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"Analysis and Cost Comparative study of Conventional Industrial building with PEB structure"

Er. Vivek Thakre
M.tech. Structural Engineering, G. H. Raisoni Academy of Engineering & Technology Nagpur – 17, India

Abstract: Pre-Engineering Building (PEB) concept is a new concept of single story industrial building construction. The Present work involves the comparative study and design of Pre Engineering Buildings (PEB) and Conventional Steel Building (CSB).Conventional steel building is old concept which take lots of time, quality and typical erection factor to modified that issues Pre Engineering concept developed. It introduced to the Indian market in 1990's. PEB concept is totally versatile not only due to its quality, prefabrication, light weight and economical construction. The study is achieved by designing a typical frame of industrial warehouse shed using both the concept and analyzing the designed frame using the structural analysis and design software STAAD Pro.

Keywords: AISC, MBMA, Pre-Engineered-Buildings, Conventional Steel building, Staad Pro and Utilization *Ratio.*

Introduction

An industrial building is any structure that is used to store raw materials, house a manufacturing process, or store the furnished goods from a manufacturing process. Industrial buildings can range from the simplest warehouse type structure to highly sophisticated structures integrated with manufacturing system. These buildings are low rise steel structures characterized by low height, lack of interior floor, walls, and partitions. The roofing system for such a building is a truss with roof covering. Design of basic elements of the structure (Roof deck, Purlins, Girders, Columns and Girt) is not difficult, but combining them into functional and cost effective system is a complex task. In Industrial building structures, the walls can be formed of steel columns with cladding which may be of profiled or plain sheets, GI sheets, precast concrete, or masonry. The wall must be adequately strong to resist the lateral force due to wind or earthquake.

Steel industry is growing rapidly in almost all the parts of the world. The use of steel structures is not only Economical but also Eco friendly at the time when there is a threat of global warming. Here, "economical" words stated considering Time and Cost. Time being the most important aspect, steel structures (Pre-fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB). Pre-engineered buildings are nothing but steel buildings in which excess steel is avoided by tapering the sections as per the bending moment's requirement. One may think about its possibility, but it's a fact many people are not aware about Pre Engineered Buildings. If we go for regular steel structures, time frame will be more, and also cost will be more, and both together i.e. time and cost, makes it uneconomical.

The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behavior in high winds. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Pre-engineered Buildings have bolted connections and hence can also be reused after dismantling. Thus, pre Engineered buildings can be shifted and expanded as per the requirements in future.

Pre-Engineered Buildings

Pre-Engineered Building concept involves the steel building prefabricated systems which are predesigned. As the name indicates, this concept involves Pre-Engineering of structural elements using a predetermined registry of building materials and manufacturing techniques that can be proficiently complied with a wide range of structural and aesthetic design requirements. The basis of the PEB concept lies in providing the section at a location only according to the requirement at that spot. The sections can be varying throughout the length according to the bending moment diagram. This leads to the utilization of non-prismatic rigid frames with slender elements. Tapered I sections made with built-up thin plates are used to achieve this configuration. Standard hot-rolled sections, cold-formed sections, profiled roofing sheets, etc. is also used along with the tapered sections. The use of optimal least section leads to effective saving of steel and cost reduction. The typical PEB frame of the structure is as shown in the Figure.

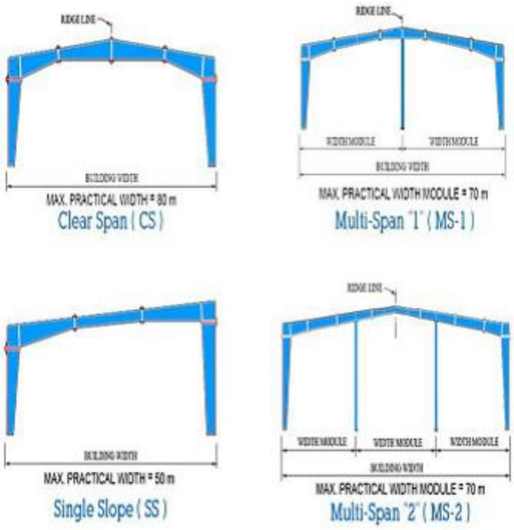
Pre Engineered Building

Conventional Steel Buildings

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. The CSB frame of the structure considered in the study is as shown in Figure.

Conventional Steel Building

Typical Pre-engineered steel frames



Pre Engineered Building types

Various Loads on an Industrial Building

Dead Load

The dead load of truss includes the dead load of roofing materials, purlins, trusses and roof bracing systems. The dead weight of the trusses may be assumed to be equal to 10% of the load on the truss. The weight of the bracing may be assumed to be 12- 15 N/m^2 of the plan area. A simple for the estimation of the approximate dead weight of the roof truss in N/m^2.

Superimposed Load

The load assumed to be produced by the intended use of occupancy of a building, including the self weight of movable partitions, distributed, concentrated loads, loads due to impact and vibration sand dust load but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement etc. IS: 875 (part 2) 1987 specifies live loads to be assumed in the analysis of an industrial building.

Wind Load

The most critical load on an industrial building is the wind load. For the roof and walls of an industrial building, consideration must be made for pressure difference between the opposite faces of such elements to accounts for external and internal air pressures exerted by wind blowing against the building. When the negative air pressure is less than the atmospheric pressure is known as suction. IS 875(part 3) 1987 specifies the following wind load coefficients to be assumed in the analysis of an industrial building.

The wind force F is obtained by an equation

$$F= (Cpe – Cpi)*Apz$$

Snow Load

IS 875 (part 4) 1987 specifies the following snow load to be assumed in the analysis of an Industrial building. If the structure is situated in an area where the roof is subjected to snow, the load considered for design should be the maximum of live or snow load. The load due to snow depends upon the pitch of the roof, shape of the roof and roofing material. Snow load may be assumed to be 2.5 N/m2 per mm depth of snow. When the roof slope is greater than 50 degree snow load may be neglected.

Advantages Of Steel Construction

1. High quality, aesthetic
2. Lower maintenance costs
3. Non-combustible to fire
4. Steel is environmentally friendly
5. Components can be used again and again
6. Steel components are frequently functional
7. Steel construction is strong, durable and stable
8. Steel Construction promotes good design and safety
9. Construction with Steel is sustainable to Temperature effects
10. Steel frame construction is rigid in structure and dimensionally stable
11. Steel can be re-used without effecting the environment
12. Construction with Steel components is very fast compared to other materials
13. Steel construction of buildings with steel components is resistant to termites and other destructive insects
14. Steel constructions are cheaper than any other construction methods
15. Steel construction is a fast method of construction

Disadvantage of Steel Construction

1. Economical point as compare to RCC structure it's costly
2. Water leakage problem faces on rainy season
3. Steel structure considered for wind or seismic effect as compare to other structure
4. Rusting problem faces due to moisture
5. Molding of structure as per architectural geometry is quite difficult

Application of PEB

The most common applications of Pre-Engineered Buildings are:-

1) Factories
2) Steel Mills

3) Sports Stadiums
4) Shipyards
5) Logistic Centre
6) Waste Treatment Factories
7) Cold Storage
8) Ware Houses

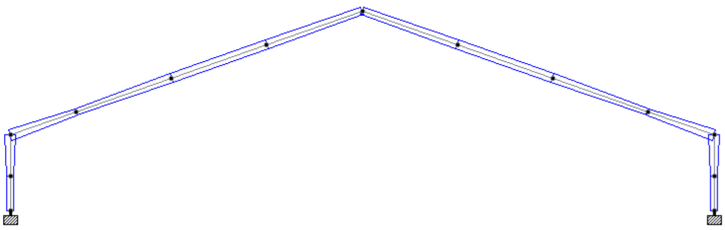
Overview

The designed loads play a crucial role in case of PEB & CSB. The Failure of the structure occurs if not properly designed for loads. The determination of the loads acting on a structure is a complex problem. The nature of the loads varies essentially with the architectural design, the materials and the location of the structure. Loading conditions on the same structure may change from time to time, or may change rapidly with time. The various Codes have been referred to understand the various criteria of project undertaken.

From the codes data is summarized for work.
For the purpose of designing any element, member or a structure, the following loads (actions) and their effects shall be taken into account, where applicable, with partial safety factor.
a) Dead loads
b) Imposed loads (live load, crane load, snow load, dust load, wave load, earth pressures, etc.)
c) Wind loads
d) Earthquake loads
e) Erection loads
f) Secondary effects due to contraction or expansion resulting from temperature changes, differential settlements of the structure as a whole or of its components, eccentric connections, rigidity of joints differing from design assumptions.

Structural Geometry of PEB Building

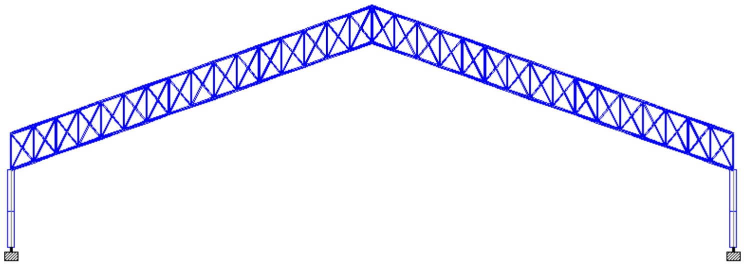
SR.NO.	DESCRIPTION	PEB
1.	Length	40.0 M
2.	Width	30.0,45.0 & 60.0 M
3.	Height	6.0 M
4.	Slope	1 : 03
5.	Bay spacing	6.0,8.0 & 10.0 M
6.	Brick wall	3.0 M



Typical PEB Frame

SR. NO.	DESCRIPTION	CSB
1.	Length	40.0 M
2.	Width	30.0,45.0 & 60.0 M
3.	Height	6.0 M
4.	Slope	1 : 03
5.	Bay spacing	6.0,8.0 & 10.0 M
6.	Brick wall	3.0 M

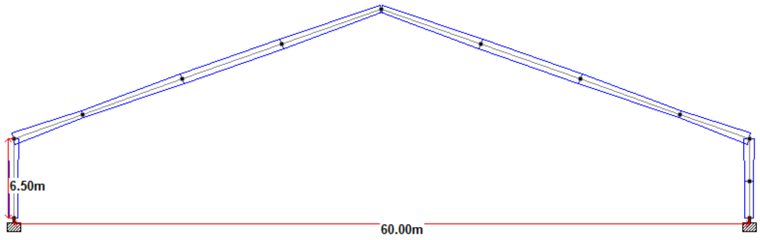
Structural Geometry of CSB Building



Typical CSB Frame

Modelling Consideration

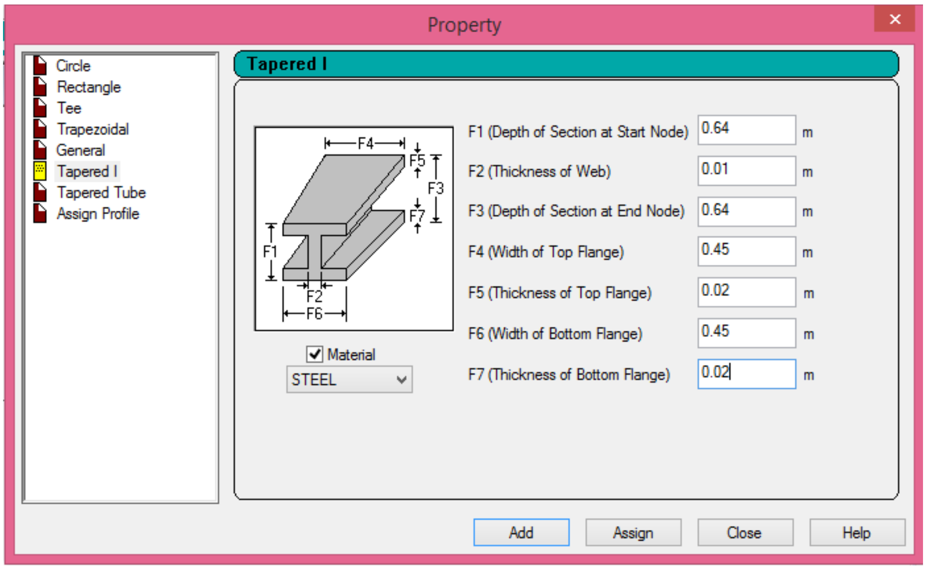
Properties for Pre-Engineering Building



Geometry of PEB Frame

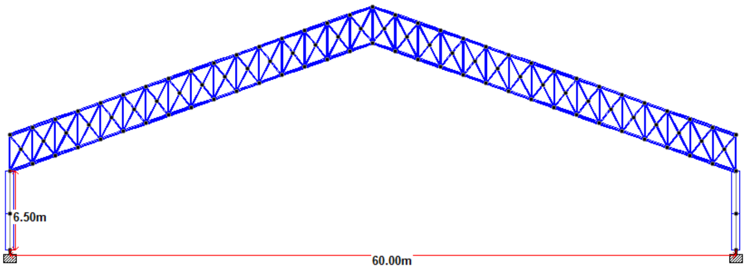
Geometry Limitation for PEB

Profile	Limitations
Depth of Web	300 to 1800 mm
Thickness of Web	5 to 25 mm
Width of Flange	150 to 500 mm
Thickness of flange	6 to 25 mm



Properties by STAAD Pro

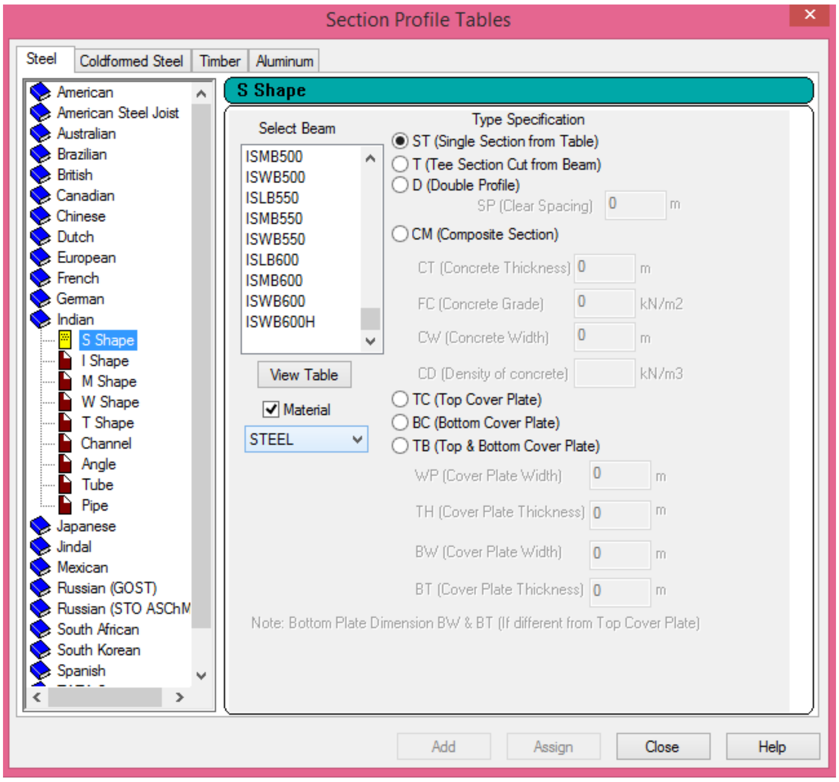
Properties for Conventional Steel Building



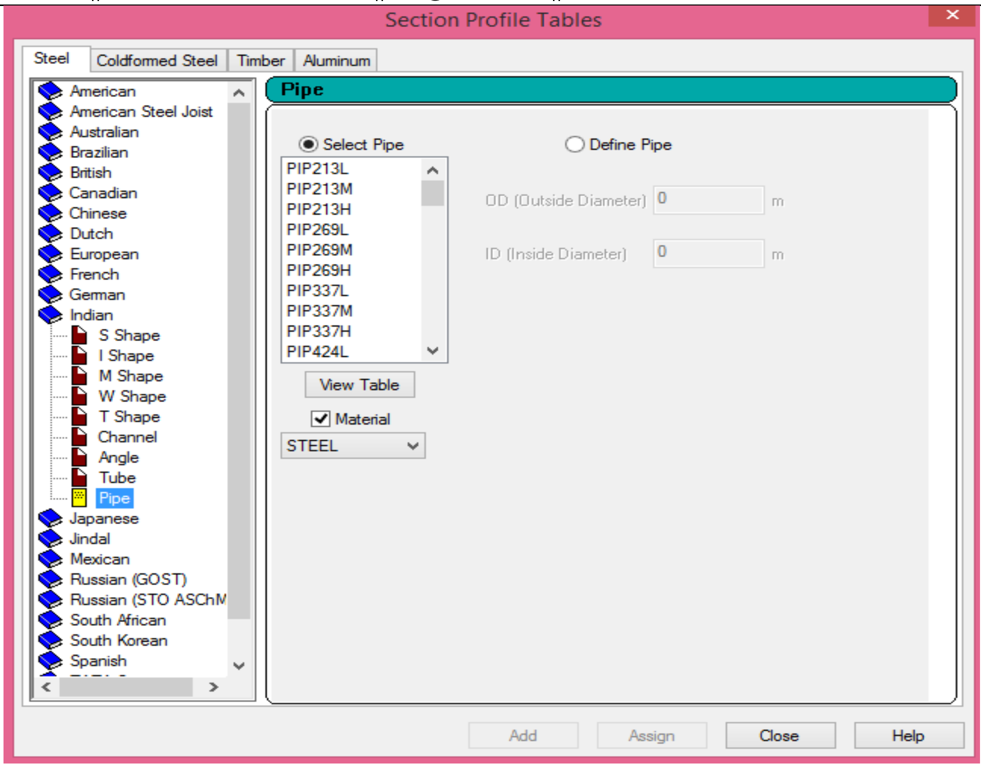
Geometry of CSB Frame

Geometry Limitation for CSB

Profile	Limitations
Hot Rolled Section	(ISLB 75 – ISWB 600H)
Angle Section	ISA (20X20X3 – 200X200X5)
Pipe Section	PIP(213L –3556H)
Tube Section	TUB(25252.6 - 1501506)



Properties by STAAD Pro



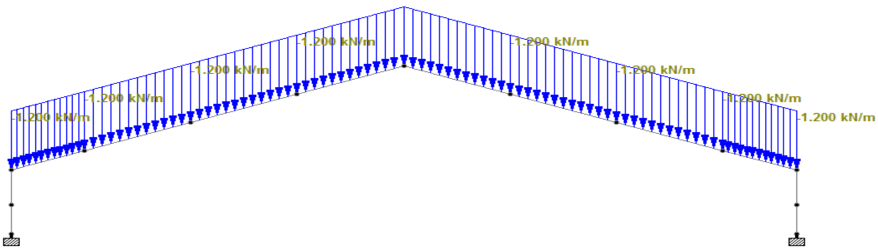
Properties by STAAD Pro

Calculation of loads

Dead Load

Dead Load (Sheet + Purlin)= 0.15 KN/m^2

For 8.0 m bay D.L = 0.15 x 8.0 = 1.2 KN/m^2

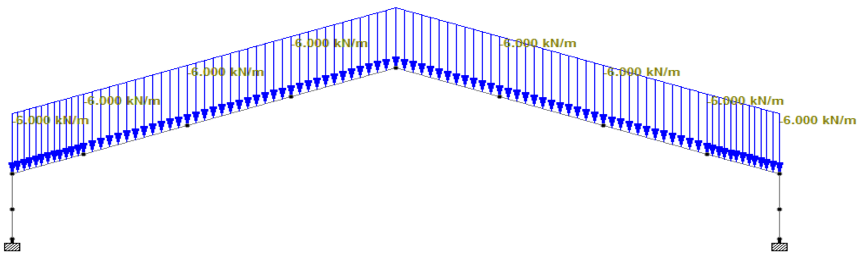


Acting Dead Load

Live Load

Live Load = 0.75 KN/m^2

For 8.0 m bay D.L = 0.75 x 8.0 = 6.0 KN/m^2



Acting Live Load

Calculation for Wind loads

Wind loads are calculated as per IS 875 Part-III (1987) & SP 64 in this example. For the present work, the basic wind speed (Vb) is assumed as 50 m/s and the building is considered to be open terrain with well scattered obstruction having height less than 10.0 m with maximum dimension more than 50.0 m and accordingly factors K1,K2 ,K3 have been calculated as per IS-875-Part-III (1987).

Terrain Category – 3
Building Class – B
K1 = Probability Factor (risk coefficient) = 1.0
(General buildings and structures)
K2 = Terrain height and size factor = 0.88
K3 = Topography factor = 1.0
Vb = 44 m/s (For Nagpur Zone)

Design Wind speed
Vz = Vb (K1 x K2 x K3)
Vz = 44 (1 x 0.0.88 x 1)
Vz = 38.72 m/s

Design Pressure
$Pz = 0.06\ Vz^2$
$Pz = 0.06 \times (38.72)^2$
$Pz = 0.899\ KN/m^2$
Ratio = H/W = 0.20, L/W = 1.33

Wind Pressure Co-efficient

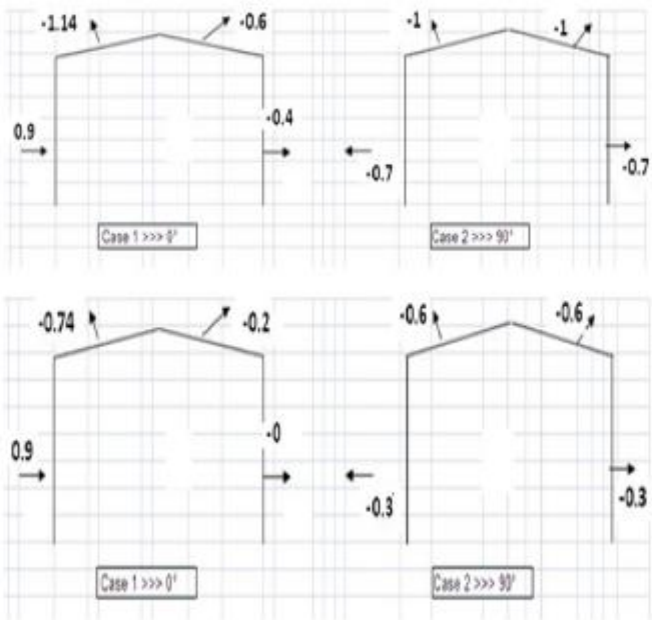
External and Internal wind co-efficient are calculated for all the surfaces for both pressure and suction. Opening in the building has been considered less than 5 % and accordingly internal co-efficient are taken as +0.5 and -0.5.

The external co-efficient and internal co-efficient calculated as per IS-875 Part-II (1987).

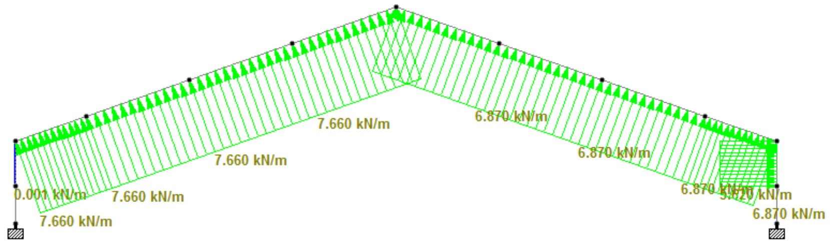
Wind load on individual member are then calculated as below:

F = (Cpe – Cpi) x A x P

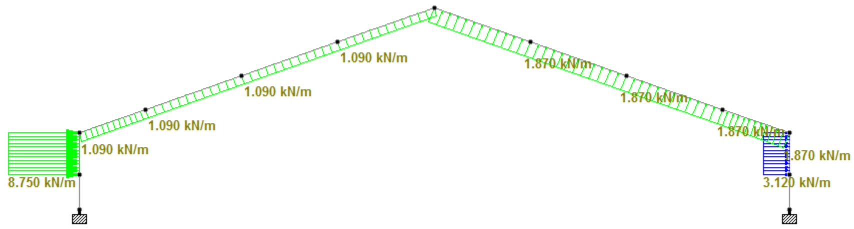
Where, Cpe and Cpi are external co-efficient and internal co-efficient respectively and A and P are Surface area in $m^2$and design wind pressure in KN/m^2 respectively.



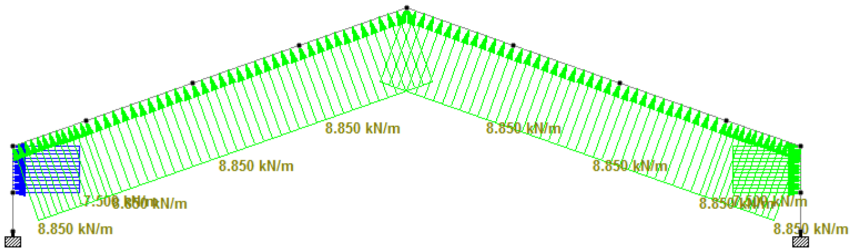
Wind Co-efficient Chart



Wind Co-efficient by IS Code for Transverse Direction (Pressure)



Wind Co-efficient by IS Code for Transverse Direction (Suction)



Wind Co-efficient by IS Code for Longitudinal Direction (Pressure)

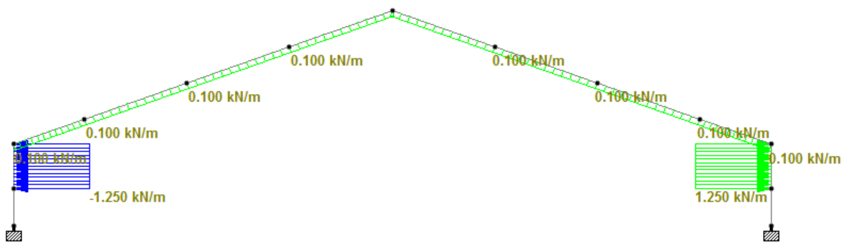


Figure 4.14 Wind Co-efficient by IS Code for Longitudinal Direction (Suction)

Results & Discussion

The structural analysis and design of the structural frame considered was done using the Staad Pro software which is very user friendly and effective. First a typical frame is selected from the structure. First the frame was analyzed and designed according to the PEB concept and then by the CSB concepts. On comparing the results of both the analysis, the following results were obtained.

Discussion

Pre-Engineered Buildings have vast advantages over the Conventional Steel Buildings. The results of the software analysis and literature studies conducted for both the concepts suggest the same. The various inferences made from the studies are described below.

a) Material Take off

PEB structures are lighter than CSB structures, the software analysis it was found that the PEB roof structure is almost 30% lighter than the CSB structure. Regarding the secondary members, light weight Z purlins are used for PEB structure whereas heavier hot-rolled sections are used for CSB structure.

b) Design

PEB design is rapid and efficient compared CSB design. Basic design steps are followed and optimization of materials while software analysis is possible for PEB, increasing the quality of design, CSB design is done with fewer design aids and each project needs to develop the designs which require more time. Connection design is also lesser for PEB when measured up to CSB.

c) Foundation

Support reaction for PEB is much lesser than CSB as per the analysis. Hence, light weight foundation can be adopted for PEB which leads to simplicity in design and reduction is cost of construction of foundation. Heavy foundation will be required for CSB structure.

d) Delivery of materials

For PEB, delivery is done in around 6 to 8 weeks and for CSB it is 20 to 26 weeks.

e) Erection

Erection procedure is standard for all the projects and it is done free of cost by the manufacturer which results in faster and cost effective erection for PEB. Erection of CSB differs from project to project and separate labour has to be allocated, leading to 20 percent more expense than PEB.

f) Earthquake resistance

Low weight flexible frames of PEB offer higher resistance to earthquake loads than rigid heavy frames of CSB.

g) Cost

PEB costs 30% lesser than cost for CSB. Outstanding architecture can be achieved at low cost for PEB. Single sourcing and co-ordination of PEB is highly cost effective than multiple sourcing system of CSB. Building accessories are mass produced for PEB which also leads to economy.

h) Change of order

Due to standardized design, PEB manufacturers are able to stock large amount of elements and accessories which can be flexibly used in many types of PEB construction. Hence change of order can be fulfilled easily at any stage of construction. Cost for change of order is also lesser in this case. In case of CSB, change of order is expensive and time.

i) Future expansion

Single sourcing of PEB is advantageous for future expansion whereas multiple sourcing of CSB poses difficulty. Future expansion is easy and simple for PEB whereas it is most tedious and costly for CSB.

j) Performance

All components of the PEB system are specially designed to act together as a system for highest efficiency. PEB designs are revised regularly with respect to the actual field conditions and in accordance with various country codes, which resulted in improved standardized designs leading to high performance of the structure. CSB system components are conventionally designed for a specific project and the performance depends on how the individual project is designed.

k) Advantages of PEB

The concept of Pre-Engineered Buildings is extensively used for the construction single story industrial steel buildings. This system has many benefits than the conventional construction concepts that have been using. PEB systems have numerous advantages including cost effectiveness, quality control, speed in construction, ease in expansion, and achievement of large span, long durability, exceptional architecture, and standardization of materials, standardization of design, single sourcing and co-ordination, speed in delivery. By understanding the preliminary design concepts, it is easy to achieve the design of PEB system.

l) 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 structure.

Future Scope

The present study on PEB & CSB structures has been carried out .However, it is proposed that future study needs to investigate the following aspects related to the present analysis.

- Software's like E-TAB, MBS, SAP 2005 can also be used for analysis of PEB & CSB Structures.
- Design the structure for future expansion or addition of other components like crane, mezzanine on it.
- PEB can also design and fabricated for residential buildings.
- Analysis of unsymmetrical PEB structure can be done.
- Analysis and design of various zones can be done in future.
- Other international codes can be used for analysis and comparison like AISC and MBMA.

Conclusion

This paper effectively conveys that PEB structures can be easily designed by simple design procedures in accordance with country standards. In light of the study, it can be concluded that PEB structures are more advantageous than CSB structures in terms of cost effectiveness, quality control speed in construction and simplicity in erection. The paper also imparts simple and economical ideas on preliminary design concepts of PEBs. The concept depicted is helpful in understanding the design procedure of PEB concept.

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