

# **Comparative Study of Seismic Analysis and Design of Pre-Engineering Building with Conventional Industrial Building on different bay spacing**

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**ABSTRACT:** Steel structures are preferred in building construction because it is cost effective, durable, time consuming and can withstand on heavy loads. Large floor area, column free, light weight structures are the most essential and economic type of industrial structures. Pre-Engineering building (PEB) is technological improvement in the construction of single storey steel industrial building which satisfies all above requirements as compared to Conventional steel building (CSB). This paper comprises about the comparative study of total steel take off for both the frames along different bay spacing of about 4m, 6m, 8m and 12m for same area this is achieved by using STAAD Pro V8i software for analysis and design. The structure is designed for static and dynamic forces which include wind load and earthquake load according to IS codes. The deflection is controlled by providing cross bracings.

**KEYWORDS:** Pre-Engineering building; Conventional Steel building; Bay spacing; Cross bracings; STAAD Pro V8i; IS codes.

## **I. INTRODUCTION**

Steel industry is growing rapidly in almost all parts of world. Steel is a material which has high strength per unit mass. A steel building is a metal surface fabricated with steel for the internal support and for exterior cladding. Steel buildings are used for a variety of purposes including storage, work spaces and living accommodation. They are classified into specific types depending on how they are used. They first gained popularity in the early 20<sup>th</sup> century. These buildings have been widely accepted, in part due to cost efficiency. Steel frame is a building technique with a “skeleton frame” of vertical steel columns and horizontal beams. The use of steel framed structures for large industrial buildings with large and uninterrupted span areas, with the advantage of low cost, light weight and easy installation. In steel construction, there are two main types of structural members one is hot rolled shapes and other is cold formed steel sections.

Conventional Steel Building (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof truss can be used for these structures depending on the Pitch of the truss. The selection of roof truss includes the slope of the roof, fabrication and transportation methods, aesthetics, climatic conditions, etc. For large span, Fink type truss can be used. They are manufactured or produced in the plant itself. The primary and secondary steel members are selected from standard hot rolled sections along with the gusset plates which are heavier.

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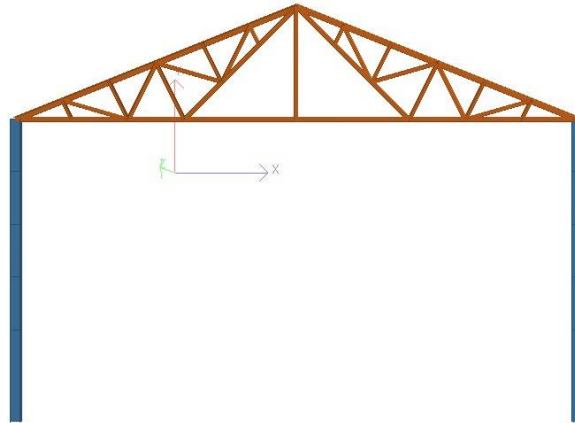


Fig. 1. Conventional Steel Building frame

Pre-Engineering Buildings (PEB) are technologically improved over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the Pre-Engineered buildings. The concept of Pre-Engineered steel buildings originated from United States of America in 1960s. Pre-Engineered buildings use a combination of built-up sections, hot rolled sections and cold formed elements which provide the basic steel frame work with a choice of single skin sheeting with added insulated sandwich panels for roofing and wall cladding. The basis of PEB concept lies in providing the section at a location. The sections can vary throughout the length according to the bending moment diagram. This leads to the utilization of non-prismatic rigid frames with slender elements.

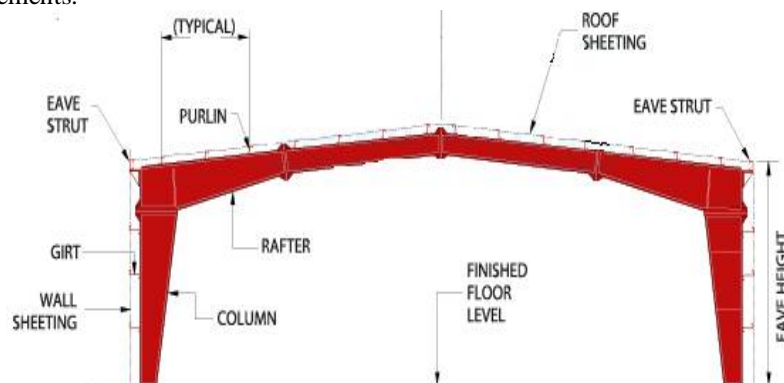


Fig. 2. Pre-Engineering Building frame

## II. RELATED WORKS

1. **Jinsha M S et al., 2016**, has investigated about Analysis of Pre-Engineering Buildings. In this paper Pre-Engineered Building of 25m width & 6m Eave Height have been analyzed and designed by using STAAD Pro.2007 to understand the behaviour of Pre -Engineered structure & to check in which case it achieve the economy in steel quantity by varying bay spacing as 6m, 8m, 10m, & 12m. Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings fulfils this requirement along with reduced time and cost as compared to conventional structures. In the present work, Pre Engineered Buildings (PEB) is designed for wind forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987.
2. **Rohith E et al., 2016**, has stated about weight optimization of pre-engineered steel building by genetic algorithm. Typically, a pre-engineered building is a metal building that consists of light gauge metal standing

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seam roof panels on steel purlins spanning between rigid frames with light gauge metal wall cladding. It is a relatively flexible structure v/s a conventional steel framed building. In other words, it has a much greater vertical and horizontal deflection. During the last few years, several methods have been developed for the optimal design of steel structures. Most of the methods are calculus based nature and leads to unrealistic solutions and therefore, they are not used in practice, which still prefers to rely on the more traditional iterative methods. This paper describes the use of genetic algorithm (GA) in performing optimization of 2D truss structures to achieve minimum weight. The GA uses fixed length vector of the design variables which are the cross-sectional areas of the members. The objective considered here is minimizing the weight of the structure.

3. **Aditya P et al., 2016**, has investigated about overview of Pre-Engineering Buildings. Buildings & houses are the basic requirements of any human being. There are several changes in construction technology since the beginning. The basic requirements of construction nowadays are best aesthetic look, fast, economical & high quality. Pre-engineered building is best option for these all requirements. Pre-engineered buildings are cost effective, time consuming as compared to other conventional buildings. Generally pre-engineered buildings are faster than conventional buildings, 25 % less time consuming & 30% lighter than conventional buildings. The plan & load on the building are calculated at the beginning, & the members are manufactured in factory & they are just assembled on actual site at time of construction.
4. **Shrunkhal V B et al., 2015**. has stated about a study on pre-engineered building – a construction technique. 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. 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). This review from the past experiences presents the results of experimental and analytical studies done on Pre Engineered Building. Results show that these structures are economic, reduces construction cost and time, energy efficient and flexibility of expansion.

### III. METHODOLOGY

This paper includes the analysis and design of Conventional and Pre-Engineered building structure located at Madurai. The actual structure is proposed as a Conventional Steel Building frame with fink type of roof truss having 16m width and 48m longitudinal length and an eave height of 8.6m. Pre-Engineered Building also designed for same geometrical conditions. Both the frames are designed and analyzed with different bay spacing of 4m, 6m, 8m and 12m. The step by step process of this work is listed below,

1. This work is aimed to complete with the help of STAAD Pro software. STAAD Pro gives more precise and accurate results than manual techniques. It is one of the effective software which is used for the purpose of analysis and design of structure by structural engineers.
2. The power tool for the computerized structural engineering STAAD Pro is the most popular structural engineering software product for three-dimensional model generation, analysis and multi-material design.
3. Graphical models are generated based on the commands for creating mathematical models. A horizontal member represents tension members whereas a vertical member represents compression members.
4. After the member generation, the properties are assumed. In conventional building, standard rolled steel sections are used whereas in Pre-Engineered building tapered sections are provided for primary elements like rafter and standard rolled steel sections were used in other secondary elements.
5. Then the load is calculated as per IS codes and load is applied to the proposed structure.
6. Steel is designed based on IS 800:2007 by providing parameters and commands by using software.
7. The both Conventional and Pre-Engineered buildings are modelled and analyzed for static and dynamic loads which include wind loads and earthquake loads.
8. STAAD Pro software is used to understand the behaviour of both frames and to check the economy in steel quantity for proposed structures.

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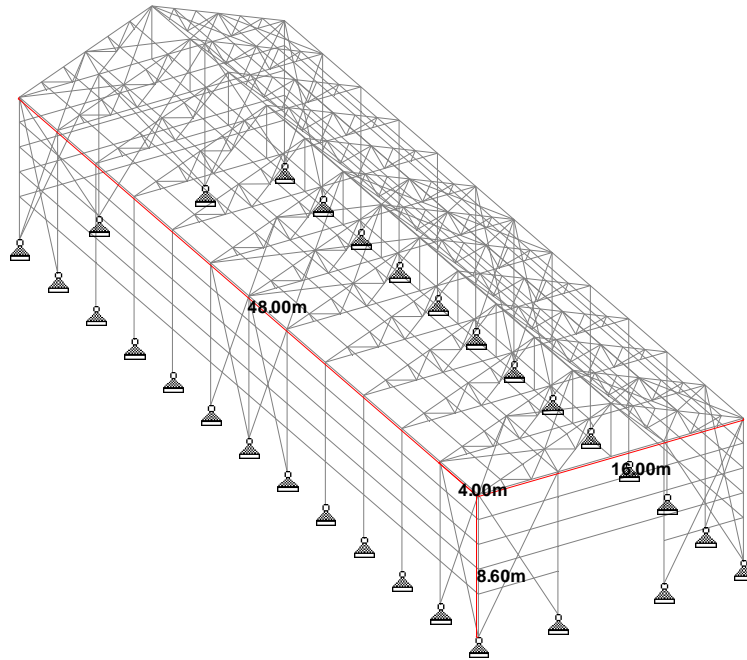


Fig. 3. Three Dimensional model View (Conventional Steel Building 4m bay spacing)

The above figure shows model view of Conventional Steel Building for 4m bay spacing. As like the model view the building is modelled for different bay spacing by using STAAD Pro Software.

## IV. CALCULATION OF LOADS AND LOAD COMBINATIONS

In this example, static and dynamic loads are calculated for both the frames on 4m bay spacing. Static loads i.e. Dead load and live load are considered as per IS 875 (Part I) – 1987 and IS 875 (Part II) – 1987. Dynamic loads i.e. Wind loads and earthquake loads are considered as per IS 875 (Part III) – 1987 and IS 1893 (Part I) – 2002 respectively.

### 4.1. General Particulars of the building:

Type of structure	: Industrial structure
Location	: Madurai
Width of building (L)	: 16m
Length of building	: 48m
Truss type	: Fink truss
No. of Nodes	: 13
Slope of roof	: 21.8°
Length of rafter $L_R$	: 8.616m

### 4.2. Conventional Steel Building:

Plan Area	=	Span X bay Spacing
	=	16 X 4
	=	64 m <sup>2</sup>
Inclines Area	=	$L_R \times (L/2)$
	=	8.616 X 8
	=	68.928 m <sup>2</sup>

#### i) Dead Load:

Weight of AC Sheet on inclined area	=	9.994 kN
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Weight of Bracings on plan area	=	0.96 kN
Weight of Purlin load on plan area	=	5.76 kN
Self-weight of truss	=	6.592 kN
Total load (DL)	=	23.306 kN
DL on intermediate nodes	=	23.306/13
	=	1.793 kN
DL on End nodes	=	1.793/2
	=	0.896 kN
<i>ii) Live Load</i>		
Load	=	0.75 – 0.02 (θ -10)
	=	0.514 kN/m <sup>2</sup>
Live Load on plan area	=	32.896 kN
LL on intermediate nodes	=	2.530 kN
LL on End nodes	=	1.265 kN
<i>iii) Wind Load</i>		
Basic wind speed $V_b$	=	39 m/s
Risk coefficient $K_1$	=	1
Terrain factor $K_2$	=	1.018
Topography factor $K_3$	=	1
Design wind speed $V_z$	=	$V_b (K_1 K_2 K_3)$
	=	39.702 m/s
Design pressure, $P_d$	=	$0.6 V_z^2$
	=	0.946 kN/m <sup>2</sup>

#### *iv) Earthquake loads*

The earthquake loads are calculated by using STAAD Pro software by providing general information like code for provision i.e. IS 1893 (Part I) Zone factor (Z) for city Madurai=0.1, Response reduction factor (R) for Special moment resisting frame=0.5, Importance factor (I) for all general buildings=1.0, soil type as hard soil and time period is calculated according to height and length of the building the generate the loads and apply those loads then analyze the structure.

### **4.3. Pre-Engineering Building:**

#### *i) Dead Load:*

Weight of AC sheeting	=	0.415 kN/m <sup>2</sup>
Weight of fixtures	=	0.043 kN/m <sup>2</sup>
Weight of Purlins	=	0.09 kN/m <sup>2</sup>
Total dead load	=	0.278 kN/m <sup>2</sup>
DL for 4m bay spacing	=	1.112 kN/m

#### *ii) Live Load:*

Load = 0.75 – 0.02 (θ -10)	=	0.514 kN/m <sup>2</sup>
LL for 4m bay spacing	=	2.056 kN/m

#### *iii) Wind Load and Earthquake loads:*

These loads are calculated as same as we calculated in Conventional frame.

### **4.4. Load Combinations:**

- 1.7 ( DL + LL )
- 1.7 ( DL ± EL )
- 1.3 ( DL + LL ± EL )
- 1.5 ( DL + LL )
- 0.9 DL + 1.5 WL
- DL + LL
- DL + WL

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## V. RESULTS AND DISCUSSIONS

Conventional and Pre-Engineering frames are analyzed and designed for respective loads and load combination by using STAAD Pro V8i software. Their total weight is compared for both frames to select economic frame with optimum bay spacing.

Table 1. COMPARATIVE RESULTS OF FRAMES

Bay Spacing (m)	Weight of Steel (kN)	
	Conventional Steel Building	Pre-Engineered Building
4	1067.276	988.667
6	1019.567	918.577
8	1583.476	1038.874
12	1737.386	1105.310

In this table, it is seen that the weight of the Pre-Engineering Building is less when compared to Conventional Steel Building in all Bay spacing. From this we can say that the Pre-Engineering Buildings are economic way in the construction of steel buildings. The steel weight of Pre-Engineering Building is depends on the bay spacing, with the increase in bay spacing up to certain spacing, the weight decreases and further increase makes the weight heavier. Pre-Engineering Building with bay spacing 6m is found to be most economical for proposed structure.

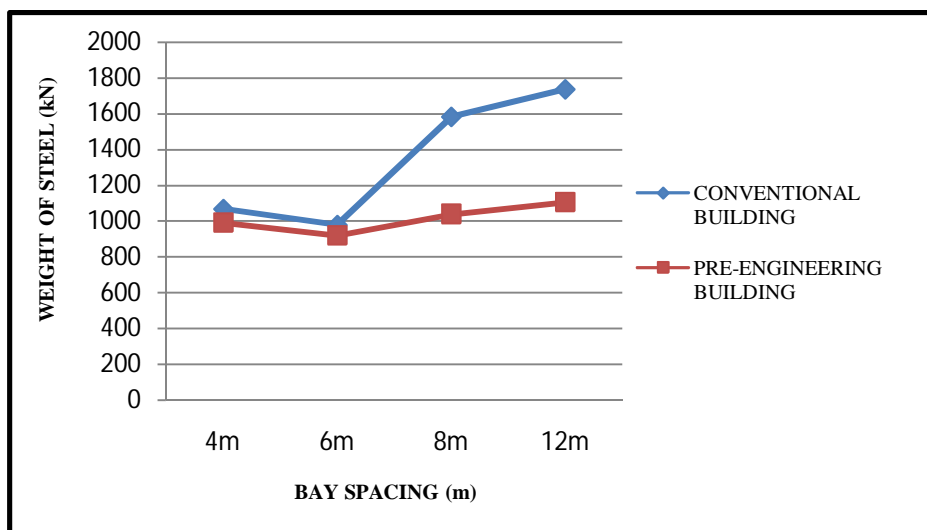


Fig. 4. Line diagram showing comparative steel weight for Conventional and Pre-Engineered building

In general, steel quantity is primarily depends on primary members and secondary members. As bay spacing of portal increased, the steel consumption is decreased for primary members like main rafter and steel consumption is increased for secondary members like purlin, bracings etc. In these structures, deflection is controlled by providing cross bracing on roof truss and between columns.

With the increase in bay spacing from 4m to 6m the weight of structure is decreases and from 6m to 8m weight increase and again from 8m to 12m bay spacing weight of the Pre-Engineering Building is increased. In Pre-Engineering Building, tapered members are provided at main rafter and rafter based columns and weight of those tapered members decreases with increase in bay spacing.

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## VI. CONCLUSION

The following conclusions were made based on the results of this study are as follows

1. The weight of structure depends on the bay spacing, with the increase in bay spacing up to certain spacing, the weight of the Conventional and Pre-Engineering Building reduces and further increases makes the structural weight heavier.
2. The cross bracings (X bracings) are provided to control deflection in the structure.
3. The weight of Pre-Engineering Building is less than the conventional building when comparing to the respective bay spacing this shows that Pre-Engineering Building is cost effective way of constructing steel building.
4. Pre-Engineering Building with bay spacing 6m is found to be most economical.
5. Thus Pre-Engineering Building is having advantages like cost effective, durable, strength, design flexibility, adaptability and recyclability.

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## BIOGRAPHY



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