

ADVANTAGES OF PRE-ENGINEERED BUILDING OVER CONVENTIONAL STEEL BUILDINGS

A.A.Arrote¹, V.R.Rathi², P.K.Kolase³

¹P.G student Department of Civil Engineering, Pravara Rural Engineering College Loni, India-413736

²Professor, Department of Civil Engineering, Pravara Rural Engineering College Loni, India-413736

³ Professor, Department of Civil Engineering, Pravara Rural Engineering College Loni, India-413736

Abstract - In recent years, the introduction of Pre-Engineered Building (PEB) concept in the design of structures has helped in optimizing design. 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). In pre-engineered building concept the complete designing is done at the factory and the building components are brought to the site in knock down condition. Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures. PEB methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. Here this is study is achieved by designing 3D frame of an Industrial Warehouse building using both the concepts and analyzing the frames using suitable analysis and design software after due validation. The various loads like dead, live, wind, seismic and snow loads according as per IS codes are considered for the present work for comparative study of Pre Engineered Buildings (PEB) and Conventional Steel Building (CSB). The economy of structure is discussed in terms of its weight comparison.

Key Words: *Pre-engineering building, Conventional Steel Building, Ware House, Tapered Section, STAAD Pro V8i*

1. INTRODUCTION (Size 11, Times New roman)

Buildings & houses are one of the oldest construction activities of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. India has emerged as one of the key global markets for pre-engineered buildings (PEB).

A lot of this growth has got to do with the way how perceptions towards steel buildings have been changing in the country. Among the major reasons earlier for the slow pace of growth of the steel buildings industry was the lack of awareness, lack of availability of specialized manpower and the dearth of an organized supply chain. The entry of global players facilitated the influx of latest technologies and there has been no looking back since then. Today the scene is such that PEBs are estimated to about 30% of market share in the construction industry. Rapid industrialization, along with the rise of the warehousing and retail sector has been factors enabling this growth rate. The growth of the metal building industry in India makes for interesting reading. It all started with the onsite fabrication model. This was during the time when almost all the large infrastructure projects were under the control of governmental agencies. With the opening up of the economy in the 1990s though, things began to change. Adherence to strict project completion deadlines was important for private players. This was the trigger for predominantly “factory built” buildings and rise in the might of the PEB industry. The rising emphasis on sustainable building strategies has been another one of the key reasons behind the rise of the PEB industry in recent times. Today, whether it is residential, commercial or industrial construction, going green seems is the trend. While it is well known that PEBs are inherently green, so far as environmental sustainability is concerned, they are also economically sustainable, as compared to conventional construction methods. This is because in their case, precise estimations based on computer generated models are used. The resulting calculations lead to no or very little material wastage. The labor cost on PEBs is also less as most of the building comes partially constructed. In the case of industrial and commercial projects, prefabrication allows, minimization of onsite workload, since a vast majority of the work is carried out offsite, eliminating most of the onsite works such as welding and bolting of reduction in the number of

onsite lifting requirements. All these lead to a significant savings in project costs to developers, factor that has become crucial in these days and times of economic turbulence. PEBs enable all this without any compromise on the quality front. PEBs are extremely durable, strong enough to withstand every kind of climatic conditions, ranging from heavy snowfall to high winds or heat, a factor that has made them a favorite for industrial and commercial buildings, with demand picking up on the residential side too, in recent times. The technology also enables lower life cycle cost, as compared to conventional methods of construction, a fact that is not lost on the modern day Indian contractor. Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the PEB. Through, its origin can have tracked back to 1960's potential has been felt only the recent years. This was the mainly due to the development in technology, which help in computerized the design. The scientific-sounding term pre-engineered buildings came into being in the 1960. Until 1990 the use of PEB was confirmed mostly to North America and the Middle East. Since, then the use of PEB has spread throughout Asia and Africa where the PEB construction concept has now been widely accepted and praised. A growing number of prominent International contractors and designers, who previously specified conventional structural steel buildings exclusively, have recently converted to the PEB approach. They now enjoy significant cost saving and benefits from the faster construction cycle resulting from this concept. A recent survey by the Metal Building Associations (MBMA) shows that about 60% of the non-residential low rises building in USA are PEB.

A. History of PEB

Pre-engineered buildings came into being in the 1960s. The improving technology was constantly expanding the maximum clear-span capabilities of metal buildings. The first rigid-frame buildings introduced in the late 1940s could span only 40 ft. In a few years, 50-ft, 60-ft, and 70-ft buildings became possible. By the late 1950s, rigid frames with 100-ft spans were made; ribbed metal panels became available, allowing the buildings to look different from the old tired corrugated appearance. Third, collared panels were introduced by Strand-Steel Corp. In the early 1960s, permitting some design individuality. At about the same time, continuous span cold-formed Z purlins were invented also by Strand-Steel, the first factory-

insulated panels were developed by Butler, and the first UL-approved metal roof appeared on the market. 1st And last, but not least, the first computer-designed metal buildings also made their debut in the early 1960s. With the advent of computerization, the design possibilities became almost limitless. All these factors combined to produce a new metal-building boom in the late 1950s and early 1960s. As long as the purchaser could be restricted to standard designs, the buildings could be properly called pre-engineered. Once the industry started to offer custom- designed metal buildings to fill the particular needs of each client, the name pre-engineered building became somewhat of a misnomer. In addition, this term was uncomfortably close to, and easily confused with, the unsophisticated prefabricated buildings, with which the new industry did not want to be associated. Despite the fact that the term pre-engineered buildings are still widely used, and will be often found even in this book, the industry now prefers to call its product steel building systems.

B. Conventional Steel Building

The design of conventional industrial buildings is governed by functional requirements and the need for economy of construction. Conventional Steel buildings are consultant and conservative. The Structural members are hot rolled and are used in conventional buildings. The materials are produced or manufactured in the plant and are shifted to the site. The raw materials are processed in the site for the desired form and erected. The modifications can be done during erection by cut and weld process. Conventional steel building design uses selected rolled "T" sections which are standardized in length but must be cut, punched, and bolted up onsite. Standardization can create cost savings at the time of purchase; however, customizing them onsite requires skilled labour and time. 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.

C. Pre-Engineered Building

Pre Engineered Steel Buildings are manufactured or produced in the plant itself. The manufacturing of structural members is done on customer requirements. A pre-engineered building (PEB) is designed by a manufacturer to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. Within some geographic industry sectors these buildings are also called Pre-Engineered Metal Buildings. Historically, the primary framing structure of a pre-engineered building is an assembly of I shaped members, often referred as I beam. In PEB, I section beams used are usually formed by welding together steel plates to form of I section. I section beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Cold formed Z and C-shaped members may be used as secondary structural elements to fasten and support the external cladding. Roll-formed profiled steel sheet, wood, tensioned fabric, precast concrete, masonry block, glass curtain walls or other materials may be used for the external cladding of the building. In order to accurately design a pre-engineered building, engineers consider the clear span between bearing points, bay spacing, roof slope, live loads, dead loads, collateral loads, wind uplift, deflection criteria, internal crane system and maximum practical size and weight of fabricated members. The use of optimum least section leads to effective savings in steel and cost reduction.

2. REVIEW OF LITERATURE:

A. Preliminary Remarks

Pre-engineered buildings have become an essential option for a number of buildings such as warehouses in infrastructure projects and production shops for every conceivable manufacturing activity. With the large, clean floor area free of columns or obstructions, afforded by this concept, PEB's find favour with organisation who have very dynamic plans related to products and process handled by them over a period of time. In warehouses, the pre-engineered building allows for more storage and stacking than the conventional concepts such as concrete and site fabricated structural steel. PEBs permit end user to optimize column free space to suit racking arrangements and internal logistical requirements. The full-scale experimental and theoretical work presented

in this thesis would not have been possible without studying previous works of other researchers. The following are some of the works which the author studied and referred to extensively throughout this research project.

B. Design Proficiency

Muthu Meena M et. al. (2017) have studied the PEB have evolved after years of process of elimination and with PEB been partially applied alongside with conventional buildings. With the passage of time gradually the whole PEB structure came into existence with specialized computer analysis design program and optimizes material selection. Today from concept to completion the PEB projects are computerized using standard detail that minimizes the use of project custom details. With this applications speed and efficiency is arrived since PEB are mainly formed by standard sections and connections design. Also with more and more standardization there is greater optimization as the production skill is enhanced and the cost has reduced. Today design shop detail sketches and erection drawings are supplied free of cost by the manufacturer and the approval drawing is usually prepared in short time. PEB designers design and detail PEB buildings are built almost every day of the year resulting in improving the quality of design every time they work. Dharma lingam G. et.al. (2017) have noted that the adoption of PEB design concept in place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are designed as per bending moment diagram thereby reducing the material requirement. PEB structures can be easily designed through simple design procedures in accordance with country standards, which is energy efficient, speedy in construction, saves cost, sustainable and most important it's reliable as compared to conventional buildings. Pre-engineered building creates and maintains in real time multidimensional, data rich views through a project support is currently being manually design and same has been verified with analytical software design for concluding the safety of the structure with respect the loading of dead, live, wind, self-weight, seismic and snow load etc.

C. Structure Proficiency

C. M. Meera et.al. (2013) carried out the study effectively conveys that PEB structures can be easily designed by simple design procedures in accordance with country standards, which is energy efficient, speedy in

construction, saves cost, sustainable and most important it's reliable as compared to conventional buildings. Low weight flexible frames of PEB offer higher resistance to earthquake loads. M.S.K.Chaitanya et.al. (2016) have studied the PEB roof structure is almost 26% lighter than conventional Steel Building. In secondary members, light weight "Z" purlins are used for PEB structure, whereas heavier hot-rolled sections are used for CSB. Support reactions for PEB are lesser than CSB as per analysis. Light weight foundation can be adopted for PEB which leads to simplicity in design and reduction in cost of construction of foundation. Heavy foundation will be required for CSB structure. Thus Pre- Engineering Building is having advantages like cost effective, durable, strength, design flexibility, adaptability and recyclability. Hence the use of PEB technology is preferred in today's world since it is advantageous by all means as compared to the CSB technology.

D. Delivery and Logistics

L. Maria Subashini et.al. (2015) have found that in the pre- engineered building structure has average 6 to 8 weeks as compared to conventional structure has average 20 to 26 weeks. At the present work, the weight of steel can be reduced for the building, providing lesser dead load which in turn offers higher resistance to seismic forces. PEB building cost is 35% lesser than the cost of CSB structure. For longer span structures, Conventional buildings are not suitable with clear spans. 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.

E. Erection Cost and Time

Pooja V. Raut et.al. (2015) have studied that both costs and time of erection are accurately known based upon extensive previous experiences with similar buildings and also the erection process is faster and much easier with very less requirement of equipment. The time that is saved on construction is another key factor that ups the sustainability quotient of PEBs. For one, the foundation is easier to construct, being light weight and consisting of standard sections and connections. This saves erection cost and time. Erection is typically around 20% faster than in the case of conventional steel buildings. Mr. Aditya P. Mehendale et.al. (2016) have observed that Contrary to popular perception, outstanding architectural designs can also be achieved using PEBs. This apart,

PEB systems can also be designed keeping in mind future expansion plans. Another important thing to remember with PEBs is that since a single supplier can coordinate all facts including, design, erection, and installation, which ensures faster construction cycles. Moreover, with increasing competition, manufacturers are also assuring clients of prompt after sales service support, which is not the case with conventional buildings. Apurv Rajendra Thorat et.al. (2017) they observed that the pre- engineered building calls for very fast construction of buildings and with good aesthetic look, high quality, and fast construction, cost effective & innovative touch. Pre- engineered steel building concept forms a unique position in the construction industry in view of their being ideally suited to the needs of modern Engineering Industry. It would be the only solution for large industrial enclosures having thermal and acoustical features. The major advantage of steel building is the high speed of design and construction for buildings of various categories.

F. Cost Effectiveness

Sagar Wankhede et.al. (2014) carried out the study of Pre- Engineering Building with Conventional Steel Building has been carried out the observations made based on this study are very much useful to the practicing structural engineers. The Pre-engineered steel structures are design for resistant to moisture, adverse weather conditions, earthquakes, termites and fire that provide you with lifelong durability, safety and very low cost maintenance. Syed Firoz et.al. (2012) have noted that the roofing system in PEB is latest product & since it is made of steel, it is easier to maintain compared to the conventional sheets. PEB building cost is 25% lesser than the cost of CSB structure. To conclude "Pre-Engineered Building" construction gives end users a much more economical and better solution for long span structures where large column free areas are needed.

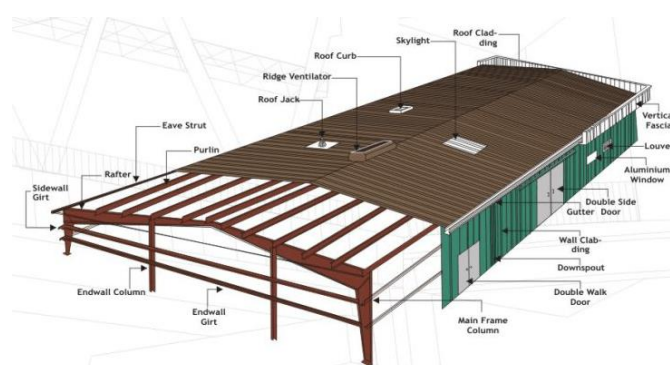


Figure- 1. Pre-Engineered Building Structure

3. DESIGN OF PRE-ENGINEERED BUILDING:

We can have a case study to explain the comparison between the conventional building and the pre-engineered building. A building of an industrial structure is considered for design with conventional steel structure and pre-engineered building structure. In this chapter we discussed (25m x 52.5m building) only, other building having 15m & 35m width are discussed in Appendix-A .The description of the building which is considered for the design purpose is tabulated in table 3.1

Building Parameters			
1	Type of Frame	Clear span- 15M, 25M, 35M	
2	Roof Slope	1 in 10	
3	Width (m)	24.7 m c/c of column	
4	Length (m)	52.5m c/c of column	
5	Exterior Columns Base Condition	Columns with pinned base condition	
6	Eave -height (M) from FFL	10.0 m	
7	Bay spacing (m)	7@ 7.5m c/c of columns	
8	End walls	Right End wall	Frame type :Tapered columns with No Future expansion
			Girts: Continuous
		Column Spaces ; 4@6.175m	
		Left End wall	Frame type :Tapered columns with No Future expansion
			Girts: Continuous
		Column Spaces ; 4@6.175m	

Table 1- Description of Building

3. 1 Design Assumptions

The following assumptions are considered for pre-engineered building system design.

- All the column bases are pinned at base.
- The roof purlins & wall girts are continuous beams supported at frame locations and spans the bay spacing of the building.

- The roof and wall sheeting provide lateral support for purlins and girts.
- The longitudinal stability of the building is provided through the cross braced bays of the building in the roof and side walls.
- Roof support system is truss with strut and tie members.
- The main frame rafters and exterior columns are rigidly connected to each other (using moment type connections)

3.2 Building Drawing :

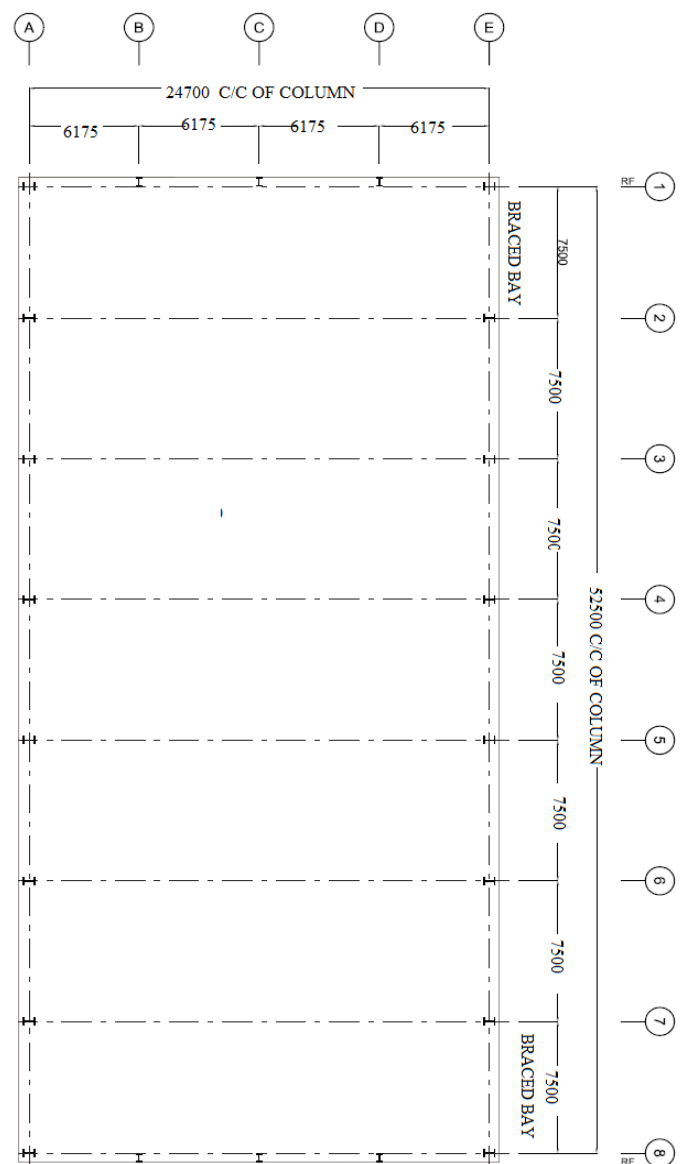


Figure- 2. Column -Layout Plan

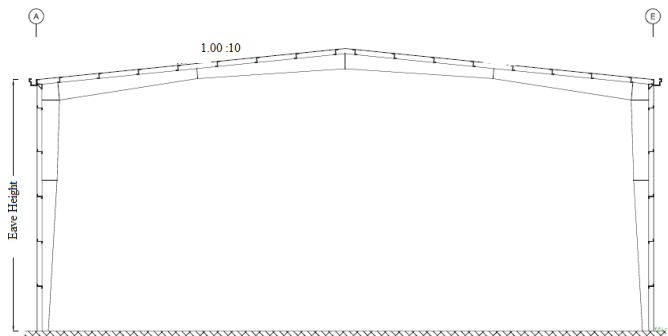


Figure- 3. Cross Section

3.3 Applicable Standard Codes

The industrial building described in this case study is designed according to the Indian codes that have been referred to in the design:

- The loads as described in the design Summary Sheet have been applied on the structure in accordance with: IS-875- PART- I to III - 1987 – Code of Practice for Design Loads for Building and Structures.
- Hot rolled sections and built up components have been designed in accordance with: IS-800-1984- Code of Practice for General Construction in Steel.

3.4 Design Loading Details

Following table represents the design data considered for the calculations.

Design Dead Load on roof & frame	0.12 KnZ/m ²
Collateral Load on roof	0.75 KN/m ²
Design Live Load (on frame)	0.75 KN/m ²
Basic Wind Speed based on 50 years return period, V _b = 39 m/s	<p>As per IS: 875 (Part III)</p> <ul style="list-style-type: none"> Risk Coefficient k₁=1.0 (Clause 5.3.1) Terrain & height multiplier factor (k₂) = As per design based category. (Clause 5.3.2.2) Topography factor (k₃)=1 (Clause 5.3.3) Importance factor for Cyclonic Region (k₄)=1.0 (Clause 5.3.)

- Wind coefficients shall be as per IS: 875 (part III)

Table 2- Design Load Data of Building

3.5 Loading on Frames

• Dead Load Calculations:

Roof Dead load on frame = Self- Weight of roof sheeting and purlins

$$= 0.12 \text{ KN/m}^2$$

• Collateral Load Calculations:

Roof Collateral load on frame = 0.1 KN/m²

• Live Load Calculations:

Roof Live load on frame = 0.75 KN/m²

- Wind Load Calculations: As per IS 875(part III)

4. RESULTS

4.1. Main Frame System (Primary Structural Framing)

The structural analysis & design of rigid frame system is done with the help of STAAD-Pro V8i & excel programs. Parameters like eave height and bay spacing are kept constant while building width is considered to be varied, for easy comparison of results. Table 4.1 shows building width, eave height and weight of PEB and conventional building system.

Building Width (m)	Eave Height (m)	Bay Spacing (m)	PEB Weight (kN)	Conventional Weight (kN)	Saving %
15	10	7.5	13.13	19.94	32.32
25	10	7.5	34.11	50.37	34.75
35	10	7.5	45.97	67.93	32.27

Table 3- Summary of Different Span Frame

The graphical representation of pre-engineered & conventional building system with different span but same eave height & bay spacing is shown in figure- 4

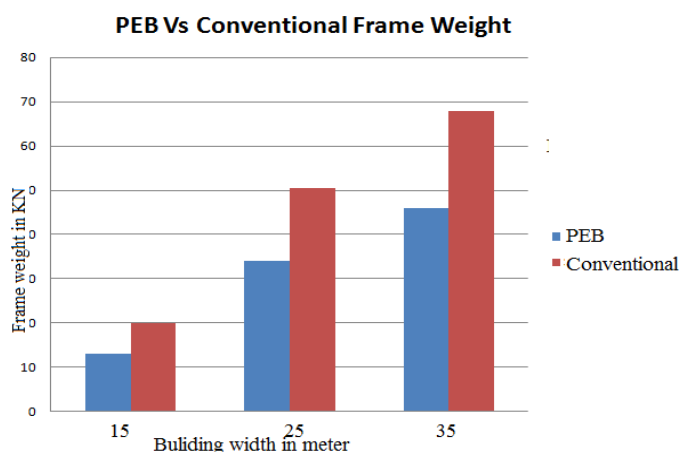


Figure- 4. Graphical Representation of Main Frame System Result

4.2 Secondary Structural Framing

4.2.1 Purlin

The structural analysis & design of purlin section is done with the help of excel programming. Parameter like loading, length are kept constant while spacing is considered to be varied, for easy comparison of result. Table 4 shows PEB & conventional weight of purlin having different spacing.

Span(m)	Conventional Weight (kN)	PEB Weight (kN)	Saving %
1.3	11.38	3.04	32.98
1.5	11.38	3.04	32.98
1.7	11.38	3.04	32.98

Table 4- Summary for the Weight of Purlin Member

The graphical representation of different spacing of purlin having constant loading for the pre-engineered & conventional building system is shown in figure- 5

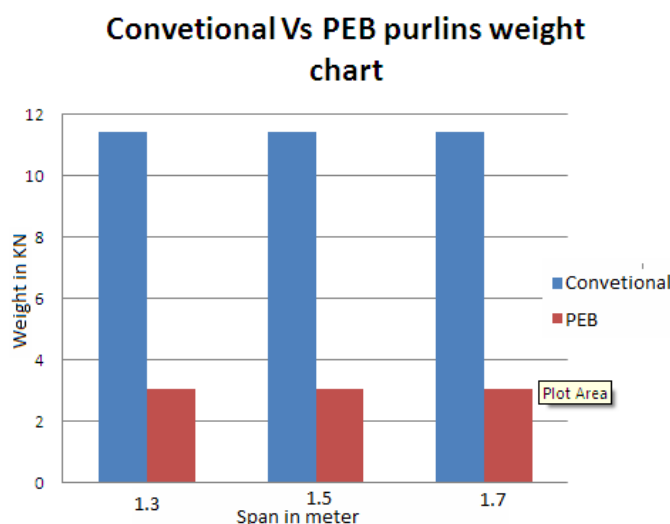


Figure- 5. Graphical Representation Purlin Result

4.2.2 Girt

The structural analysis & design of girt section is done with the help of excel programming. Parameter like loading, length are kept constant while spacing is considered to be varied, for easy comparison of result. Table 5 shows PEB & conventional weight of girt having different spacing.

Span (m)	Conventional Weight (kN)	PEB Weight (kN)	Saving %
1.3	11.38	3.04	32.98
1.5	11.38	3.04	32.98
1.7	11.38	3.04	32.98

Table 5- Summary for the Weight of Girt Member

The graphical representation of different spacing of girt having constant loading for the pre-engineered building system & conventional building system is shown in figure- 6

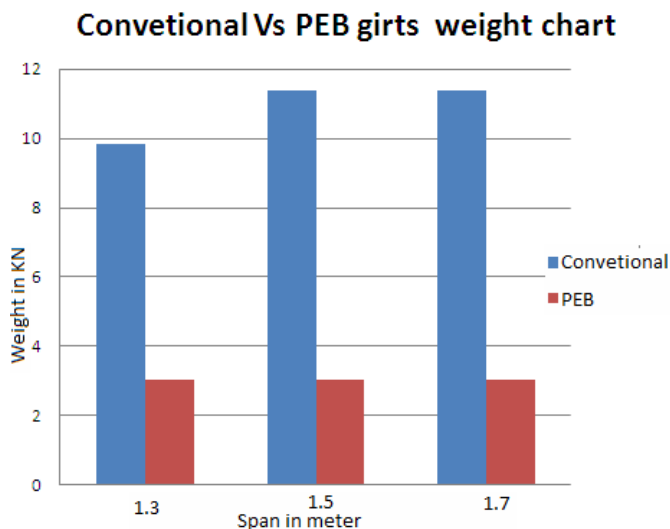


Figure- 6. Graphical Representation of Girt Result

4.3 Flow Chart of Result

Building Estimate – The estimation of whole building can be shown in figure -7 by using flow chart

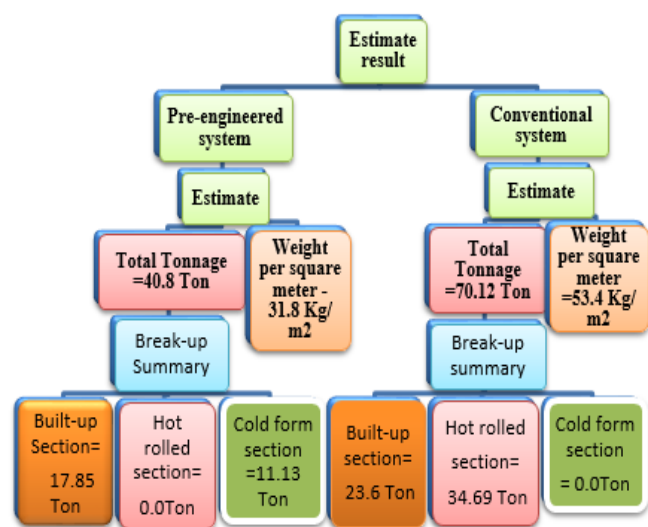


Figure- 7. Graphical Representation of Estimate Building

4.5 Main Frame Result –

Figure-8 gives the weight comparison of main frame system between conventional system and PEB system

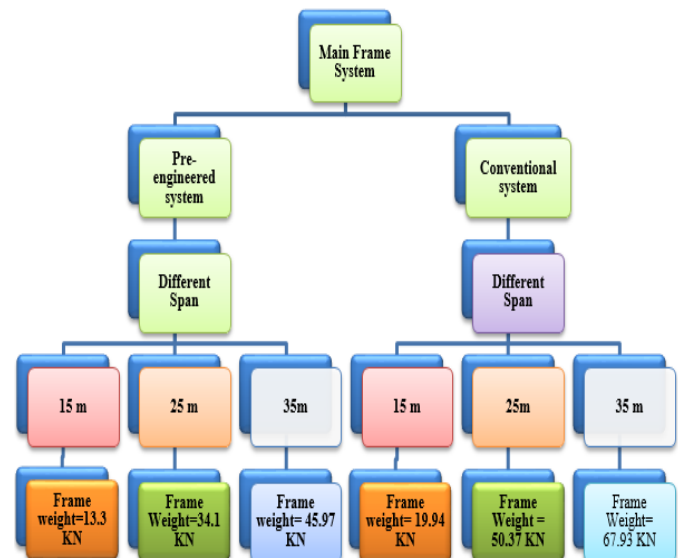


Figure- 8. Main Frame System Weight Chart

5. CONCLUSION:

Steel is a preferred material for construction, due to its various advantages like quality, aesthetics, economy and environmental conditions. From the past advancement, the use of PEB is implemented and continuously increasing, but its usage is not throughout the construction industry. Hence the pre-engineered buildings are more advantageous over conventionally designed buildings in terms of cost effectiveness, time saving, future scope, subtleness and economy. Using of PEB instead of CSB may be reducing the steel quantity. The paper also imparts simple and economical ideas on preliminary design concepts of PEBs.

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