



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 6, June 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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Analysis and Design of Pre-Engineering Building

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ABSTRACT: Pre-engineered buildings have now been considered and practiced as the most economical and efficient concept in steel construction. Steel structures employed for low-rise and single-storey buildings. Pre-engineered building structures are widely used in industrial areas because of their high strength-to-weight ratio compared to reinforced cement structures. This property of steel structures provides a more extended span and free space between the columns. Pre-engineering building is an emerging concept in steel structure design with the basic features of optimizing the structural design to maximize and also ensuring construction economics from an engineering perspective. As compared to CSB(Conventional steel buildings) or PEB(Pre-engineered buildings), steel building provide cost efficiency in fabrication and many more advantages. Here in this study of pre-engineering building design load calculation and application, the basis is based on IS 875 and IS 800, and the design is according to the AISC-2011 code and MBMA-96 in STAAD pro v8i software. A mixed type of design is adopted so as to obtain an economical section that is based on the conclusion of past studies and research.

KEYWORDS: Pre Engineered Building, AISC-2011, MBMA-96, IS 875, IS 800:2008, STAAD pro v8i

I. INTRODUCTION

For projects to succeed, the construction sector places a high priority on expeditious progress and efficient material utilisation. Pre-engineered buildings (PEBs) provide optimal steel utilisation together with faster, more efficient construction [2]. These constructions can be developed utilising the American code for design and the Indian code for load calculation, using less material for the same loading.

A pre-engineered building is one whose components have already been planned and designed; the only task left to complete in the field is to connect the pre-planned component. Each and every member of the building design is drawn to get the optimum amount of steel, which contributes to the economy of the building, which is a major factor in the construction industry [6]. Fabrications of each element are done according to the drawing and high precision is achieved during the process of fabrication [8].

Popular programme STAAD Pro v8i is used to analyse and design structural elements in buildings. It is quick and easy to use, supports a variety of design codes, and has 3D visualisation for effective structure design [3].

II. LITERATURE REVIEW

A. Selection of PEB structure as compared to CSB structure for industrial structures.

In comparison to the CSB structure, the PEB structure model designed by IS 800:2007 has a higher wind resistance and is 64% lighter. Due to its lighter weight, it has a lower support reaction and reduced axial, shear force, and bending moment [9]. Pre-engineered building (PEB) construction is an efficient and cost-effective solution for long-span structures where large column-free areas are needed. PEB structures can be easily designed by simple design procedures in accordance with country standards and are energy efficient and speedy in construction[1], [2]. Simple design processes in compliance with national standards can be used to create PEB structures. They are energy efficient, quick to build, low cost, long-lasting, and most importantly, dependable. PEB is becoming more popular, however it is still not widely used in the building business[3], [4].The weight of steel in this pre-engineered building structure has been lowered by 38.47 percent. Built-up sections and built-up members are specified by the designer when the desired qualities or configuration cannot be provided in a single hot-rolled section [5].In terms of cost effectiveness, quality control, construction speed, and erection simplicity, PEB structures outperform CSB structures[6]. In the case of PEB, increasing the area of the building reduces the material and cost of the building. However, in the case of conventional buildings, increasing the area of the building does not reduce the material and cost [7].The weight of steel in a

warehouse can be lowered by 30% by employing Tapered I sections. Pre-engineered buildings are the ideal option for structures with greater spans and no inner columns, such as an industrial structure with an 88m span. They are better suited to buildings with longer spans since customers prefer greater space in a structure [8].

B. Reason for selecting IS code for load calculation.

“In IS code, the live load is 0.75 KN/m², whereas in MBMA, it is 0.57 KN/m². As a result, the loading according to Indian codes is higher than the MBMA code” [2], [9] therefore higher value of load contributes toward safety of structure.

C. Why AISC Code is adopted here for checking structural element parameters?

In comparison to AISC, IS code provides a more conservative portal frame design[10].IS code deflection limits are higher than MBMA deflection limits. The limiting ratios of the sections are the reason for the greater weight in IS 800-2007 compared to AISC/MBMA [3], [9], [10].

D. Necessity of bracing.

The displacement of a pre-engineered building with bracings along the X-axis is 34 percent smaller than that of a pre-engineered building without bracings in the longitudinal direction. Although the displacement along the Y-axis is 13 percent smaller than the Pre Engineered Building without bracings, it is permitted in both situations therefore no additional bracings are necessary for specified ground motion. When compared to a Pre Engineered Building without bracings, displacement along the Z-axis is 23 percent lower [11].

III. EXPERIMENTAL INVESTIGATION

A. Structure Configuration

In this study, a three-dimensional single-storey industrial building with symmetry in the X and Y directions and a rectangular shape (80m X 25m) is investigated (Table 2: Structure configuration). In the pre-engineered frame model, a steel frame with a tapered "I" section is utilized. A steel rod is used for bracing (X-type) in the models. The structure is supported by fixed support and all joints are absolutely stiff. IS: 875-1987 (Parts I, II), IS: 875-2015, IS: 800-2007 are used for load calculation, and AISC and MBMA are used for checking the criteria of structures[12]–[17].

Table 1: Structure Configuration

Location	Jagdalpur
Length	80 m
Width	25 m
Eave height	9 m
Seismic zone	Zone II
Wind speed	39 m/s
Wind terrain category	2
Wind class	C
Lifespan	50 years
Slope of roof	1 in10
Soiltype	Medium
Bay space	8 m c/c
Support condition	fixed
Importance factor	1
Response Reduction Factor	5

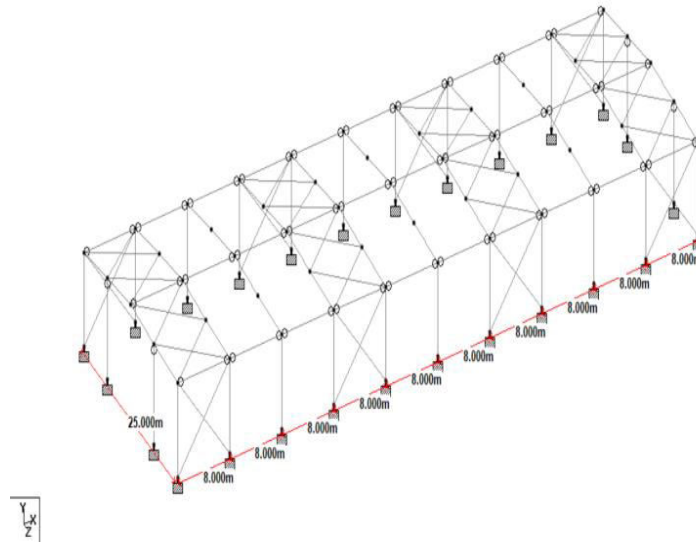


Fig.1 PEB Frame Model 3D View

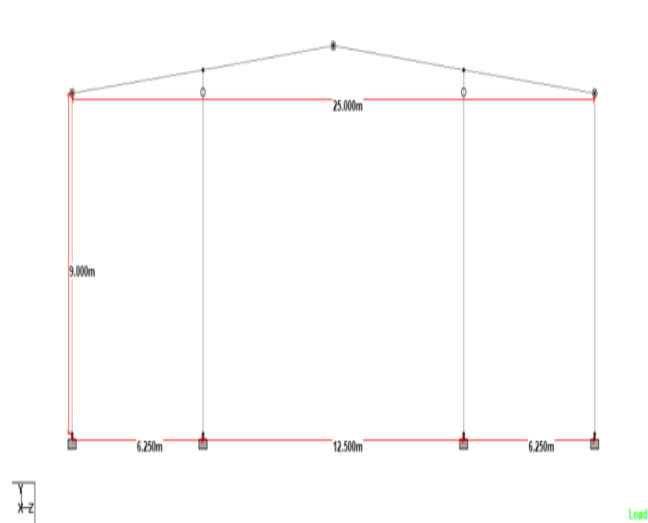


Fig.2 PEB Frame Front View

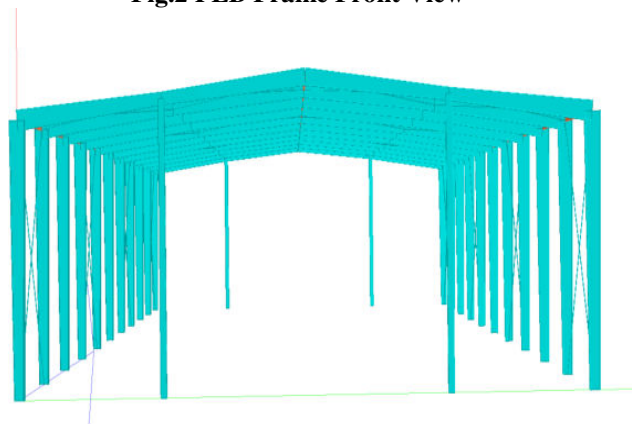
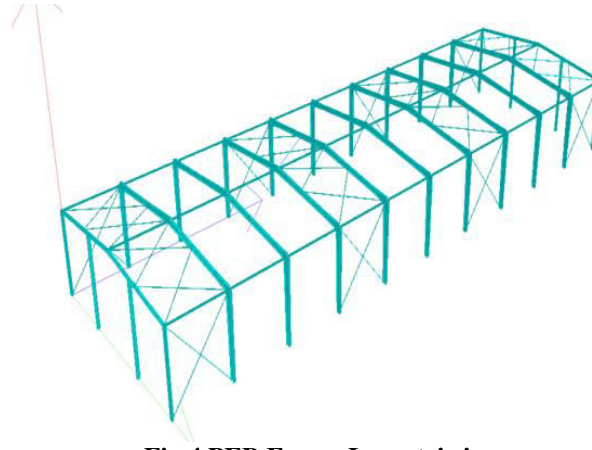


Fig.3 PEB Frame Render image

**Fig.4 PEB Frame Isometric image*****B. Dead Load Calculation***

Sheet (Galvanized iron sheet) as per IS 875 (part 1)-1987 page 10[19].

Thickness= 0.63 m

Sheet wt. = 0.054 KN/m²

Purlin wt. = 0.08 KN/m²

Fixtures like (sag rod, bracing etc) wt. = 0.043 KN/m²

Total Dead Load = 0.054+ 0.084+0.04 = 0.181 KN/m²

Dead load for 8 m bay = 0.181 x 8 =1.448 KN/m

For end frame = 1.448/2 = 0.724 KN/m

C. Live Load Calculation

As per IS 875 (part 2)-1987 page -14 [14]

For slope roof with slope up to 10° (including) and access not provided = 0.75KN/m²

Slope <10° no extra calculations is required

Line Load for 8m bay space = 0.75 x 8 = 6KN/m

For end frame = 6/2 =3KN/m.

D. Wind Load Calculation

As per IS 875 (part 3)-2015 [15]

K_d for triangular, square, and rectangular

$K_d= 0.9$

K_a value depend upon tributary area

$K_a= 0.837$

K_c depend upon pressure and suction of roof

$K_c =0.9$

V_b , Basic wind speed (for Jagdalpur)

$V_b= 39$ m/s

K_1 , Risk coefficient

For design life 50 year

$K_1=1$

K_2 , Terrain, height factor

Here terrain category=2

For height= 9 m

$K_2=1$

K_3 , Topography K_3 factor

Here slope is less than 3°

$K_3=1$

K_4 Cyclonic factor

(As Jagdalpur is located > 60 km from east coast) Therefore, for industrial building with no cyclonic factor

$K_4=1$

V_z , Design wind speed at height Z

$V_z = V_b \times K_1 \times K_2 \times K_3 \times K_4$

$V_z = 39$ m/s

P_z , Wind pressure at height Z

$P_z = 0.913$ KN/m²

P_d , Designed wind pressure

$P_d = K_d \times K_a \times K_c$

$P_d = 0.64$ KN/m²

“The value of P_d , however shall not be taken as less than $0.70 P_z$ ” [15].

$F = (C_{pe} - C_{pi}) A P_d$

where

C_{pe} = external pressure coefficient,

C_{pi} = internal pressure coefficient,

A = surface area of structural element or cladding unit, and

P_d = design wind pressure [21].

For both pressure and suction, external and internal wind factors are determined for all surfaces. Because the opening in the building is smaller than 5%, the internal coefficients are +0.2 and -0.2, respectively [15].

E. Load Combination

Here the load combination is taken as per IS 800:2007 and not as per AISC because as location of the project the loading conditions depends and load combination by IS 800:2007 gives higher value which contribute towards safety of structure. As per AISC-2011, there is no need for different load combinations for strength and deflection [10].

DL+LL

DL+WL

DL+0.8LL+0.8WL

1.5(DL+LL)

1.5(DL+WL)

(0.9DL+1.5WL)

1.2(DL+LL) +0.6WL

1.2(DL+LL+WL)

DL denotes Dead Load, LL denotes Live Load and WL denotes Wind Loads.

IV. RESULT AND DISCUSSION

Here the results obtained from STAAD Pro v8i software are tried to be represented in the form of a pictures, which is an output of the process.

A. Utilization ratio check

In the construction business, pre-engineered buildings (PEB) offer quicker, more effective construction with optimal steel utilisation, utilising American and Indian load calculations and requiring less material.

B. Reaction at supports and Bending Moment about Z due to DL

Support reaction of single frame generated due to applied load and load combinations are represented below in pictorial form.



Fig.6 Support Reactions

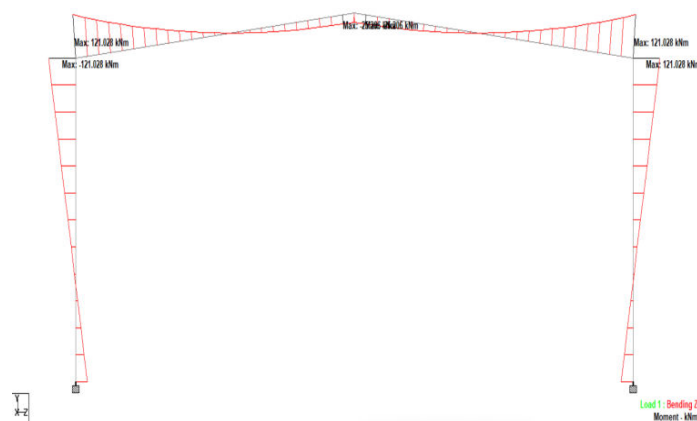


Fig.7 Bending Moment about Z axis due to DL

C. Shear about Y axis

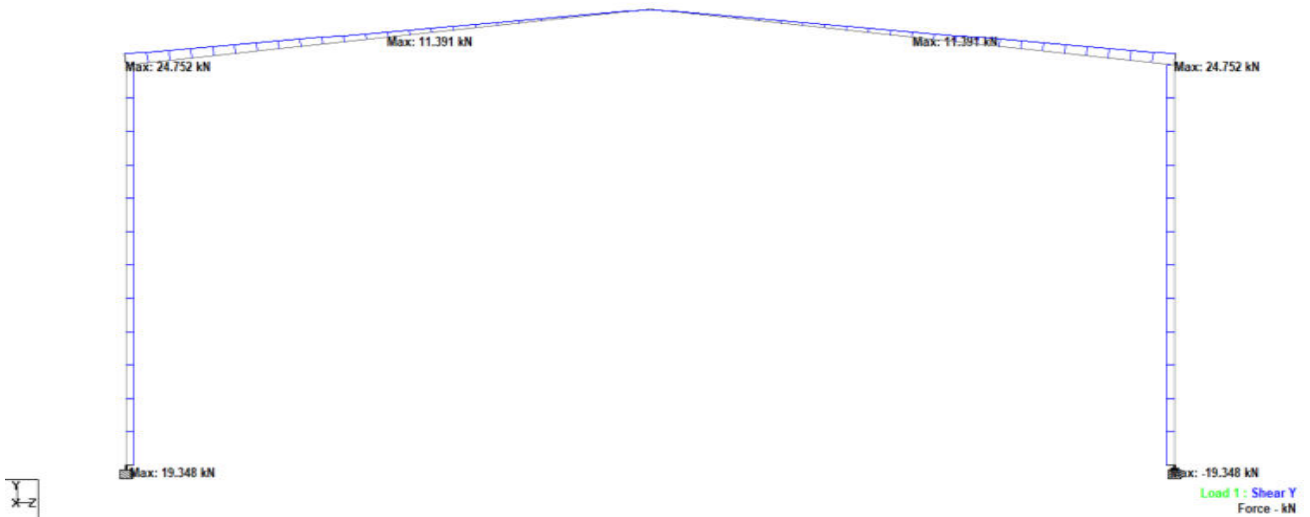


Fig.8 Shear about Y axis

S.No	Description	Vertical	Horizontal
1	Main frame	L/180	H/60
2	Wind column		H/120
3	Mezzanine Beam	L/240	L/325
4	Purlin	L/180	L/180
5	Girt	L/120	L/180
6	Minimum Thickness	4	1.6

D. Deflection

Deflection Limit according to AISC code.

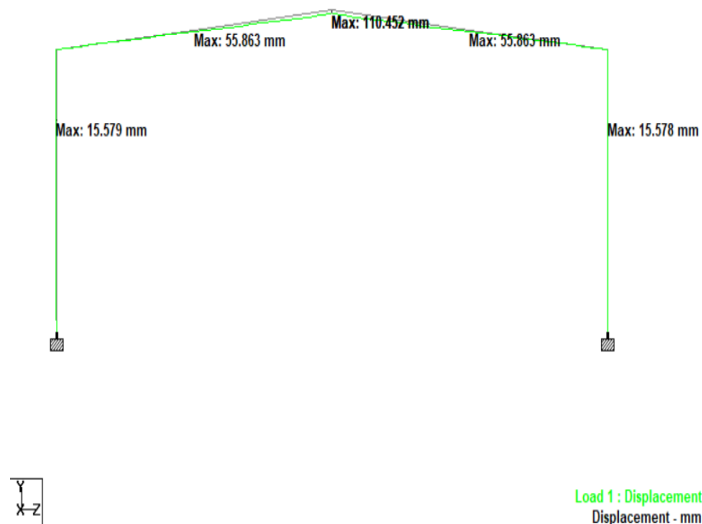


Fig.9 Displacement under LL&DL

E. Steel Take off

Steel take off is the quantity of steel to be used for the designed construction project. It generally provide the detail of the material to be consumed in the project. These features of STAAD pro enable us to estimate the quantity of material as per code standard.

STEEL TAKE-OFF

PROFILE	LENGTH (METE)	WEIGHT (KN)
Tapered MembNo: 1	198.00	115.294
Tapered MembNo: 3	138.19	95.326
Tapered MembNo: 5	138.19	71.866
Tapered MembNo: 64	38.50	10.854
D ISMC125	240.00	61.210
ST RD50	518.14	78.015
TOTAL =		432.565

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

Fig.10 Steel take off

V. CONCLUSION

- In this type of design is adopted where IS 875:1987 part 1, part 2, 875:2015 part 3 and IS 800:2007 is used for load calculation and load combination
- The amount of Steel take off = 432.565 KN
- Generally AISC is adopted for Pre-Engineered Buildings (PEB) construction because of more flexible design criteria and cost efficiency. As Indian code restrict the dimension of section which may cause material wastage.

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