AN ANALYTICAL STUDY ON PRE ENGINEERED BUILDING BY USING STAAD PRO

Submitted by:

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ABSTRACT:

With the development of science and technology in the field of structural engineering as well as in Civil engineering , the adaptation of pre engineered building can be observed in industrial as well as residential building sectors. In the earlier days, even if Pre Engineered Building ideas were there, it was quite a lengthy process to design and check whether the structure is acceptable or not. But in this modern day world , with the coming of various softwares like Staad pro, it has become more convenient to adopt the practice of pre engineered building than conventional steel building.

LITERATURE REVIEW:

1.Syed Firoz, et. al; (2012) observed that, The pre-engineered steel building system construction has great advantages to the single storey building, practical and efficient alternative to conventional buildings, the system representing one central model within multiple disciplines. Pre-engineered building creates and maintain in real time support is currently being implemented by Staad Pro 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. Steel is the basic material that is used in the materials that are use for Pre-engineered steel building. It negates from regional sources. It also means choosing reliable industrial products which come in a huge range of shapes and colors, it means rapid site installation and less energy consumption. It means choosing to commit to the principles of sustainability. Infinitely recyclable, steel is the material that reflects the imperatives of sustainable development. A tall steel building is not more in the total number of tall steel structures that are built around the world. A large steel structures that are built are only single storey building for industrials purpose. Secondary structural members span the distance between the primary building frames of metal building systems. They play a complex role that extends beyond supporting roof and wall covering and carrying exterior loads to main frame. Secondary structural, as these members are sometimes called, may serve as flange bracing for primary framing and may function as a part of the building's lateral load-resisting system. Roof secondary members, known as purlins, often form an essential part of horizontal roof diaphragms; wall secondary members, known as girts, are frequently found in wall bracing assemblies. The majority of steel structures being built are only low rise building are normally used for steel plants, automobiles industries, light, utility and process industries, thermal power station, warehouses, assembly plants, storages, garages small scale industries, etc. these building requires large column free areas. Hence interior columns, wall and partition are often eliminated or kept to a minimum. Most of these building may require adequate headroom for use of an overhead travelling crane. A third type of secondary framing, known by the names of eave strut, eave purlins, or eave girt, acts as part purlins and part girts top flange support roof panels, its web part siding. Girts, purlins, and eave struts exihibits similar structural behavior. Since most secondary members normally encountered in metal building system are made of cold-formed steel our discussion starts with some relevant issues in design of cold-formed steel structures.

2.C.M. Meera (2013) , has carried out a comparative study of PEB and CSB concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concept and analyzing the designed frames using the structural analysis and design software Staad Pro. The designing of industrial warehouse includes designing of the structural element including principal rafter or roof truss, column and column base, purlins, sag rods, tie rods, gantry girder, bracing, etc. A combination of standard hot-rolled sections, cold-framed Industrial building can be categorized as Pre-Engineered Building (PEB) and Conventional Steel Building (CSB), according to the design concepts. The paper starts with the discussion of methods adopted in the study. Loads and the load combination adopted for carrying out the analysis of the structure is well defined in the further portions. A section depicting the importance of the software used and the software procedure followed is included. Final portion explains the results obtained from the software analysis of the case study and the inferences from the literature studies. The paper aims at developing a perception of the design concept of PEB structures and its advantages over CBS structure.

3.Sagar Wankhede et.al; (2014) has given a review paper on comparisons of Conventional Steel Building and Pre- Engineered Building. The paper starts with discussion of various element of industrial building such as Purlins, sag rod, Principal rafters, Roof Truss, Gantry Girders, Brackets, Column and Column Base, Girt Rods, Bracing. Further carried by study load and load combination as per IS 875-1987. Then he has given an overview of concepts of Pre engineering

Building by stating its advantages, effective use and about its frame. The final portion consist of describing about the component of Pre Engineered
Building that are, Main Frame, Secondary frame, wind Bracing and Exterior Cladding. He has also shown us Comparisons between PEB and CSB. And finally concluded that PEB structures are more advantageous than CSB structures in term of cost effectiveness, quality control speed in speed in construction and simplicity in erection.

4.Shrunkhal V. Bhagatkar et. al;(2015), has shown a study on Pre Engineered Building with review of various authors of papers on Pre Engineered Building. The paper aimed to assess from the past advancement, the use of PEB is implemented and continuously increasing, its usage is not throughout the
construction industry. It is reviewed that PEB structures can be easily designed by simple design procedures in accordance with country standards, it is energy efficient, speedy in construction, saves cost, sustainable and most important its reliable as compared to conventional buildings. Thus PEB
methodology must be implemented and researched for more outputs.

5.Prof. P. S. Lande et. al;(2015) analyze and design of Conventional Steel Building and Pre-Engineered
Building has been carried out and conclude that PEB structure can be easily designed by simple design procedures in accordance with country standards. Low weight Flexible frames of PEB offers higher resistance to wind load. Cold Formed steel section over hot rolled section as purlin is almost lighter than
32%. Pre Engineered Building weight is 35% lesser than weight of conventional steel building. Pre Engineered Building construction gives end users a much more economical and better solution for long span structures where column free areas are needed. The study is achieved by designing 3D frame of a
Industrial Warehouse building using both the concept and analyzing the frame using the Staad Pro software. The economy of structure is discussed in terms of its weight comparisons.

INTRODUCTION:

HISTORY OF PRE ENGINEERED BUILDING

Pre Engineered Building is a steel structure designed and fabricated according to the needs by a manufacturer or a supplier.
During the 1960s, standardized steel designs for buildings were available in the market and they were named as pre engineered buildings. Since day one, I sections were used as standard shape and structure for pre engineered buildings. The fabricated steel sections or beams were assembled at sites using nuts and bolts. Different dimension from large to small were fabricated according to the load and size of the structures required.
Later on, it was found that with standardized pre engineered buildings, the cost of the projects could be reduced with a huge difference and also the total weight of the structure were also up to 30% more lighter in case of pre- engineered building than that of conventional steel designs.

OBJECTIVES:

1)To utilize the flexibility of Staad pro software to get a preferable result.
2) To reduce the cost of the whole project.
3) To analyse the advantages of peb to that of conventional steel structures.

ANALYSIS USING STAAD PRO V8i SS5

Staad Pro V8i SS5 software has been used to analyse and design Pre-engineered building structures and conventional structures in this project. For the first structure, a 3D pre engineered building model of A WAREHOUSE building has been designed and compared with conventional structure using conventional steel. In the second example, a 2D plane frame of width 88m has been designed with tapered sections for PEB, this structure cannot be constructed using conventional method since it is not feasible and also not economical to design. Different Bay spacing were considered to check the most suitable one.

PRE ENGINERRED BUILDING BY STAAD PRO

Staad pro V8i SS5 comes with various tools and modes to benefit us with a user friendly interface. Design and analysis can be done side by side to check any errors in the designs. For, PEB design, different dimensions of the Tapered I sections can be checked for a stable and optimised structure and the same is for conventional steel design, where pre rolled section with dimensions available in the market are accessible for designing and analysis purposes.

STAAD Pro software can be used for analysing and designing of the pre-engineered buildings. It can analyse the Bending Moment, Axial Forces, Shear Forces, Torsion, Beam Stresses of a steel structure so that the design can be done using tapered sections and check for the safety.

For the current project, common stiffness matrix method has been used for the analysis of the structure. The members of Pre-engineered building used are tapered using the in-built option of the Software. The software provides options for support options for our requirements. Here in this project, fixed supports are assigned. For the loads, we calculated it manually and assigned it to our structure using the correct steps.

WAREHOUSE DESIGN DATA

BUILDING DETAILS:

- Length = 42m
- Width = 30m
- Height = 6 m
- Basic wind speed = 47m/s

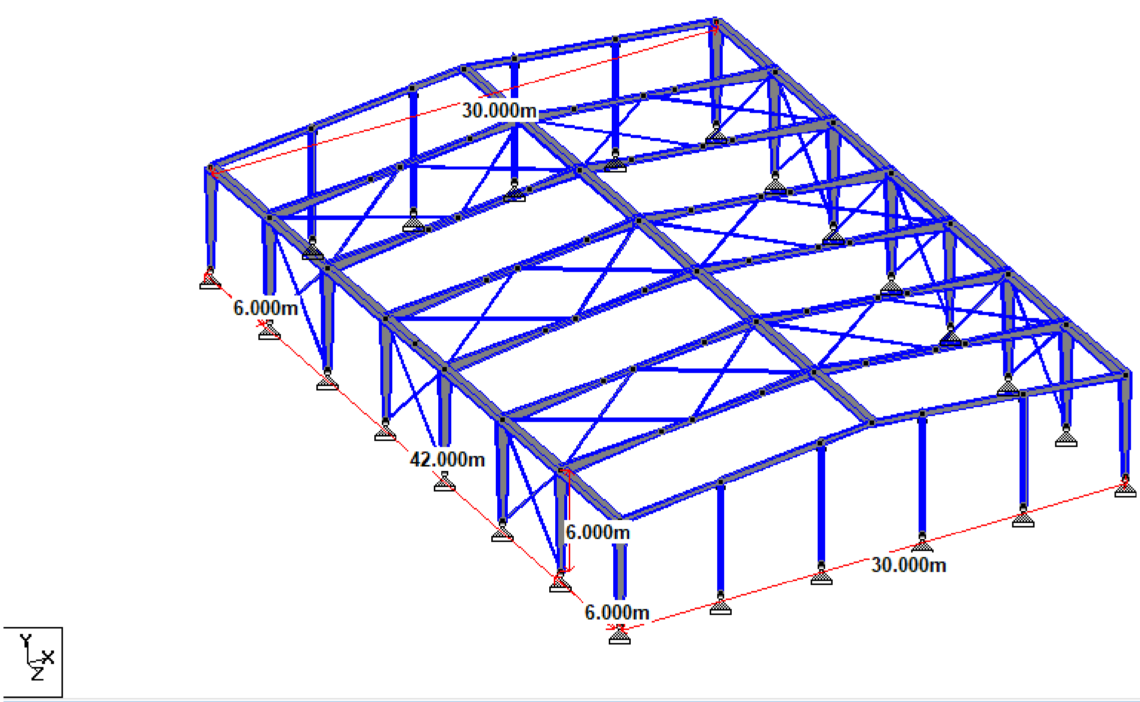
- Roof slope = 1:10
- Bay spacing = 6m

Loadings:
Dead load:

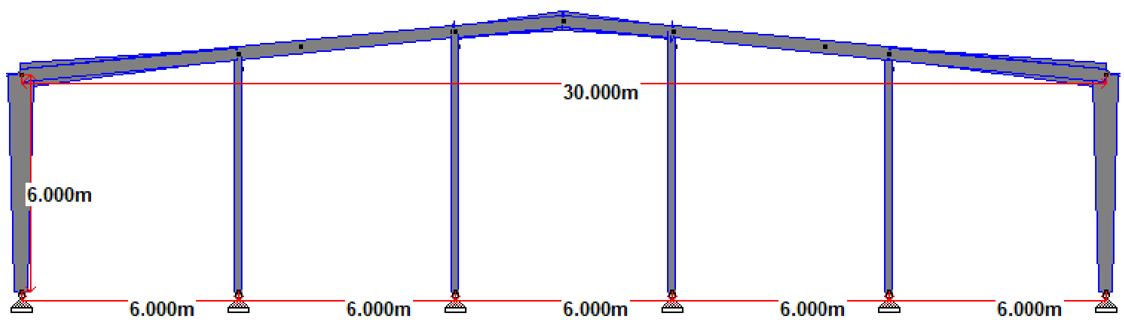
- Weight of sheets = 5kg/sq. Metre
- Weight of purlins= 4.12 kg/sq. Metre
- Bracings, clips, etc.= 4.7 kg/sq.m

Total=13. 82 kg/m2
Collateral load (solar panel) = 25 kg/ sq. Metre.

WHOLE SECTION OF THE WAREHOUSE WITH DIMENSIONS.



SIDE VIEW OF THE STRUCTURE



CALCULATION OF LIVE LOAD

AS PER IS 875, FOR NON ASSESSIBLE ROOFS, THE VALUE OF LIVE LOADS IS 75 KG/ SQ. METRE, which is 0.75 kn/ m2
So, udl load = 0.75 * 6
=4.23 kn. M

CALCULATION OF WIND LOAD

Wind loads are calculated as per IS 875 Part II (1987). The basic wind speed (Vb) is taken as 47m/s and the building is considered to be open terrain with well scattered obstructions having height less than 10m with maximum dimension more than 50m and accordingly factors K1, K2, K3 have been calculated as per IS 875 Part II (1987).
Terrain Category- 2,
K1- Probability factor- 1.0
K2- Terrain, height and size factor- 1
K3- Topography factor- 1.0 (SLOPE LESS THAN 3 DEGREE)
K4- NON CYCLONIC REGION- 1

Design wind speed, $V_z = V_b (K1 \times K2 \times K3 \times K4)$
$V_z = 47 m/s$
Design pressure, $P = 0.06 V_z^2$
$= 1.384 kN/m^2$

Ratio- H/W=0.2, L/W=2.1

Wind Pressure Coefficients

External and Internal wind coefficients are calculated for all the surfaces for both pressure and suction. Opening in the building has been considered less than 5% and accordingly internal coefficients are taken as +0.2 and -0.2.
The external coefficients and internal coefficients calculated as per IS 875 Part II (1987).

Wind load for individual members

$$F= (C_{pe}- C_{pi}) \times A \times P \qquad (5)$$

Where, Cpe, Cpi are external coefficients and internal coefficients respectively and A and P are Surface Area in m² and Design Wind Pressure in kN/m² respectively

LOAD COMBINATION

For the present work, various primary loads that are considered are given below-

1. Primary DEAD LOAD
2. Primary LIVE LOAD
4. Primary WIND load left towards right
5. Primary WIND load right towards left

For the Primary loads considered for the study, following are the Load Combinations taken for the warehouse:

- Combination of DL+LL
- Combination of DL+WLTR
- Combination of DL+WRTL
- Combination of DL+LL+WLTR and DL+LL+WRTL

Following Table gives the summary of node displacement for individual members for which the design has been carried out.

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	87	3 WLTR	71.509	0.194	-0.000	71.509	-0.000	0.000	-0.004
Min X	87	9 DL+LL+WR	-73.250	-121.145	-0.572	141.569	-0.009	0.000	0.003
Max Y	29	3 WLTR	53.588	174.207	-4.412	182.317	0.006	0.000	-0.003
Min Y	23	5 DL+LL	-0.001	-242.481	-0.422	242.481	0.002	0.000	-0.000
Max Z	83	3 WLTR	38.240	-0.013	346.670	348.773	0.050	-0.037	0.001
Min Z	94	4 WRTL	-36.247	-0.006	-347.626	349.510	-0.050	-0.040	-0.001
Max rX	5	9 DL+LL+WR	-36.287	-0.753	-57.045	67.612	0.273	-0.002	-0.000
Min rX	68	8 DL+LL+WL	38.192	-0.562	-0.477	38.199	-0.357	-0.002	0.000
Max rY	76	3 WLTR	0.000	0.000	0.000	0.000	0.031	0.077	-0.005
Min rY	77	3 WLTR	0.000	0.000	0.000	0.000	0.032	-0.077	-0.005
Max rZ	99	5 DL+LL	9.820	-140.283	-1.923	140.640	0.001	-0.000	0.028
Min rZ	98	5 DL+LL	-9.823	-140.281	-1.922	140.638	0.001	0.000	-0.028
Max Rs	94	4 WRTL	-36.247	-0.006	-347.626	349.510	-0.050	-0.040	-0.001

The table below gives the summary of beam end forces

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	12	9 DL+LL+WR	13	121.808	83.410	-1.815	0.025	2.116	480.196
Min Fx	53	4 WRTL	60	-83.520	-25.144	1.315	-0.001	0.795	-3.407
Max Fy	19	3 WLTR	21	-68.258	85.825	-0.040	-0.000	-0.000	-0.000
Min Fy	27	9 DL+LL+WR	30	113.221	-83.769	0.338	0.000	0.000	-0.000
Max Fz	96	4 WRTL	49	-3.004	0.001	20.984	-0.001	-55.219	0.001
Min Fz	110	4 WRTL	54	0.947	0.001	-23.480	0.003	49.400	-0.002
Max Mx	77	8 DL+LL+WL	84	-10.062	2.016	15.709	1.105	-11.434	-1.398
Min Mx	79	8 DL+LL+WL	86	-7.214	6.379	-15.537	-1.106	12.207	9.824
Max My	97	4 WRTL	58	-5.493	0.009	-13.215	0.003	77.746	0.009
Min My	111	4 WRTL	63	-5.329	0.010	18.029	-0.002	-105.532	0.015
Max Mz	27	9 DL+LL+WR	31	109.054	-83.769	0.338	-0.000	2.030	502.615
Min Mz	47	5 DL+LL	54	94.692	75.796	0.001	-0.000	0.007	-454.778

The weight of PEB is calculated and compared in the following two tables and the result came out to be that the PEB section is lighter in weight.

STEEL TAKE-OFF

PROFILE			LENGTH(METE)	WEIGHT(KG)
Tapered	MembNo:	2	96.00	6798.146
Tapered	MembNo:	4	59.94	2419.039
Tapered	MembNo:	5	72.12	3222.421
Tapered	MembNo:	6	37.14	1877.575
Tapered	MembNo:	12	72.00	3893.886
Tapered	MembNo:	72	55.20	2120.510
Tapered	MembNo:	90	126.00	7757.895
ST	PIP1143M		333.07	4044.075
			TOTAL =	32133.547

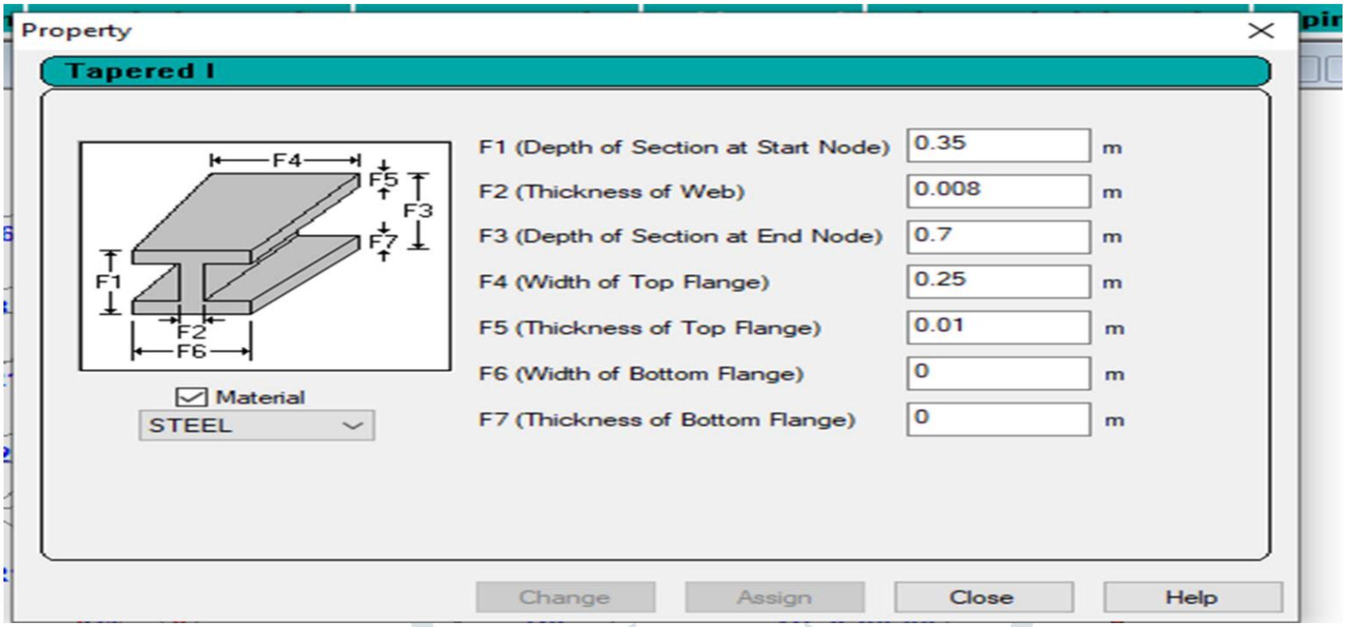
************ END OF DATA FROM INTERNAL STORAGE ************

Steel take off of the same structure using hot rolled sections

STEEL TAKE-OFF

PROFILE		LENGTH(METE)	WEIGHT(KG)
ST	ISMB500	151.20	13146.967
ST	ISMB400	241.20	14831.751
ST	ISMB450	126.00	9110.099
ST	PIP1270M	333.07	4800.708
		TOTAL =	41889.525

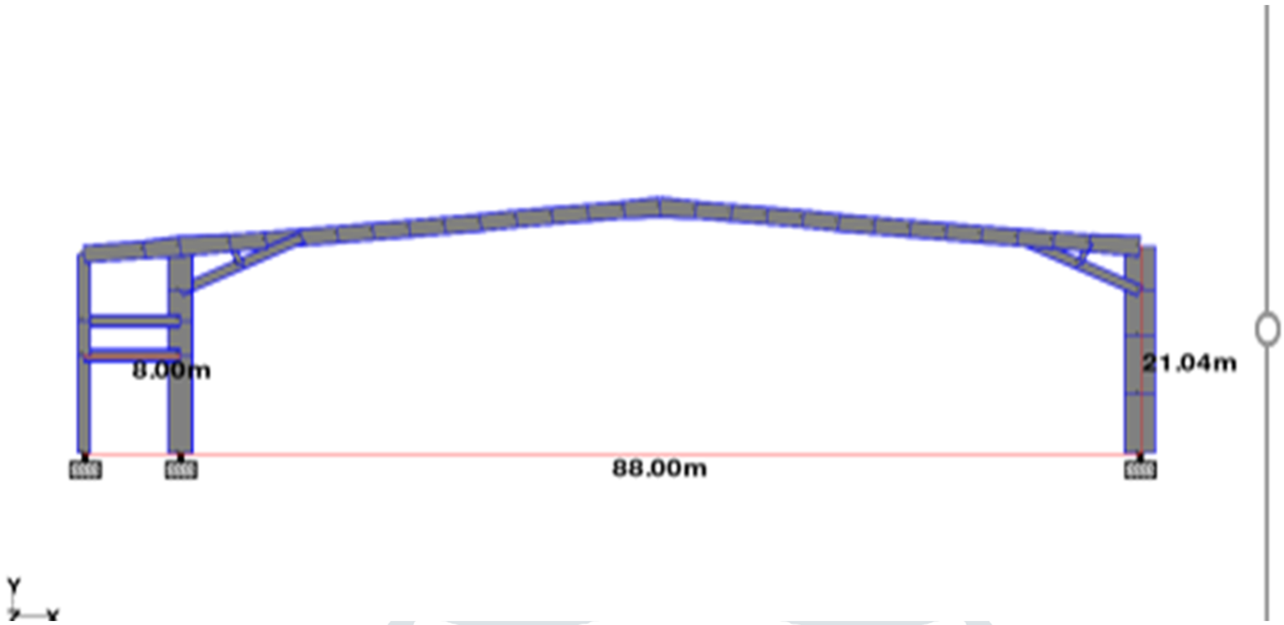
Tapered I section used in the PEB structure



It is observed that the weight of the tapered section is around 30% less than that of the conventional steel structure.

PLANE FRAME WITH LONG SPAN:

Pre engineered building has an advantages in term of capabilities of bearing loads in long span structures up to 90m. In conventional buildings, it is not possible to design a structure with clear spans for large spans. Here, an industrial building with long span is designed for different bay spacing- 8m, 8.88m, 10m, 11.425m, 13.33m and the weights of each one is calculated as steel take off to know the most economical one. A 2D structure is considered for this problem.



LOADINGS:

Dead loads and Live load as per IS 875 (Part II) – 1987 and Wind loads as per IS 1893 Part I (2002) and IS 875 (Part III) - 1987 respectively.

(As per IS 875 (Part II)) - 1987

Calculation of Dead Load

Dead load = 0.10 kN/m²

Bay spacing = 8m

DL per met = 0.8 kN/

Calculation of Live Load

Live Load = 2.5 kN/m²

Bay spacing = 8 m

LL per meter = 20 kN/m

Calculation of Wind Loads- As Per IS 875 (PartIII) - 1987

For the calculation of wind loads:

Max Bay Spacing: 8m with Roof Slope: 5.71º

Location for Wind: Bangalore Vb=33m/s.

For this structure, building height is assumed to be less than 10m with the structure lying in an open terrain with well scattered buildings in the surroundings with maximum dimension more than 50m and accordingly factors K1, K2, K3 have been calculated as per IS 875 Part II (1987).

Terrain Category-	2
Class-	C
K1- Probability factor-	1.0
K2- Terrain factor-	0.97
K3- Topography factor-	.9

Design Wind Speed

Vz = (K1XK2XK3) X Vb

Design Wind Pressure, P,

P =O.6 $(Vz)^2$ =0.62 kN/m² 1

Wind Coefficients-

External and Internal wind coefficients are calculated for all the surfaces for both pressure and suction. Opening in the building has been considered 0% and accordingly internal coefficients are taken as +0.2 and -0.2.

Pressure-

Internal Wind Coefficient: -0.2; [Openings: 0%]

External Wind Coefficient: (0.7, -0.94, -0.4, and -0.20)

Overall Wind Coefficient: (0.5, -1.14, -0.6, -0.40)

Wind normal	Wind parallel
Left wall: 0.5 x 0.62 x 8= 2.48 kN/m	Left wall -0.7*(0.62 x 8) = -3.48kN/m
Right wall: -0.40 x 0.62 x 8 = -2 kN/m	Right wall -0.7*(0.62 x 8) = -3.48 kN/m
Left roof: -1.14 x 0.62 x 8= -5.66kN/m	Left roof -1*(0.62 x 8) = -4.96 kN/m
Right roof: -0.4 x 0.62 x 8 = -1.98 kN/m	Right roof -1*(0.62 x 8) = -4.96 kN/m

Suction-

Internal Wind Coefficient: 0.2; [Openings: 0%]

External Wind Coefficient: (0.7, -0.94, -0.4, and -0.20)

Overall Wind Coefficient: (0.9, -0.74, -0.2, -0.00)

Wind normal	Wind parallel
Left Wall: 0.9 x 0.62 x 8 = 4.47 kN/m	Left Wall -0.3*(0.62 x 8) = -1.499kN/m
Right Wall: -0.0 x 0.62 x 8 = 0 kN/m	Right Wall -0.3*(0.62 x 8) = -1.499kN/m
Left Roof: -0.74 x 0.62 x 8= -3.68kN/m	Left Roof -0.6*(0.62 x 8) = -2.98 kN/m
Right Roof: -0.2 x 0.62 x 8 = -1 kN/m	Right Roof -0.6*(0.62 x 8) = -2.98 kN/m

Results:

Large and clear spans are a must for an ideal industrial building and with the help of pre engineered building, such types of structures can be constructed with ease. The balancing of the structure should be considered while designing long span structures .

High strength steel plates are ideal for pre engineered buildings and in turns , it gives more load carrying capacity to the structure. In addition to this, cold form purlins which are lighter in weight but higher in strength and also galvalumed profile sheets are also common in the construction of pre engineered building. With the help of these materials , the structure is subjected to more tensile strength and lighter weight with good esthetic looks.

For our work, comparisions of different bay spacing are considered to find the most economical value of our 80m long span and the weights calculated for different bay spacing are shown in the Table BELOW.

In this table, column 1 shows bay spacing for a length of 88m. Column 2 shows the number of frames and column 3 shows weight for each plane frame of respective spacing. The total weight is calculated by multiplying the weight per frame by number of frames. The total weight of the sections calculated is shown in column 4.

Table BELOW- Weights for different Bay spacing

Spacing (m)	No of Frames	Weight/ frame (Kn)	Total (kN)
8	11	782	8602
8.88	10	805	8050
10	9	948	8537
11.425	8	1046	8374

The structure with the 8.88m bay spacing gives the least weight.

CONCLUSION

It can be said that pre engineered buildings are more economical and also environmental friendly than conventional steel structures since the steel used in pre engineered buildings can be recycled in case of demolition and hence it becomes a more sustainable approach.
As it is seen in the present work, the weight of steel can be reduced to 30% for warehouse using Tapered I sections.

For longer span structures, Conventional buildings are not suitable with clear spans. Pre-engineered building are the best solution for longer span structures without any interior column in between as seen in this present work, an industrial structure has been designed for 88m. With the advent of computerization, the design possibilities became almost limitless. More materials can be saved on low stress area of primary framing members and thus making it convenient for low rise building spanning upto 90 metres. PEB structures are found to be costly as compared to Conventional structures in case of smaller span structures.
It is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces and further increase makes the weight heavier.

To conclude, pre engineered structures are more suitable for longer spans building as consumers prefers more space in a structure.

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