

In order to calculate the steel weight of conventional steel building the following member properties are used (Table 3). Hot rolled "I" sections are assigned for columns. For the truss members Indian standard angles are used. For purlins, girts and eave strut ISMC (Indian Standard Medium Channels) are used. Now using the above parameters the weights are calculated accordingly

TABLE III. STEEL TAKE OF FOR CONVENTIONAL STEEL BUILDING

Profile	Weight (Tonne)
ISWB600	20
ISMC150	20.50
ISA150×150×12(Double)	25
ISA80×80×12	5.350
Base plate 850×350×25	1.10
Add 30% for bolts, gusset plates, sag rods, bracings etc.	21.60
Total	93.55

B. Weight of steel for Pre-Engineered building

In order to calculate steel weight of PEB the following member properties are used (Table 4). For columns and rafters tapered "I" sections are assigned. For the purlins and girts cold formed "Z" sections are used.

TABLE IV. STEEL TAKE OF FOR PRE-ENGINEERED BUILDING

Profile	Weight (Tonne)
Tapered member 1 (AB)	10
Tapered member 2(BC)	15.20
Z purlin CZ 220× 30	11.30
Base plate 490×300×25	0.52
Add 40% for bolts, gusset plates, sag rods, bracings stiffeners etc.	14.81
Total	51.83

C. Comparisson of Axial forces and Moments

Comparison of member forces and joint displacements at ridge and haunch portion with critical load and at same location was as mentioned below. From the comparison it is observed that,

- At ridge and haunch of the building Maximum bending moment for PEB is more than CSB by 4.81 % and 16 % respectively. This is due to the entire force will concentrated in PEB where as in CSB it is distributed.
- At ridge of the building axial force for CSB is more than PEB by 18.31 %, at haunch of the building PEB is more than CSB by 27% this is due to the entire force has to transfer at haunch like beam action in PEB where as in CSB it is like a truss arrangement.
- At ridge and haunch of the building shear force for PEB is more than CSB by 16.5 % and 30 % this is due to the entire force will concentrated in PEB where as in CSB it is distributed

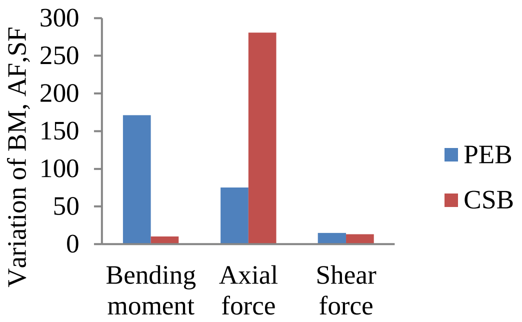

Fig. 9. Variation of bending moment, axial force and shear force for PEB and CSB at ridge

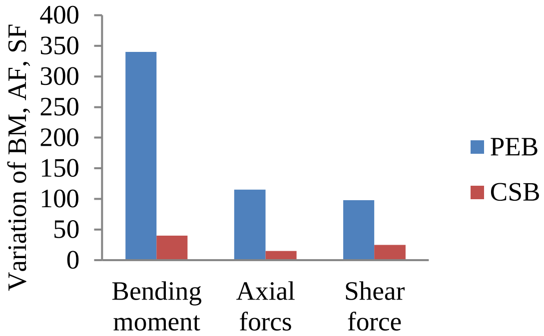

Fig. 10. Variation of bending moment, axial force and shear force for PEB and CSB at haunch

V. CONCLUSIONS

Choosing steel to design a Pre-engineered steel structures building is to choose a material which offers low cost, strength, durability, design flexibility, adaptability and recyclability. In light of the study, it can be concluded that PEB structures are more advantageous than CSB structures in terms of,

- Quality control speed in construction and simplicity in erect
- The total steel take off for PEB is 45% lesser than that of CSB
- It is observed than maximum moment will be high for PEB than CSB
- The axial force at ridge is higher for CSB than PEB but axial force at haunch is higher for PEB than CSB
- The shear force for PEB is greater compared to CSB
- Architectural versatility

But we cannot completely conclude Pre engineered building should be used for all constructions. Because the concept of PEB's introduced from the conventional methods and there are cases where we cannot adopt PEB's such as,

- Projects which lacks funds for the high initial investments
- For small span structures
- Places far from the PEB manufacturing factories and CSB materials are locally available etc.

Hence it can be concluded that both the concepts are useful for the future construction industry with improved versions and design criteria.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 01, January-2022

Steel building find a large scope for the future of Indian construction industry and the day is quite close when steel buildings would be the rule rather than being the exception.

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