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Comparative Study on the Economy between Pre-Engineered and Conventional Steel Buildings

Shashank Pattanshetti[1], Prof. Sachin M. Kulkarni[2]

[1]P G Student, Construction Technology, Jain College of Engineering, Belagavi, Karnataka, India
[2]Assistant Professor, Department of Civil Engineering, Jain College of Engineering, Belagavi, Karnataka, India

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Abstract - *For the past few decades, pre- engineered buildings have become popular in the construction industry. Pre- engineered structure is an idea designed with a view to replace conventional steel structures as the structural components are manufactured under controlled environment conditions tend to produce products with high quality & precision, reduce resource wastages and decrease the budget considerably. The paper presents a comparative study conducted between conventional steel structure and pre-engineered structure discussing the economy of the structures in terms of structural weight and material optimization. To conduct the study a 3D model of a conventional steel structure and pre- engineered building is deigned and analysed on STAAD. Pro, a structural designing software.*

Key Words: Conventional steel structure, Pre- Engineered Buildings, Economy, STAAD Pro.

1. INTRODUCTION

The construction industry is growing immensely large by the day. A lot of investment is poured for the development of a country to improve the standard of living. The economy is on the rise and the need for buildings, infrastructures, machines, etc. is in great demand by the population. To keep up with the progress and development, the resources should be available and maintained at all times. Industrial sector is fast growing and the demand to house, store and export materials is on the rise. Temporary sheds or structures which can be erected and maintained within minimum cost and time, moved to different locations and provide a salvage value after its life span are mainly adopted for construction. Structures designed by steel have proved to be the best material to satisfy the criteria for temporary structures.

1.1 Structural Steel

Steel is a material resource produced from the ores extracted from the earth's crust. Steel and its forms have become one of the primary material required in various fields of engineering and its demand is increasing by the day. Steel is the next material after concrete to be of great demand in the construction industry and hence the steel industry is the largest growing sector in the world. In the construction industry it is used as a primary construction material in form of HYSD bars of various diameters in concrete structures and in form of mild steel sections of various shapes for framed structures. Framed structures are designed using structural steel due to its ease of constructability and high strength to weight ratio.

The advantages of steel construction are:

1. To provides high quality, strong, durable and stable structures.
2. It has a high fire resistant property and is environmentally friendly material.
3. Construction with steel material is fast compared to other materials.
4. The steel components can be recovered, recycled and reused effectively.

Structural steel has been adopted to construct two types of framed structures:

1.1.1 Conventional Steel Structure

Structures fabricated by mild steel sections with varying cross sections are known as conventional steel structures. The type of steel sections proposed for construction varies as per the design standards and specifications. Conventional steels structures with or without concrete columns have been designed for industrial operational buildings, storage units, warehouses, etc. These steel sections are produced in lengths of 6m of various cross sections and transported to site, where they are fabricated as per needs and assembled. The sections fabricated are connected by bolts or welding processes. The level of material wastages for such methods is high and degree of precision & work quality achieved is low for such structures.

1.1.2 Pre-Engineering Building

Pre- engineered buildings are the new steel structures being designed and adopted to replace conventional steel structures. The pre- engineered components are manufactured according to design specifications and standards under controlled environment due to which high quality product with precision are achieved and are later transported and assembled at site. Pre- engineered buildings are adopted for long span structures, they are economical, provide flexibility for future expansion, require low maintenance and are easily maneuvered during its life cycle which has changed the conventional steel building practice.

2. METHODOLOGY

The study intends to compare the structural weight between conventional steel structure and pre- engineered structure to obtain an economical design. The study presents a design of an industrial building of dimensions length 24m, width 12m and eave height 6m. The truss of the conventional steel structure has been designed as an English type with span 12m, height 2m and bay spacing is taken to be 6m. An electrically operated crane of capacity 100 kN is assembled over gantry girder at a height of 5m.

The study will be carried out with the design of conventional steel structure and pre- engineered components. Loads acting on the structure are calculated as per IS 875: 1987 (Part I) for dead loads, IS 875: 1987 (Part II) for live loads and IS 875: 1987 (Part III) for wind loads and the structure is designed as per IS 800: 2007 steel codes. The proposed structure is modelled and analysed in STAAD. Pro V8i, a structural analysis software to obtain safe design.

The mild steel sections is replaced by hollow tube sections for the conventional steel structure and cold formed sections have been integrated into pre- engineered structure. The intermediate column sections at the ends have been varied for the conventional steel structure depending on the magnitude of the oncoming loads. A detailed estimate has been prepared considering the material weight and cost of material between both the structures for a comparative study. The cost for mild steel and cold formed steel per unit weight has been considered as Rs. 45/- and Rs. 70/-

3. STAAD PRO. V8i

STAAD is a computer program software used for structural design and analysis in the field of civil engineering. STAAD provides a flexible modelling space and a friendly user interface to work with. The program supports several material design codes such as steel (hot rolled and cold formed sections), concrete, aluminium and timber based projects. The software is incorporated with over 80 international codes, various unit systems and all the standardized steel cross sections to provide results to desired standards and specifications. The software helps to:

1. Design any type of structure regardless its shape and size.
2. Carries out analysis regardless the complexity of the structure.
3. It reduces duplication of iterations and minimizes errors.
4. It provides accurate analysed results.
5. Revisions can be easily incorporated and reanalysed.

The application can perform static, dynamic, linear, non-linear and buckling analysis according to relevant building codes. It automatically calculates the relevant loading parameters based on the geometry, mass, load combinations and selected building codes instantaneously. It provides results in form of documents including plans and elevations that can be used to convey design intent. The obtained results can be revised for optimization of resources as per needs and to quickly obtain safe and economical designs.

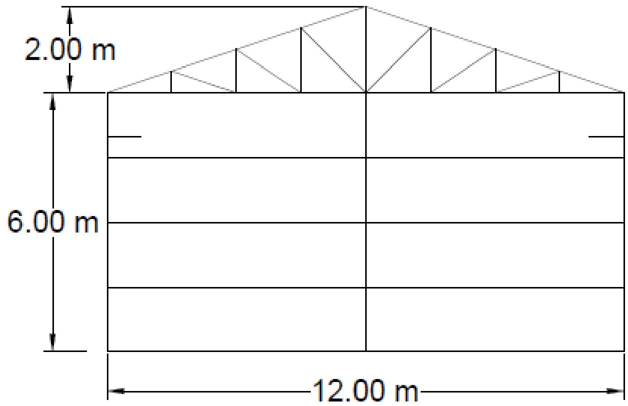

Fig 1: Elevation of Conventional Steel Structure

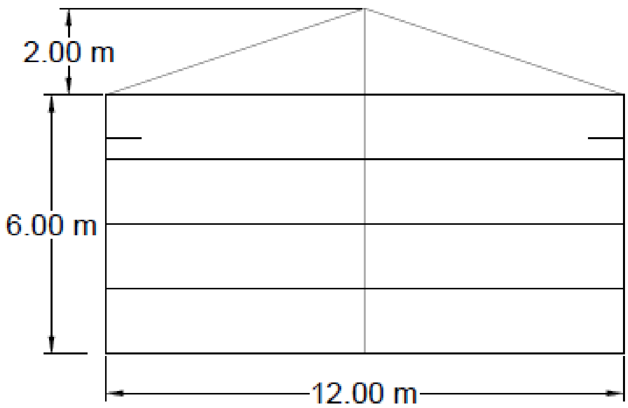

Fig 2: Elevation of Pre- Engineered Building

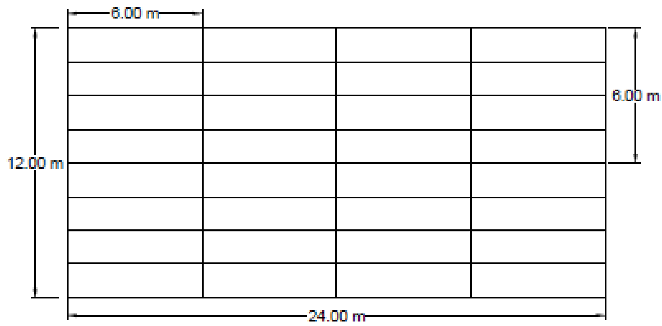

Fig 3: Plan for Conventional Steel and Pre- Engineered Structure

4. LOADS

The load acting on the structure are considered as follows:

1. Dead loads: 0.150 kN/m² [IS 875: (Part I)]
2. Live loads: 0.750 kN/m² [IS 875: (Part II)]
3. Wind load : 0.795 kN/m² [IS 875: (Part III) – 1987]

Load combinations

1. 1.0 (Dead Load + Live Load + Crane Load)
2. 1.5 (Dead Load + Live Load + Crane Load)
3. 1.2 (Dead Load + Live Load + Wind Load Pressure 0°) + 1.05 (Crane Load)
4. 1.2 (Dead Load + Live Load + Wind Load Suction 0°) + 1.05 (Crane Load)
5. 1.2 (Dead Load + Live Load + Wind Load Pressure 90°) + 1.05 (Crane Load)
6. 1.2 (Dead Load + Live Load + Wind Load Suction 90°) + 1.05 (Crane Load)
7. 1.5 (Dead Load + Wind Load Pressure 0°)
8. 1.5 (Dead Load + Wind Load Suction 0°)
9. 1.5 (Dead Load + Wind Load Pressure 90°)
10. 1.5 (Dead Load + Wind Load Suction 90°)

5. OBSERVATIONS AND RESULTS

a. Estimation of structural weight and its comparison between conventional steel structure and pre-engineered building.

Table 1: Steel estimate of conventional steel structure and pre- engineered building

Structure	Purlins and girts	Quantity (kgs)
Conventional steel	Hot rolled mild sections	21,929.114
	Hot rolled tube sections	19,710.554
Pre-engineered	Cold formed Z- sections	14,700.687

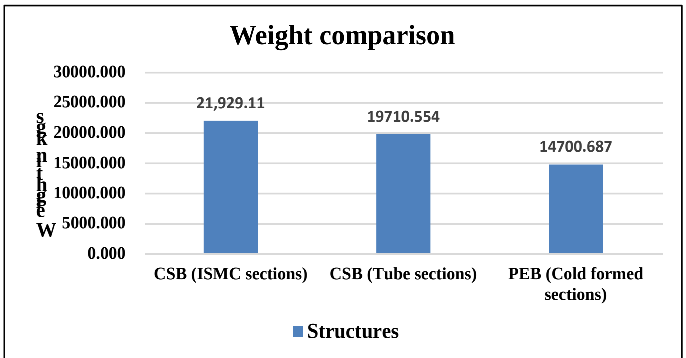

Chart 1: Structural weight comparison between conventional steel structure and pre- engineered building

- The difference in structural weight between conventional steel structure and pre- engineered structure has been estimated as 7228.427 kgs.
- On replacing the ISMC sections by tube sections for purlin and girt components and varying the column sections depending on the magnitude of axial loads, the difference in structural weight has been estimated as 5009.867 kgs.

b. Estimation of dead load contributed by hot rolled & cold formed sections to the total weight of the structure.

Table 2: Dead Load estimate of hot rolled & cold formed sections

Purlins and girts	Section Members	Quantity (kgs)	Dead Load
Hot rolled mild sections	ISMC 150 & 125	12,110.400	55.22 %
Hot rolled tube sections	Tube 145×82×5.4	10,218.200	51.84 %
Cold formed sections	Z- Sections 230×75×3.15	5,644.800	38.40 %

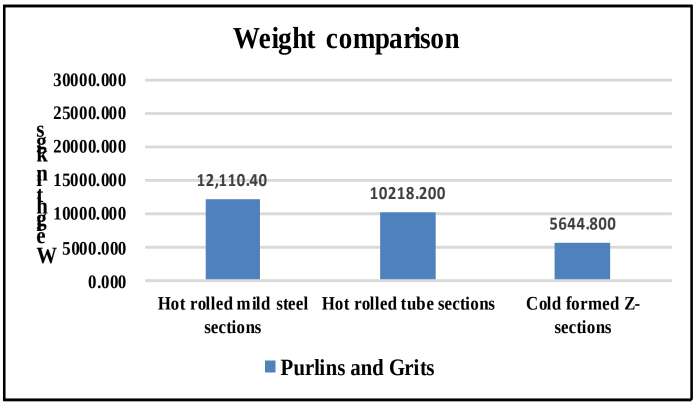

Chart 2: Dead weight comparison between hot rolled & cold formed sections

- The cold formed sections contribute 38.40 % dead load to the total weight of the structure whereas mild steel sections contribute 55.22 % of dead load.
- Replacement of ISMC sections for purlins and girts components by tube (hollow) sections tend to reduce the dead weight on the structure by 1892.2 kgs (51.84 %) thus achieving a more economical design for conventional steel structure.

c. Cost estimation of structural steel and its comparison between conventional steel structure and pre- engineered building.

Table 3: Cost estimate of structural steel

Structure	Purlins and girts	Quantity (kgs)	Total Cost (Rs)
Conventional steel	Hot rolled mild sections	21,929.114	9,86,810.130/-
	Hot rolled tube sections	19,710.554	8,86,974.930/-
Pre-engineered	Cold formed Z-sections	14,700.687	7,86,881.835/-

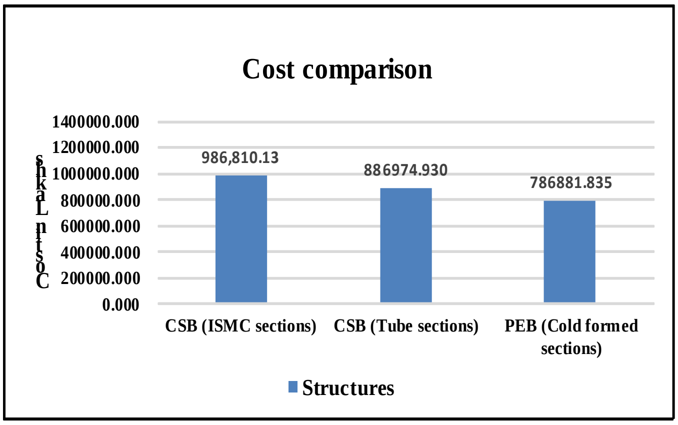

Chart 3: Cost comparison of structural steel between conventional steel structure and pre- engineered building

- The cost of steel for pre- engineered structure is found to be 20.26 % less than conventional steel structure due to the low structural weight of pre- engineered structures.
- The ISMC sections adopted for purlins and girts when replaced by hollow tube sections and varying the column sections depending on the magnitude of axial loads, the overall structural weight of the conventional steel structure is reduced. The cost reduces by Rs 99,835.200/- and thus proving to be economical.

6. CONCLUSIONS

- The weight of structural steel for pre- engineered building has resulted to be 33.00% less compared to conventional steel structure.
- Replacement of ISMC with tube (hollow) sections and varying the size of the structural components depending on the magnitude of oncoming loads has reduced the weight of the structure by 10.10 %. Thus proving that optimization of structural components based on magnitude of load helps to achieve an economical steel design.
- The cold formed sections contribute only 38.40 % dead load to the structure compared to mild steel sections that contribute 55.22 %. The cold formed sections are produced having low cross sectional area which leads to low unit weight of the components and hence contributes less dead load to the structure.
- Pre- engineered buildings prove to be light weight structures and can be highly adopted to replace conventional steel structures. The minimum number of structural components involved in the design and effectively optimizing the cross sections of the structural components based on concentration of forces and stresses developed helps achieving economy and consuming less material resource.

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