Effect of Bay Spacing on Optimization of Pre-Engineered Building

Rashmi Shankar Pawar [1], Prof. Ganesh C. Jawalkar [2]

[1] M.Tech student, Dept. of Civil Engineering, N. B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India.

[2] Professor, Dept. of Civil Engineering, N. B. Navale Sinhgad College of Engineering, Solapur, Maharashtra, India.

Abstract - *This study is conducted to analyze the Effect of Bay Spacing on Pre-Engineered Buildings and comparison of pre-engineered building with conventional building. PEB structure is designed and analyzed for different Bay spacings and the optimum structure is obtained. In first stage, the effect of bay spacing on the structure is checked and the optimum structure is selected. Then the Pre-Engineered Building (PEB) model with optimum Bay Spacing is compared with the Conventional Steel Building (CSB). The results are compared on the basis of Axial Force at Column Base, Steel consumption, Maximum deflection, Maximum Moment at Column Base. From pre-engineered building models, structure with height 9m, roof angle 10° and bay spacing 5m is selected and compared with conventional structure designed using truss members. The results shows that pre-engineered buildings are optimum and steel consumption is reduced by approximately 16%.*

Key Words: Pre- Engineered Building, Conventional Steel Building, Optimisation, Steel Consumption.

1.INTRODUCTION

Steel is used as a construction material as it has high tensile strength and ductility. The areas where concrete cannot be used, Steel proves to be beneficiary. Until recent years, Conventional steel buildings with truss were used on large scale. But now-a-days, Pre-Engineered buildings have proved to be a good alternative to the conventional steel buildings. PEB structures are being used as it is having steel sections of reducing weights, better value for money, fast erection rate, flexible fittings, etc. Tapered sections are used in PEB which effects on economy of structure.

The need of PEB optimization is to study the effect of bay spacing variation in the designing of PEB. Important dimensional variables of trusses include the spans and depths of trusses, lengths of specific truss members (especially compression members), spacing of trusses, and transverse purlin spacing. The PEB structure when designed for a particular dimension will have different results when designing factors like Bay spacing, Roof Angle are Varied.

In this paper, we will be studying the effect of Bay Spacing on the PEB structure to obtain the optimum bay spacing to be utilized for achieving economy in the structure.

1.1 Literature Review

Many papers on comparative study of PEB and CSB concepts have been presented in past years, it has been reported that PEB structures are more advantageous than CSB structures in terms of cost effectiveness, quality control, speedy construction and simple erection method.

Subodh. S. Patil, (2017) presented the paper "Analysis and Design Of Pre-Engineered Building Of An Industrial Warehouse". This paper came out with conclusion that the PEB structure can be designed by simple method using IS codes and, It also told us the benefits of PEB structures than other structure.

Balamuralikrishnan R,(2019) presented the paper "Comparative Study on Two Storey Car Showroom Using Pre-engineered Building (PEB) Concept Based on British Standards and Euro Code". The paper concluded that, As per BS 5950:2000 code analysis, tapered section design was successfully carried out and EN 1993-1-1:2005 code analysis tapered section was not supported by STAAD Pro V8i software and The tapered frames contributes to 40.63% of the total weight in BS mode.

V Vishnu Sai,(2021) presented the paper "Structural Performance of Pre Engineered Building: A Comparative Study". The study concluded that the parameters that affect the structural weight and section sizes are Wind speed and Seismic Zone.

India is one of the fastest growing economies, infrastructure development is takin place rapidly. Thus, there is a wide scope for Pre-Engineered Buildings in India for the construction of Metro Stations, Bus stands, Airports, etc. Thus, in India PEB is an upcoming field in construction industry for the rapid infrastructural growth.

1.2 Effect of Bay Spacing on Economy of Structure

The distance between the two consecutive trusses is called as Bay Spacing or Spacing of trusses. The Bay Spacing is obtained by the size of space to be covered by roof. As the spacing increases, the number of trusses may reduce but the cost of purlins increases.

The bay spacing is mostly determined by the spacing of supporting columns. The supporting column spacing is determined by the functional requirements. Where there are no functional requirements, the spacing should be such that the cost of roof is minimized. The larger the spacing, the smaller the cost of trusses, but larger is the cost of purlins (as larger sections will be required) and vice versa. Roof coverings also cost more, if spacing between the truss is large.

Let us determine an approximate formula for arriving at minimum cost, by considering the following variables.

S= Bay Spacing between trusses,

C_t= Cost of trusses per unit area,

C_p= Cost of purlins per unit area,

C_r= Cost of roof coverings per unit area,

C = Overall Cost of Roof system/unit area.

Since the Cost of truss is inversely proportional to the spacing of the truss,

$$C_t \propto 1/S$$

$$C_t = k_1/S \quad \text{------1} \qquad k_1 = \text{constant}$$

Similarly, Cost of purlins is directly proportional to the square of spacing of trusses,

$$C_p \propto S^2$$

$$C_p = k_2 S^2 \quad \text{------2} \qquad k_2 = \text{constant}$$

The Cost of roof coverings is directly proportional to the spacing of trusses,

$$C_r \propto S$$

$$C_r = k_3 S \quad \text{------3} \qquad k_3 = \text{constant}$$

Thus, Total Cost = C = $C_t + C_p + C_r$

$$= k_1/S + k_2 S^2 + k_3 S$$

For the overall cost to be minimum, dC/dS should be zero.

Thus, $-k_1/S^2 + 2k_2 S + k_3 = 0$

$$-k_1/S + 2k_2 S^2 + k_3 S = 0 \quad \text{------------ 4}$$

$$-C_t + 2\,C_p + C_r = 0$$

$$C_t = 2\,C_p + C_r \quad \text{------------- 5}$$

The equation 5 shows that an economic system can be obtained when the cost of trusses is equal to the cost of roof covering plus twice the cost of purlins.

However, it has been found that the economic range of spacing is 1/5 to 1/3 of the Span of Truss or Frame of truss.

2. Modelling of PEB and CSB

2.1 Effect of Bay Spacing on PEB

6 PEB structures with Bay Spacings of 4.5m, 5m, 5.625m, 6.43m, 7.5m and 9m are designed. The analysis of these PEB models is carried out to obtain the optimum model.

On the comparison of the results of the 6 models, an optimum Bay Spacing is finalized and used for further work in the project.

Building model details are as following

- Building Dimension = 45m x 20m
- Clear eave height = 9m
- Maximum eave height = 10.763m
- Bay Spacing = 4.5m, 5m, 5.625m, 6.43m, 7.5m and 9m
- Bracing type = Cross Bracing
- Roof slope = 10°

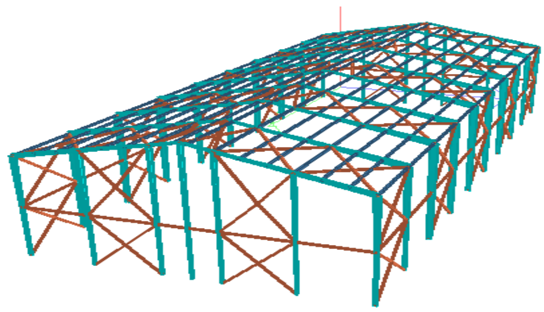


Figure 1- Pre- Engineered Building Structure

The analysis is performed using commercial software. In accordance with IS 875, load combinations are considered, which consist of Dead loads, Live loads and Wind loads. The bay spacing is varied and results are obtained.

2.2 Comparison of PEB with CSB

PEB structure with optimum bay spacing obtained is compared with CSB with same bay spacing and the results are compared.

Building Model Details are as following

- Building Dimension = 45m x 20m
- Clear eave height = 9m
- Maximum eave height = 11.5m
- Bay Spacing = 5m
- Bracing type = Diagonal Bracing
- Roof slope = 14°

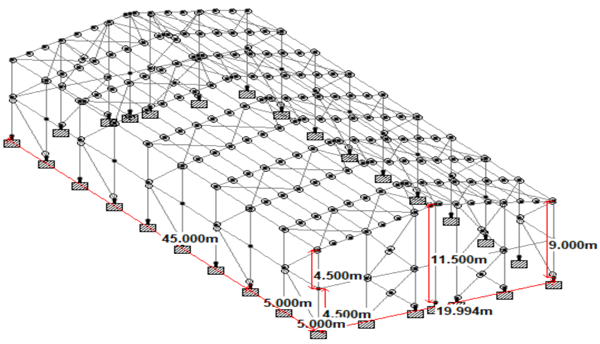


Figure 2- Pre-Engineered Building Structure (Diagonal bracing)

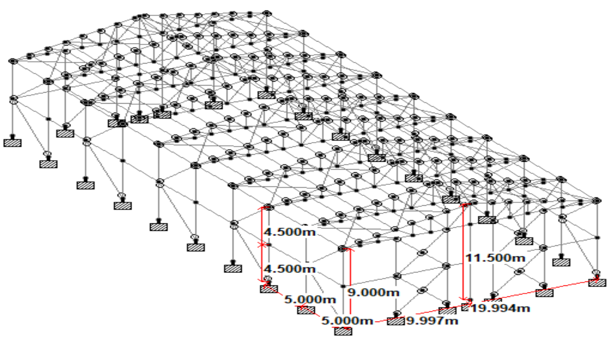


Figure 1- Conventional Steel Building Structure (Diagonal bracing)

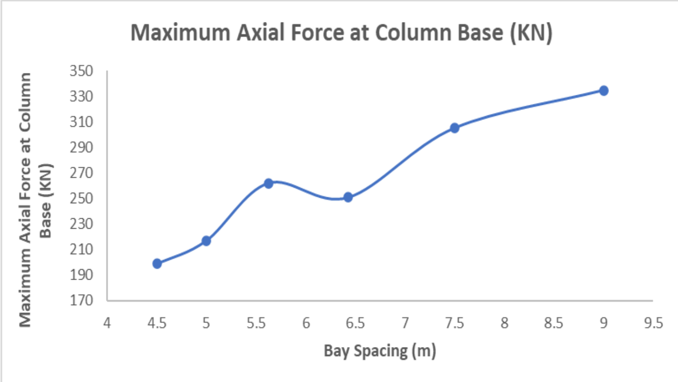
3. Results and Discussion

3.1 Effect of Bay Spacing on PEB

a. Effect of Bay Spacing on Axial Force at Column Base -

Table 1- Axial Force at Base of Column

Maximum Axial Force (KN)	
4.5m	198.808
5.0m	217.046
5.625m	262.042
6.4285m	250.871
7.5m	305.136
9.0m	334.701



Graph 1- Effect of Bay Spacing on Axial Force at Column Base (KN)

i. The above graph shows sinusoidal variation in Axial force with bay spacing variation.

ii. The above graph shows that as the Bay spacing goes on increasing, the axial force at the column base goes on increasing but later on goes on decreasing and again goes on increasing.

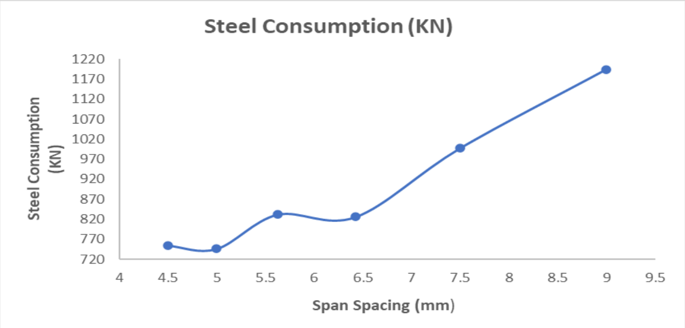
iii. According to the results obtained, 4.5m bay spacing shows the minimum value of Axial Force out of all models.

It showed 40.61 % less Axial Force than the highest value obtained for 9m bay spacing model.

b. Effect of Bay Spacing on Steel Consumption (KN)-

Table 2- Steel Consumption

Steel consumption (KN)	
4.5m	754.415
5.0m	745.834
5.625m	831.401
6.4285m	825.673
7.5m	997.212
9.0m	1194.059



Graph 2- Effect of Bay Spacing on Steel Consumption (KN)

i. The above graph shows sinusoidal variation in steel consumption with bay spacing.

ii. The above graph shows that as the Bay Spacing goes on increasing, the Steel consumption goes on increasing.

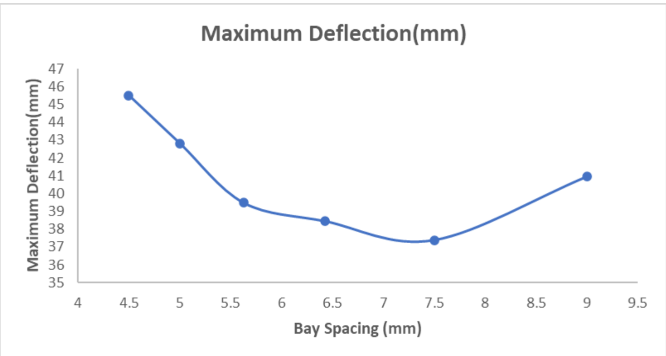
iii. The minimum the steel consumed, better is the model. According to the results obtained, 5m bay spacing showed the minimum steel consumption out of all the models.

It showed around 37.54% less steel consumption than the maximum steel consumed by model with 9m bay spacing.

c. Effect of Bay Spacing on Deflection –

Table 3- Maximum Deflection

Maximum deflection (mm)	
4.5m	45.517
5.0m	42.829
5.625m	39.489
6.4285m	38.447
7.5m	37.383
9.0m	40.945



Graph 3- Effect of Bay Spacing on Deflection(mm)

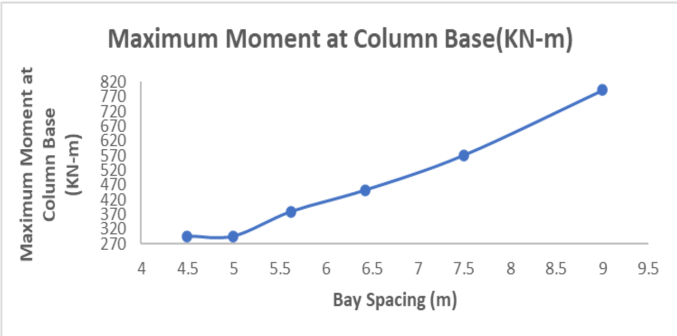
i. The above graph shows that as the Bay spacing goes on increasing, the deflection goes on decreasing and then again goes on increasing.

ii. The 7.5m and 6.4285m Bay spacing model gave approximately the same lowest values for minimum deflection which is clearly seen from the graph.

d. Effect of Bay Spacing on Moment at Column Base –

Table 4- Maximum Moment at Column Base

Maximum Moment at Column Base (KN-m)	
4.5m	296.674
5.0m	296.584
5.625m	380.227
6.4285m	453.221
7.5m	571.899
9.0m	792.056



Graph 4-Effect of Bay Spacing on Moment at Column Base (KN-m)

i. The above graph shows that as the Bay Spacing goes on increasing, the Moment at the Column Base initially goes on decreasing and then beyond 5m bay spacing goes on increasing.

ii. Here, the 5m spacing model gave the minimum Moment value which is clearly seen from the graph.

iii. It showed around 62.6% less Moment than the maximum moment model with 9m Bay Spacing.

From all the above results obtained, we can conclude that, as we are working to get economical structure, the 5m bay spacing is the optimum spacing and can take the value for further parametric study.

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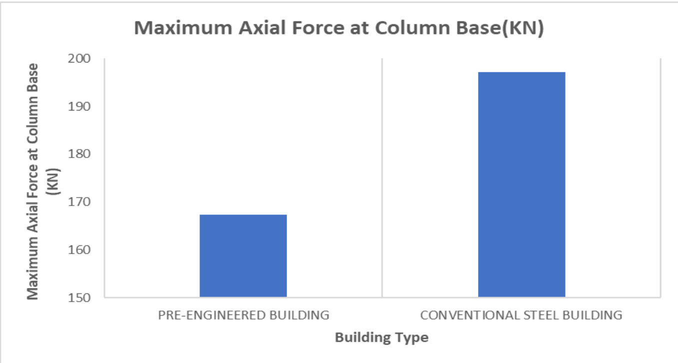
3.2 Comparison of PEB with CSB

a. Axial Force at Column Base of PEB and CSB-

Table 5-Axial Force at Column Base of PEB & CSB

Maximum Axial Force (KN)	
Pre-engineered building structure	167.291
Conventional steel structure	197.086



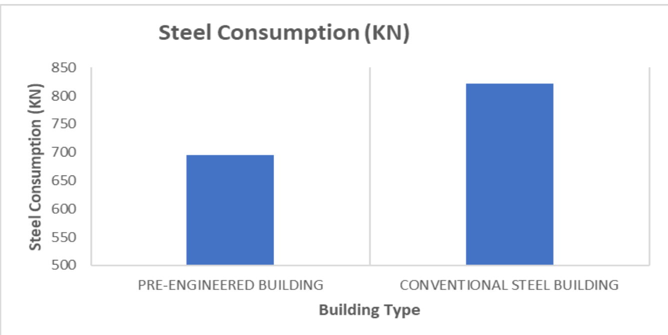
Graph 5- Axial Force at Column Base (KN) of PEB & CSB

i. The PEB and CSB are studied for comparing the Axial Forces in the above obtained graph
ii. The PEB has less Axial forces as compared to the CSB.

b. Effect on Steel Consumption of PEB & CSB-

Table 6- Steel Consumption of PEB &CSB

Steel consumption (KN)	
Pre-engineered building structure	694.8
Conventional steel structure	821.351



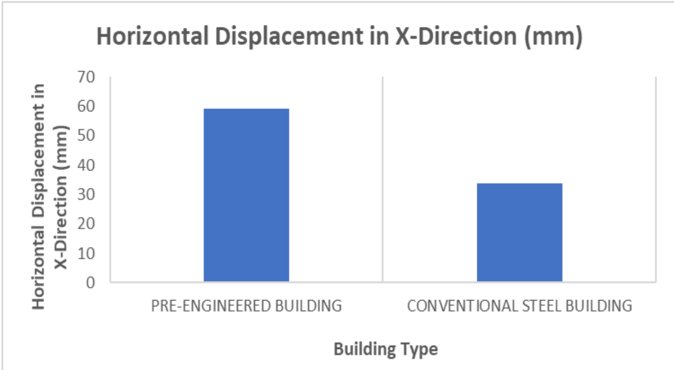
Graph 6- Steel Consumption (KN) of PEB & CSB

i. The PEB and CSB are studied for comparing the Steel Consumption in the above obtained graph.
ii. The PEB has less Steel consumption than the CSB.

c. Deflection of PEB & CSB –

Table 7- Maximum Deflection of PEB & CSB

Maximum Deflection (mm)	
Pre-engineered building structure	59.347
Conventional steel structure	33.753



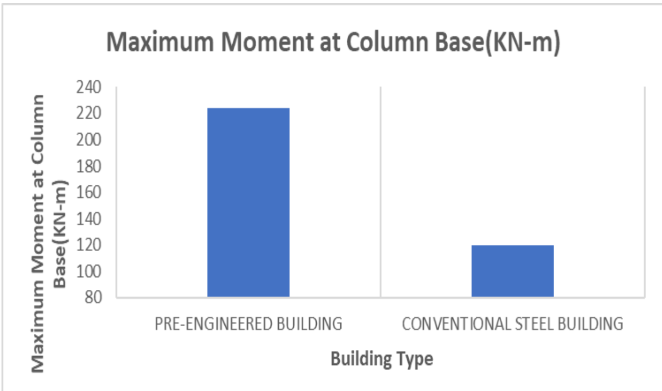
Graph 7- Maximum Deflection (mm) of PEB & CSB

i. The PEB and CSB are studied for comparing the Defection in the above obtained graph
ii. The PEB has more Deflection as compared to the CSB.

d. Effect on Moment at Column Base of PEB & CSB-

Table 8- Maximum Moment at Column Base of PEB &CSB

Maximum Moment at Column Base (KN-m)	
Pre-engineered building structure	224.216
Conventional steel structure	120.086



Graph 8- Maximum Moment at Column Base(KN-m) of PEB &CSB

i. The PEB and CSB are studied for comparing the Moment at Column Base in the above obtained graph.
ii. The PEB has more Moment at Column base as compared to the CSB.

4. CONCLUSIONS

1. Pre-engineered building showed less Axial Force at base of the column of 15.12% than conventional steel building.

2. The PEB showed less steel consumption of around 15.42% than conventional steel building.

3. The maximum deflection is more for PEB at around 51.3% than conventional steel building.

4. The maximum Moment at Column Base came more for PEB at around 46.44% than conventional steel building.

5. The PEB structure came out to be optimum and cost efficient as compared to CSB by around 15.5%.

6. The whole study gave us the staggered plan-based enhancement results, with exact values of the behavior of the various structures designed and modelled in the study. We got the exact percentages of the differences in the behaviors of the models from which we concluded the optimum PEB structure.

REFERENCES

[1] Balamuralikrishnan R., Ibrahim Shabbir Mohammedali "Comparative Study on Two Storey Car Showroom Using Pre-engineered Building (PEB) Concept Based on British Standards and Euro Code" Civil Engineering Journal Vol. 5, No. 4, April, 2019.

[2] C. M. Meera "Pre-Engineered Building Design Of An Industrial Warehouse" International Journal of Engineering Sciences & Emerging Technologies, Volume 5, Issue 2, June 2013.

[3] T.D. Mythili "Analysis and Comparative Study of Conventional Steel Structure with PEB Structure" International Journal of Science and Research, Volume 6 Issue 4, April 2017.

[4] Vishwanath Pujar, Prof. Ravi Tilaganji "Comparative Study Of Codal Provision For Pre-Engineered Building" International Research Journal of Engineering and Technology, Volume: 04 Issue: 07 July -2017.

[5] IS: 800-2007 Indian Standard General Construction in Steel-Code of Practice.

[6] IS: 875 (Part 1) – 1987 Code of Practice for design loads (other than earthquake) for building and structures (Dead Load).

[7] IS: 875 (Part 2) – 1987 Code of Practice for design loads (other than earthquake) for building and structures (Imposed Load).

[8] IS: 875 (Part 3) – 2015 Code of Practice for design loads (other than earthquake) for building and structures (Wind Load).

[9] https://www.irjet.net/archives/V8/i1/IRJET-V8I1108.pdf

[10] https://www.ijera.com/papers/Vol4_issue9/Version%206/Y4906174183.pdf

[11] Design of Steel Structures by S.S.Bhavikatti

[12] Steel Structures Design and Practice by N.Subramaniam