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A comparative study between the pre-engineered structures and conventional structures using STAADPRO

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Abstract: Pre-engineered Buildings Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. The present construction methodology calls for the best aesthetic look, high quality & fast construction, cost effective & innovative touch. One has to think for alternative construction system like pre-engineered steel buildings. [1] In recent years, the introduction of Pre-engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. 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 concept is totally versatile not only due to its quality, prefabrication, light weight and economical construction. The study is achieved by designing a typical frame of Industrial warehouse shed using both the concept and analyzing the designed frame using the structural analysis and design software STAAD Pro.* [1]

***Index Terms* – Comparative study, Pre-engineered structure, Conventional structure, Staad-pro**

1. INTRODUCTION

From the recent two to three decades the usage of steel buildings is increased very rapidly. As steel buildings are more earthquake-resistant as compared to concrete buildings, still the preference is given to the concrete buildings. One should not forget the early effect of seismic forces over the concrete buildings and concerning this factor steel buildings usage should be increased. Pre-engineered steel buildings are not a new concept in the steel building industry in the world but in India, the usage of a pre-engineered building is limited only up to some accessed regions. The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behaviour in high winds. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Pre-engineered Buildings have bolted connections and hence can also be reused after dismantling. Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Pre-engineered Buildings have bolted connections and hence can also be reused after dismantling. Thus, pre-engineered buildings can be shifted and/or expanded as per the requirements in future. In this paper we will discuss the various advantages of pre-engineered buildings and also, with the help of three examples, a comparison will be made between pre-engineered buildings and conventional steel structures.

The basis of the PEB concept lies in providing the section at a location only according to the requirement at that spot. The sections can be varying throughout the length according to the bending moment diagram. This leads to the utilization of non-prismatic rigid frames with slender elements. Tapered I sections made with built-up thin plates are used to achieve this configuration. Standard hot-rolled sections, cold-formed sections, profiled roofing sheets, etc. is also used along with the tapered sections, as in. The use of optimal least section leads to effective saving of steel and cost reduction. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure. [1]

2. STUDY AREA

The current study was taken into consideration when designing an industrial warehouse in Mumbai. STAAD Pro software has been used to analyse and design both conventional and pre-engineered building structures. For a slope of 1 in 10, dimensions of 50 m long, 20 m wide, 6.250 m between bays, and 5 m high are taken into consideration. Steel weight comparisons have been done for both PEB and conventional, and both have had designs built for them. According to IS 875 part III-1987, pre-engineered buildings and traditional steel frame structures are intended for force and wind analyses. In PEB tapered sections are used with initial dimensions which were then changed as per the design criteria. For conventional steel frames, hot rolled sections of ISMB are used. Support conditions are pinned for both the ends. Analyse & design of pre-engineered building using Bentley STAAD-ProV8i, Autodesk AutoCAD and TEKLA Structures. The analysis & design part will be completely based upon STAAD-ProV8i, Autodesk AutoCAD and TEKLA Structures.

STAAD Pro software can be used for analysing and designing of the pre-engineered buildings. It gives the Bending Moment, Axial Forces, Shear Forces, Torsion, Beam Stresses of a steel structure so that the design can be done using tapered sections and check for the safety. [1]

3. TECHNICAL PARAMETERS

3.1 DESIGN DATA

BUILDING LENGTH	- 50 Meter out to out
BUILDING WIDTH	- 20 Meter out to out
BAY SPACING	- 6.250 Meter
EAVES HEIGHT	- 5.0 Meter
SUPPORT CONDITION	- PINNED SUPPORT
SLOPE	- 1:10
LOCATION	- MUMBAI
PURLIN TYPE	- “Z” PURLIN COLD FORM
PURLIN SPACING	- 1.5 m Centre to Centre
GIRTS SPACING	- 1.5 m Centre to Centre
ROOF TYPE	- BARE GALVALUME SHEET

3.2 DESIGN CODES & STANDARDS

In general, pre-engineered buildings are designed based on American or Indian codes of practice based on customer requirements.

- AISC-89 & AISC-2005 are used for primary members
- MBMA-96 is used for load combinations
- AISI 1996 is used for old formed members
- IS 1984 & IS 2007 are used for serviceability conditions
- IS 2062 is used for design of miscellaneous members [1]

3.3 TYPES OF LOADS

3.3.1 DEAD LOAD

It includes primary member’s self-weight i.e. frames and secondary structural component weight such as purlin, girts, Flange Braces, roof, and wall braces and wallboard. Dead load includes,

- SHEETING + PURLIN – 5.00 Kg/m2 + 5.00 Kg/m2 = 10 Kg/m2

3.3.2 LIVE LOAD

According to IS: 875 (Part 2) – 1987, & MBMA -96 for roof with no access provided, the live load can be taken as 0.75 KN/m2 & 0.57 KN/m2.
Live loads are temporary usually short-lived and may be fixed or moving. Live loads on the roof and floor are provided by,

Workers’ repairs, owing to equipment and materials.
Movable artifacts during the lifespan of the system but do not include water, snow, seismic or dead load.

- Live load on rafter = 6.250 X 0.57 = 3.5625 KN/m (According to MBMA/AISC)
- Live load on rafter = 6.250 X 0.75 = 4.6875 KN/m (According to IS 875 – PART 2)

3.3.3 WIND LOAD

Wind loads are calculated as per IS 875 Part-III (1987). For the present work, the basic wind speed (VB) is assumed as 44 m/s and the building is considered. Wind load is governed by the building’s wind speed, roof slope, eave height, and enclosure conditions. Based on enclosure conditions internal pressure coefficient is taken as following,

1. Enclosed ±0.2
2. Partially enclosed ±0.5
3. Open ±0.7

3.3.4 LOAD CASES & COMBINATIONS

The load combination is taken into account according to codes. Different load combinations are used according to different codes used for PEB layout. It can be divided into three different categories:

- Load Combinations as per MBMA/AISC
- Load Combinations as per IS875/IS800-19
- Load Combinations as per IS800-2007

Table – 3.1

Type	L/C	Name
Primary	1	DL
Primary	2	LL
Primary	3	WIND LOAD X (WL +X)
Primary	4	WIND LOAD - X (WL -X)
Primary	5	WIND LOAD Z (WL +Z)
Primary	6	WIND LOAD Z (WL -Z)
Combination	7	GENERATED MBMA CODE STRENGTH 1
Combination	8	GENERATED MBMA CODE STRENGTH 2
Combination	9	GENERATED MBMA CODE STRENGTH 3
Combination	10	GENERATED MBMA CODE STRENGTH 4
Combination	11	GENERATED MBMA CODE STRENGTH 5
Combination	12	GENERATED MBMA CODE STRENGTH 6
Combination	13	GENERATED MBMA CODE STRENGTH 7
Combination	14	GENERATED MBMA CODE STRENGTH 8
Combination	15	GENERATED MBMA CODE STRENGTH 9
Combination	16	GENERATED MBMA CODE STRENGTH 10
Combination	17	GENERATED MBMA CODE STRENGTH 11
Combination	18	GENERATED MBMA CODE SERVICEBILITY 1
Combination	19	GENERATED MBMA CODE SERVICEBILITY 2
Combination	20	GENERATED MBMA CODE SERVICEBILITY 3
Combination	21	GENERATED MBMA CODE SERVICEBILITY 4
Combination	22	GENERATED MBMA CODE SERVICEBILITY 5
Combination	23	GENERATED MBMA CODE SERVICEBILITY 6
Combination	24	GENERATED MBMA CODE SERVICEBILITY 7
Combination	25	GENERATED MBMA CODE SERVICEBILITY 8
Combination	26	GENERATED MBMA CODE SERVICEBILITY 9
Combination	27	GENERATED MBMA CODE SERVICEBILITY 10

3.3.5 LIMIT STATE OF STENGTH (AISC-89/MBMA-86)

1. (DL+LL)
2. (DL+ CL)
3. 0.75*(DL+ WL)
4. 0.75*(DL+ EL)
5. 0.75*(DL+ WL)
6. 0.75*(DL+ 0.58*WL+0.75*CL)
7. 0.75*(DL+ 0.58*EL+0.75*CL)

3.3.6 LIMIT STATE OF SERVICEABILITY (AISC-89/MBMA-86)

1. (DL+LL)
2. (DL+WL)
3. (DL+EL)
4. (DL+CL)
5. (DL+0.5*WL+CL)
6. (DL+0.5*EL+CL)

Table – 3.2

Type	L/C	Name
Primary	1	DL
Primary	2	LL
Primary	3	WIND LOAD X (WL +X)
Primary	4	WIND LOAD - X (WL -X)
Primary	5	WIND LOAD Z (WL +Z)
Primary	6	WIND LOAD Z (WL -Z)
Combination	7	GENERATED IS 800-2007 STRENGTH 1
Combination	8	GENERATED IS 800-2007 STRENGTH 2
Combination	9	GENERATED IS 800-2007 STRENGTH 3
Combination	10	GENERATED IS 800-2007 STRENGTH 4

Combination	11	GENERATED IS 800-2007 STRENGTH 5
Combination	12	GENERATED IS 800-2007 STRENGTH 6
Combination	13	GENERATED IS 800-2007 STRENGTH 7
Combination	14	GENERATED IS 800-2007 STRENGTH 8
Combination	15	GENERATED IS 800-2007 STRENGTH 9
Combination	16	GENERATED IS 800-2007 STRENGTH 10
Combination	17	GENERATED IS 800-2007 STRENGTH 11
Combination	18	GENERATED IS 800-2007 STRENGTH 12
Combination	19	GENERATED IS 800-2007 STRENGTH 13
Combination	20	GENERATED IS 800-2007 STRENGTH 14
Combination	21	GENERATED IS 800-2007 STRENGTH 15
Combination	22	GENERATED IS 800-2007 STRENGTH 16
Combination	23	GENERATED IS 800-2007 STRENGTH 17
Combination	24	GENERATED IS 800-2007 STRENGTH 18
Combination	25	GENERATED IS 800-2007 STRENGTH 19
Combination	26	GENERATED IS 800-2007 STRENGTH 20
Combination	27	GENERATED IS 800-2007 STRENGTH 21
Combination	28	GENERATED IS 800-2007 STRENGTH 22
Combination	29	GENERATED IS 800-2007 STRENGTH 23
Combination	30	GENERATED IS 800-2007 STRENGTH 24
Combination	31	GENERATED IS 800-2007 STRENGTH 25
Combination	32	GENERATED IS 800-2007 STRENGTH 26
Combination	33	GENERATED MBMA CODE SERVICEBILITY 1
Combination	34	GENERATED MBMA CODE SERVICEBILITY 2
Combination	35	GENERATED MBMA CODE SERVICEBILITY 3
Combination	36	GENERATED MBMA CODE SERVICEBILITY 4
Combination	37	GENERATED MBMA CODE SERVICEBILITY 5
Combination	38	GENERATED MBMA CODE SERVICEBILITY 6
Combination	39	GENERATED MBMA CODE SERVICEBILITY 7
Combination	40	GENERATED MBMA CODE SERVICEBILITY 8
Combination	41	GENERATED MBMA CODE SERVICEBILITY 9
Combination	42	GENERATED MBMA CODE SERVICEBILITY 10
Combination	43	GENERATED MBMA CODE SERVICEBILITY 11

3.3.7 LIMIT STATE OF STRENGTH (IS 800-2007)

1. 1.5*(DL+LL)
2. 1.5*(DL+WL/EL)
3. (0.9*DL+1.5 WL/EL)
4. (1.5*DL+1.5*LL+1.05*CL)
5. (1.5*DL+1.05*LL+1.5*CL)
6. (1.2*DL+1.2*LL+0.6*WL/EL+1.05*CL)
7. (1.2*DL+1.05*LL+0.6*WL/EL+1.2*CL)
8. (1.2*DL+1.2*LL+1.2 *WL/EL+0.53*CL)
9. (1.2*DL+1.2*LL+1.2*WL/EL+0.53*CL)

3.3.8 LIMIT STATE OF SERVICEABILITY (IS 800-2007)

1. 1.5*(DL+LL)
2. (DL+WL/EL)
3. (DL+LL+CL)
4. (DL+0.8*LL+0.8*WL/EL+0.8*CL)

4. SECTION SIZES

Table – 4.1 (Built up or prefabricated sections)

Description of Member Used as Column & Rafter

Description	Dimensions of Column in m	Dimensions of Rafter in m
Depth of section at start Node	0.300	0.600
Thickness of web	0.005	0.004

Depth of section at an end Node	0.600	0.300
Width of the top flange	0.150	0.150
The thickness of the top Flange	0.008	0.008

***All the Dimensions are provided manually in Bentley STAAD PRO**

Table – 4.2

Description of Members.

Description	Type	Material
Column	Tapered – I section	Steel
Rafter	Tapered – I section	Steel
Bracing	Rod 25 DIA	Steel
Purlin	Z - 150x50-55x15 – 2 mm	Steel

***All the types are as per Bentley STAAD PRO.**

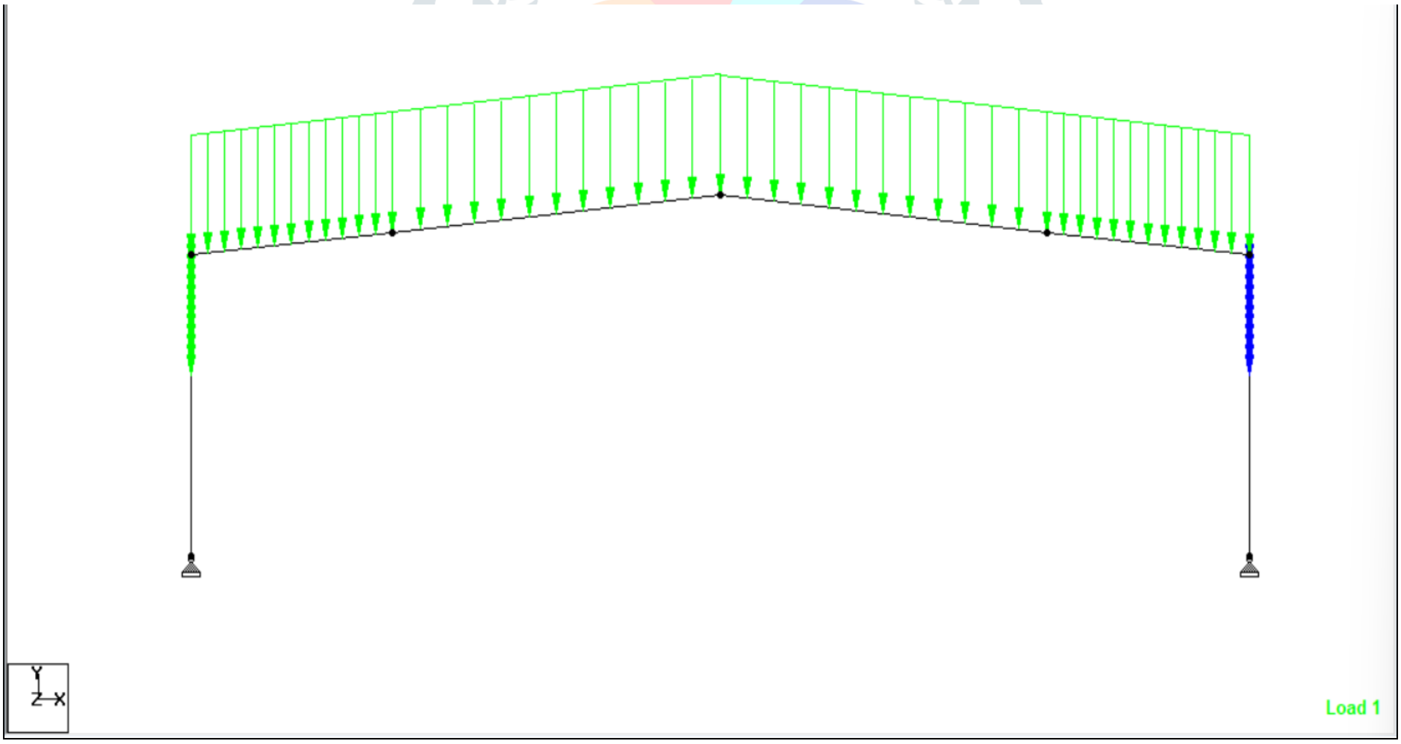


Fig. 4.1. Loading diagram

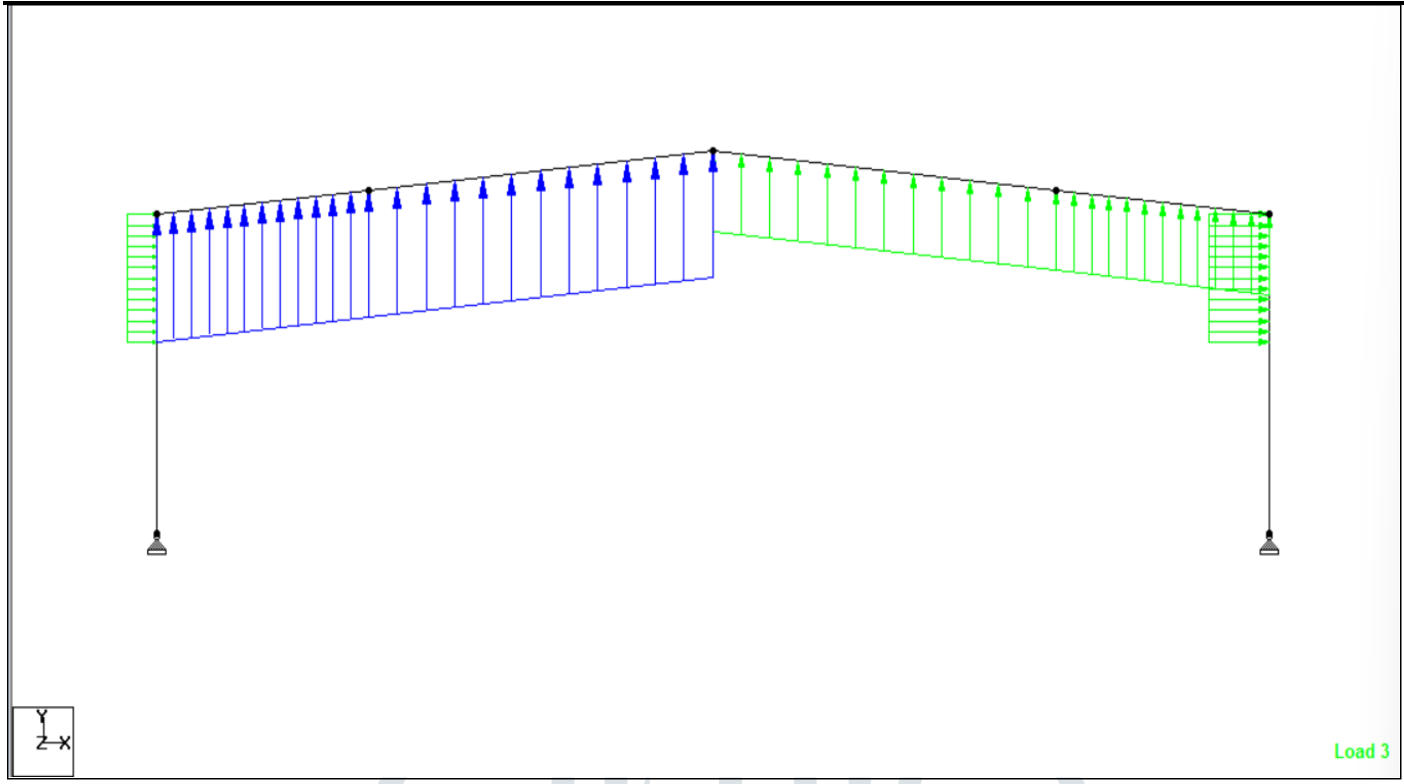


Fig. 4.1.2 Loading diagram

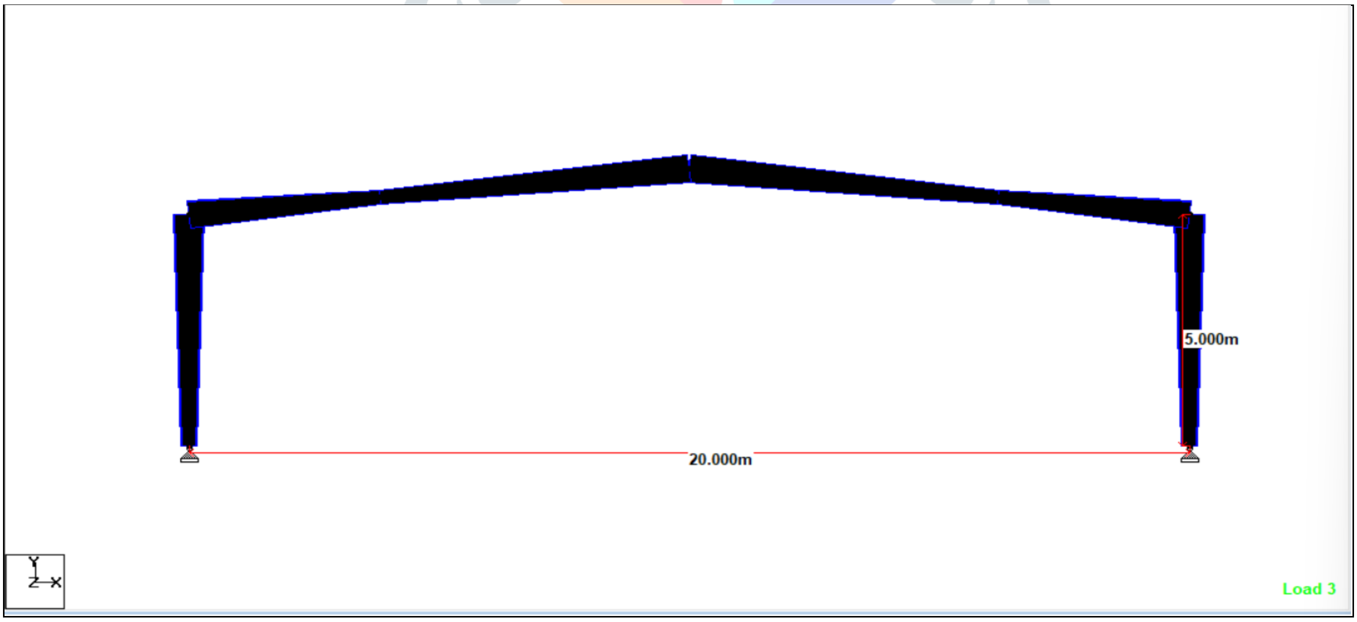


Fig. 4.1.3 Tapered sections

Table – 4.3 (Conventional sections)

Description of Member Used as Column & Rafter

Description	Type	Material
2 – ISMC 150	Column – C section	Steel

ISMB - 400	Rafter – I section	Steel
ISMB - 300	Rafter – I section	Steel

***All the Dimensions are provided manually in Bentley STAAD PRO**

4.1.1 SOFTWARE ANALYSIS & RESULT SUMMARY (Comparison between PEB & Conventional sections)

Table – 4.3

Sr.no	Description	PEB	CSB
01	Steel take off (KG)	950	1500
02	Support reactions (KN)	X – 26.67 Y – 48.93	X – 60.75 Y – 94.55
03	Deflection on Rafter (mm)	68.150	71.25
04	Maximum shear force	42.70	55.55
05	Maximum bending moment	133.38	202.47

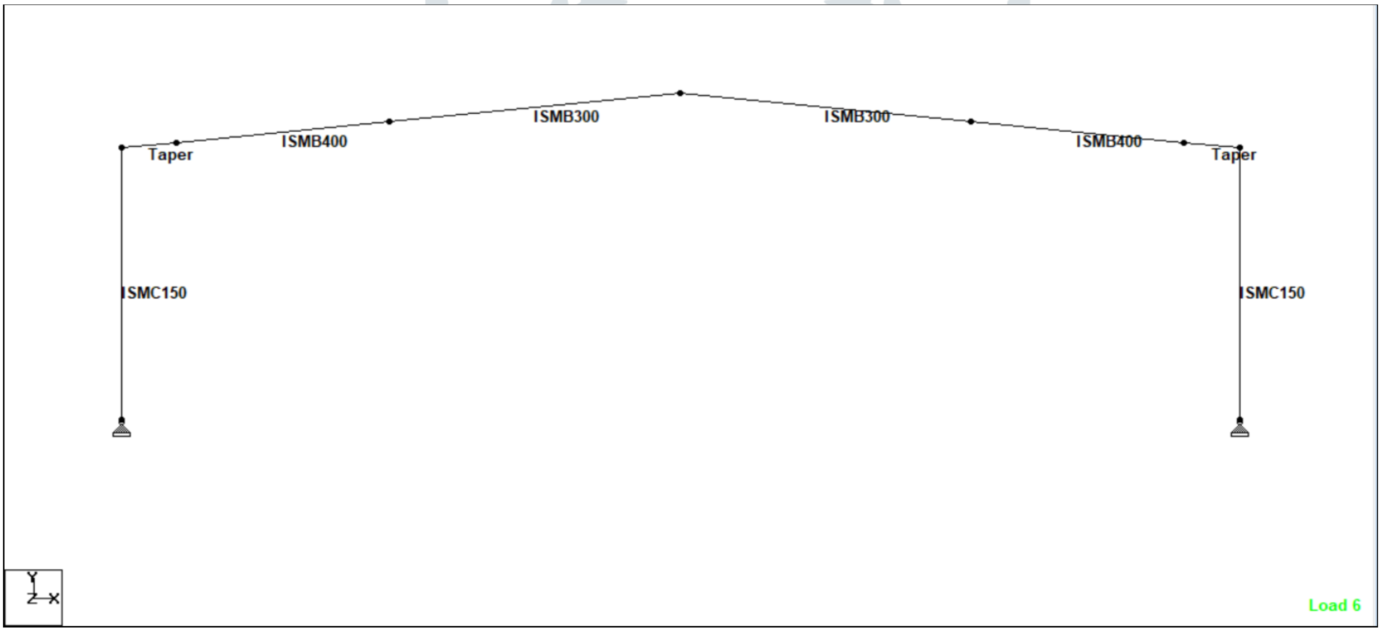


Fig. 4.1.4 Conventional sections

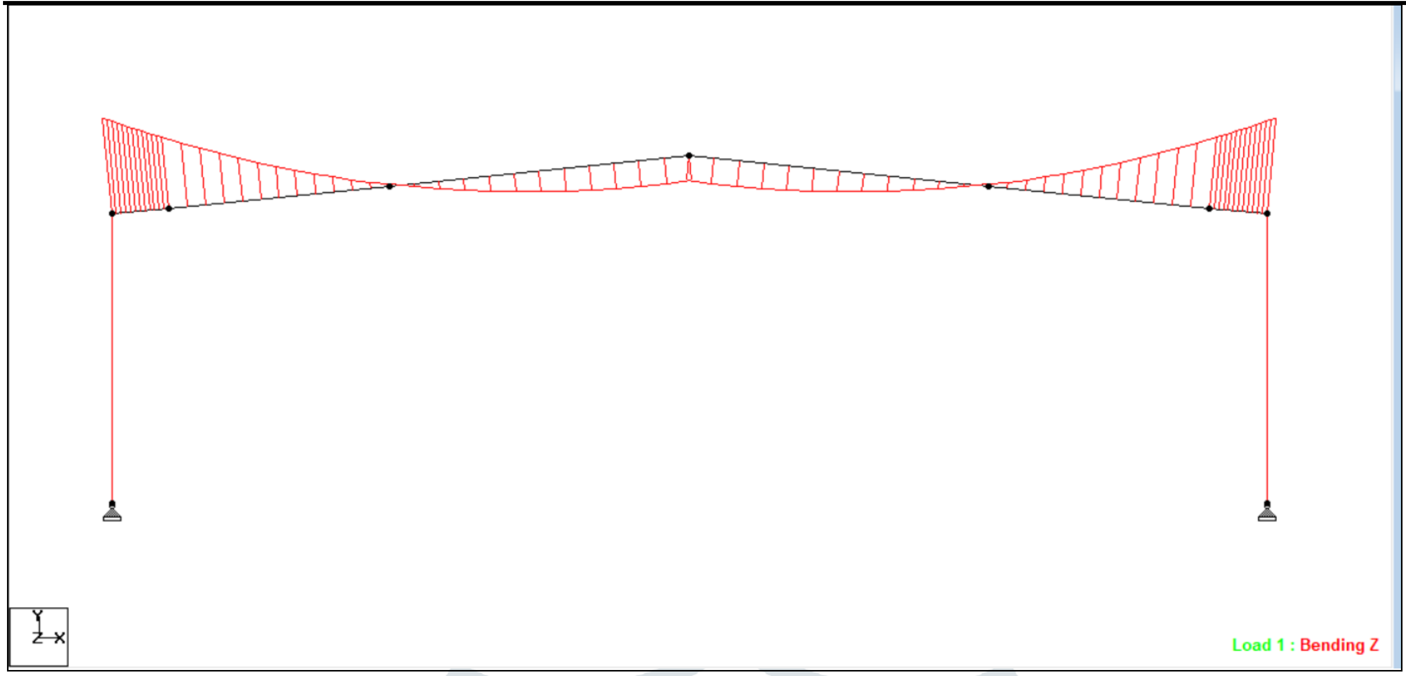


Fig. 4.1.5 Bending moment diagram of Conventional sections

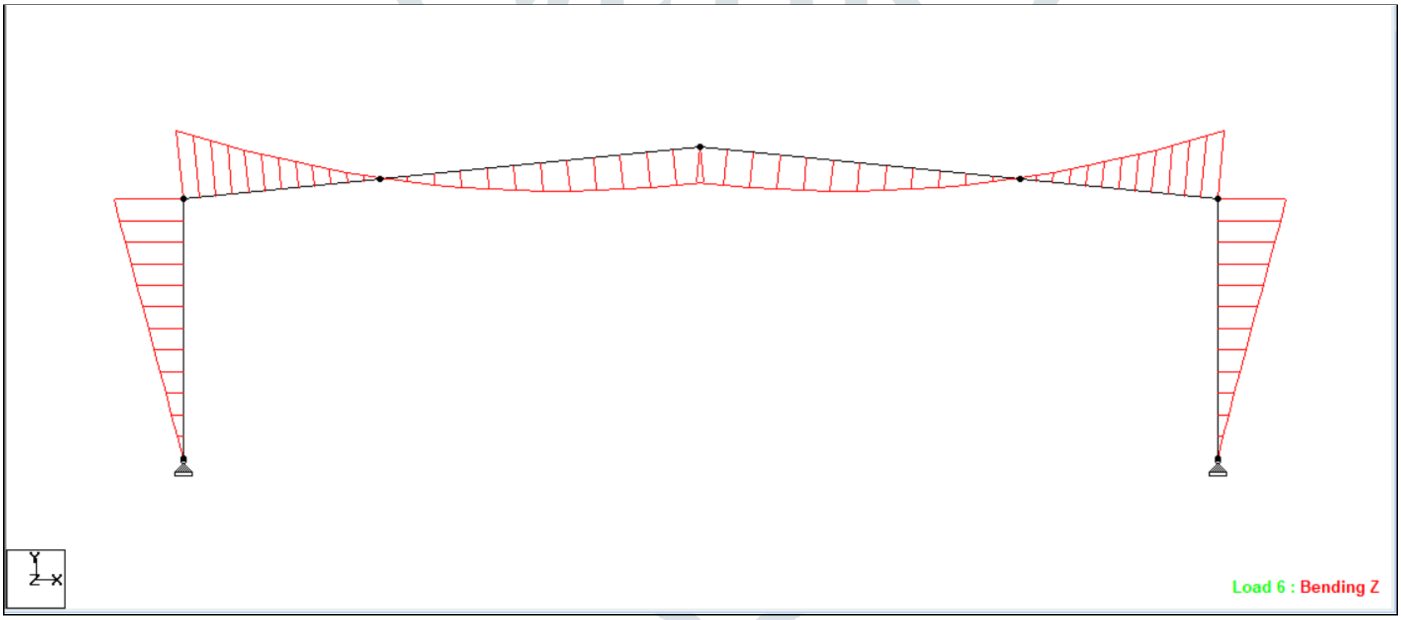


Fig. 4.1.6 Bending moment diagram of PEB sections

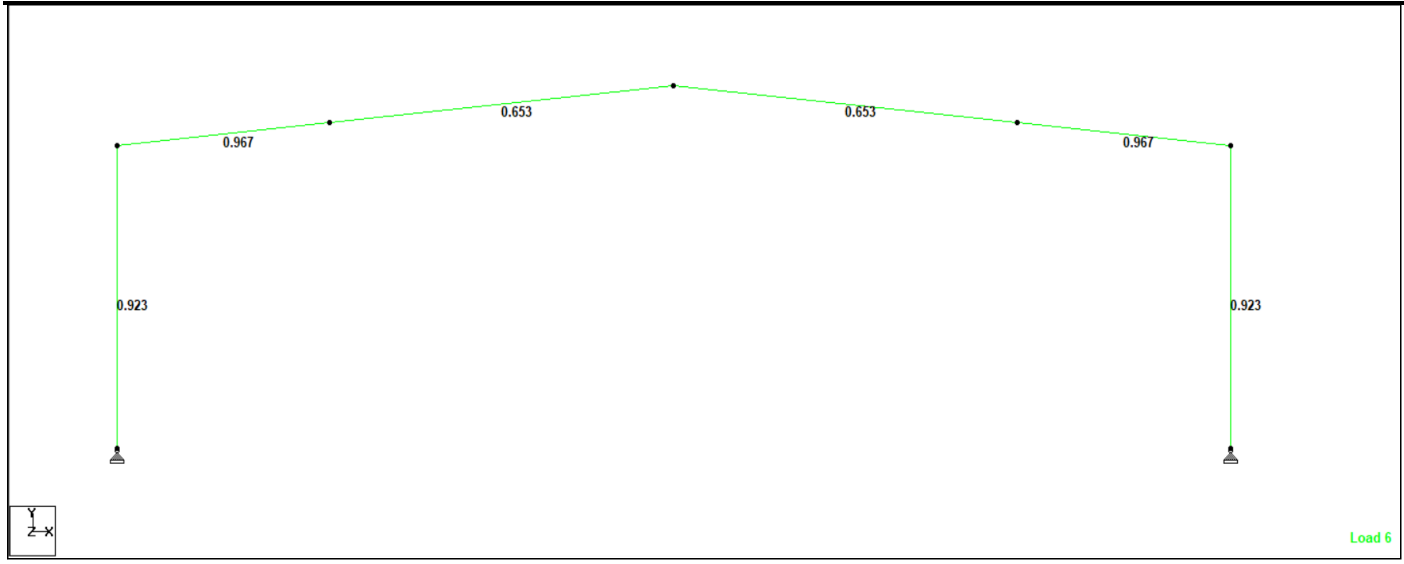


Fig. 4.1.7 Unity ratio of PEB sections

5. MATERIAL SPECIFICATION

To maintain the required inventory of raw material and to avoid any shortage of any particular material, the design department shall forward the abstract list of work-wise materials to the purchasing department in advance for the purchase of raw material.

5.5.1 PRIMARY MEMBERS OR BUILT UP SECTIONS

Built-up members are formed by using HR plates of High strength steel plate having a minimum yield strength of 345Mpa. In general, the thickness, width, and length vary from 4 to 50 mm, 1250–1500 mm, and 2100–6000 mm respectively

5.5.2 SECONDARY MEMBERS (COLD-FORMED SECTIONS)

Using high strength steel plate HR plates with a minimum yield strength of 345Mpa, built-up members are formed. For cold-formed members, the steel sheet thickness typically ranges from 1.5 mm to 3.15 mm. High strength steel coils with a minimum yield capacity of 345 MPa and a thickness range of 1.50 mm, 1.60 mm, 1.75 mm, 2.00 mm, 2.50 mm and 3.15 mm. For forming cold-formed members. [2]

5.5.3 CLADDING MATERIAL

The following materials are widely used for the manufacture of roof and wall cladding & covering sheets:

1. 0.47 mm thick bare galvalume
2. 0.50 mm thick colour coated galvalume

6. RESULT & DISCUSSTION

The overall design results and design ratios of a pre-engineered building are shown in Fig. 4.1.2 and Fig. 4.1.3 and it was found that the Pre-engineered building performed better as compared to the existing conventional steel building. The number of factors which affects the design results are studied thoroughly and are discussed further. [3]

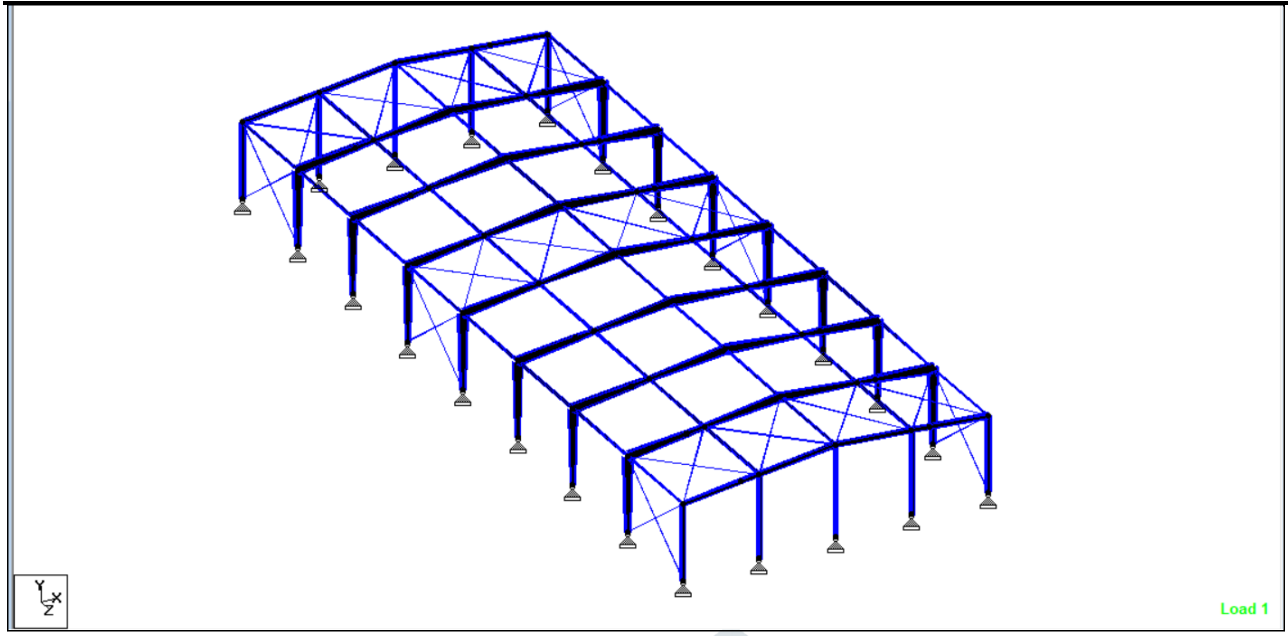


Fig. 6.1 3D frames of PEB sections

The first major aspect designed and it was found that the design of the pre-engineered building is more effective as compared to conventional steel building and that is because of the integral framing system of the pre-engineered structures. The second factor considered was the usage of simulation and modelling and concerning that aspect, the pre-engineered building can be designed using modelling and simulation but in case of conventional steel building, no such type of technological usage is possible. Modelling and simulation play a crucial role in enhancing the structural parameters but no such kind of improvement can be done in case of traditional buildings. [3]

The next aspect is the overall structural weight of both the buildings and concerning this aspect, it was found that the overall structural weight of the pre-engineered building is found to be 20 to 30 per cent lesser as compared to the conventional building and This aspect directly influences the usage of structural steel and the overall construction cost of the structure. The next factor considered was the delivery speed of the complete project and in this parameter also, the pre-engineered buildings are much faster.

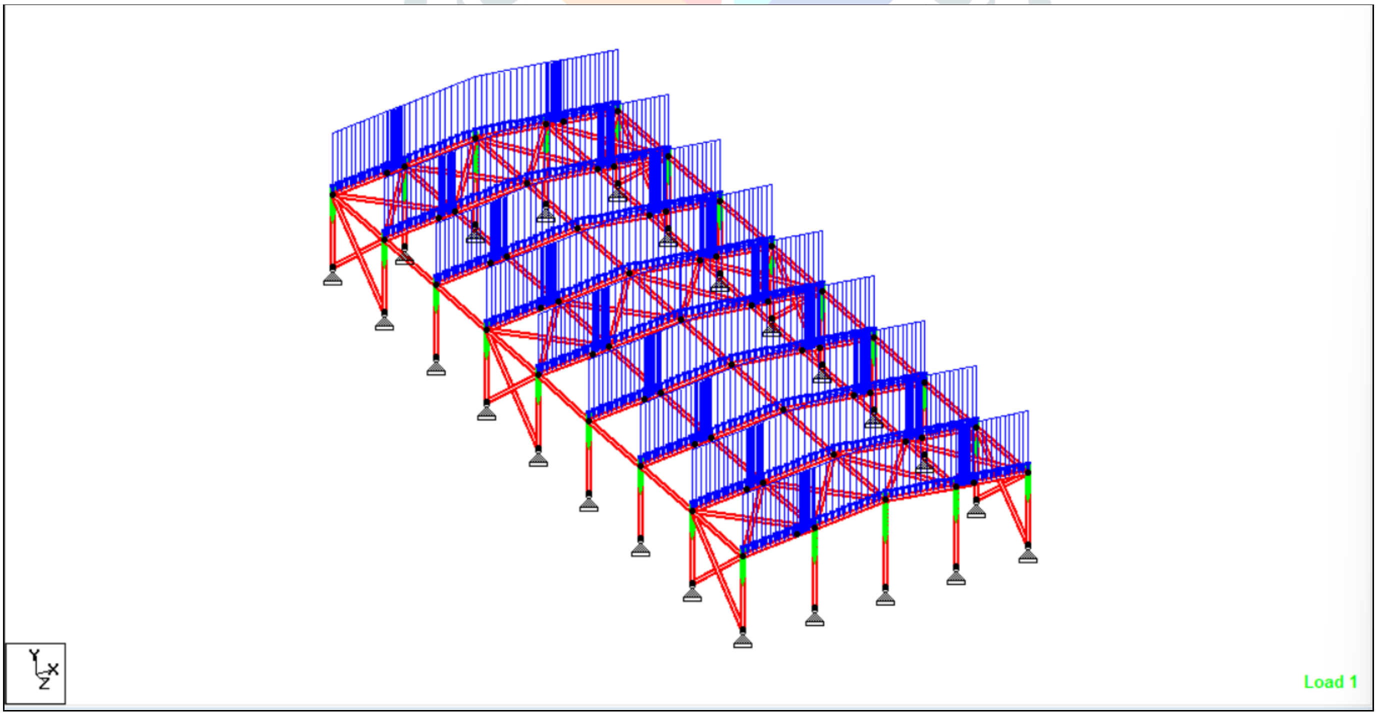


Fig. 6.2 Application of dead load

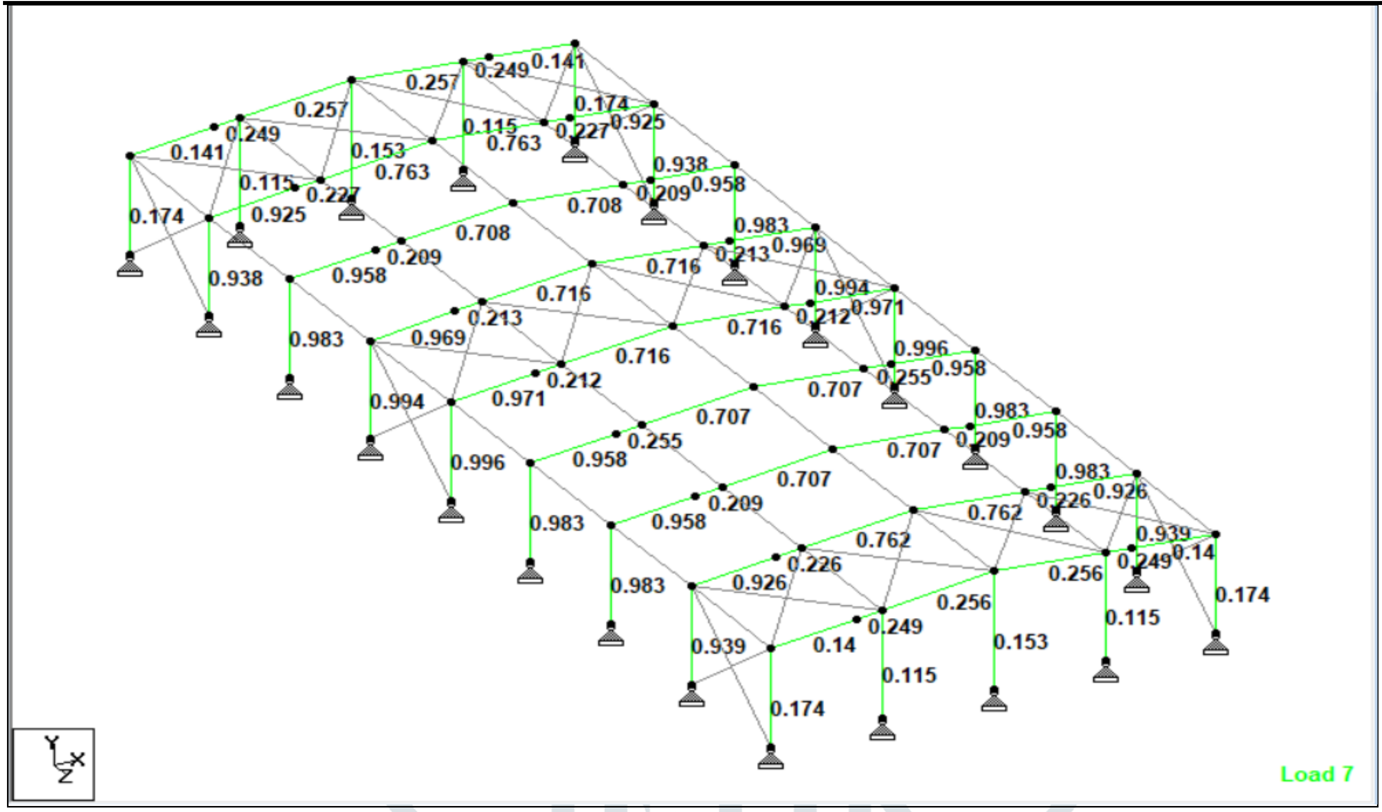


Fig. 6.3 3D frames of unity ratio

The pre-engineered building gives a better output from the architectural point of view as the pre-engineered building can be moulded as per the requirement of the user. With some further investment, the size and shape of the structure can be adjusted as per the requirement but it is not possible in case of existing conventional steel building. Also, the steel requirement is much lesser in case of the pre-engineered building as compared to a conventional steel building.

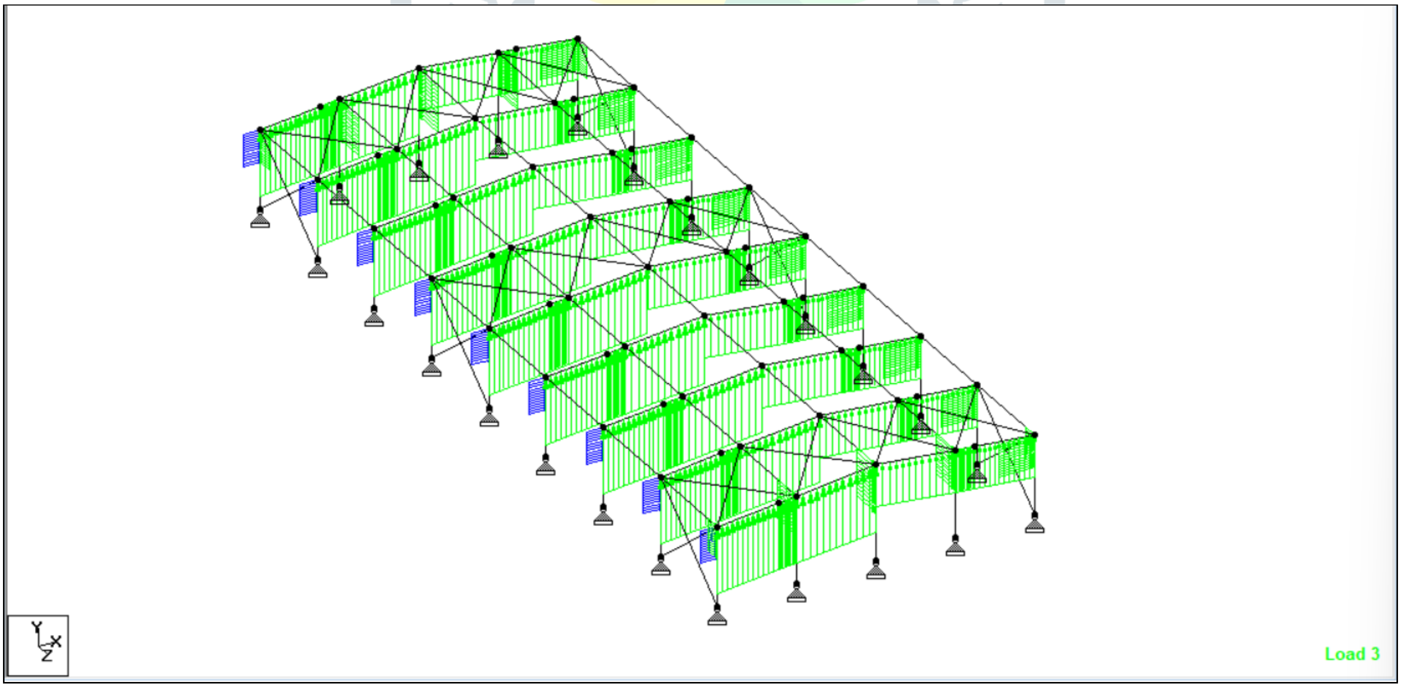
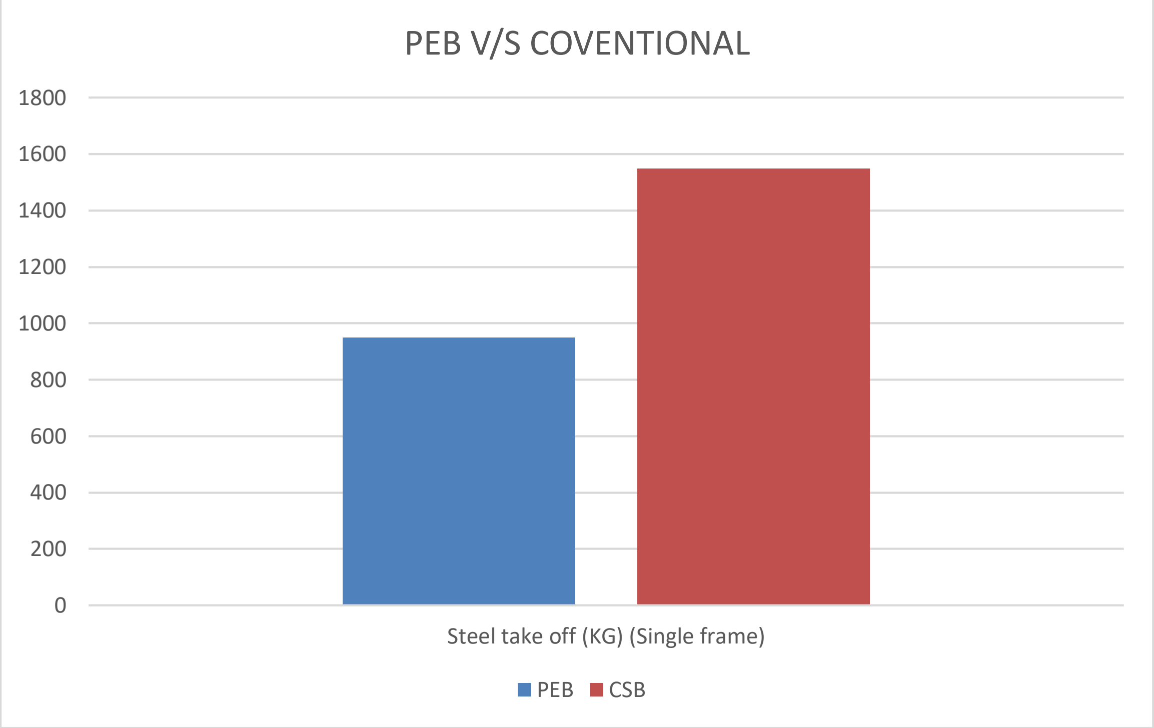
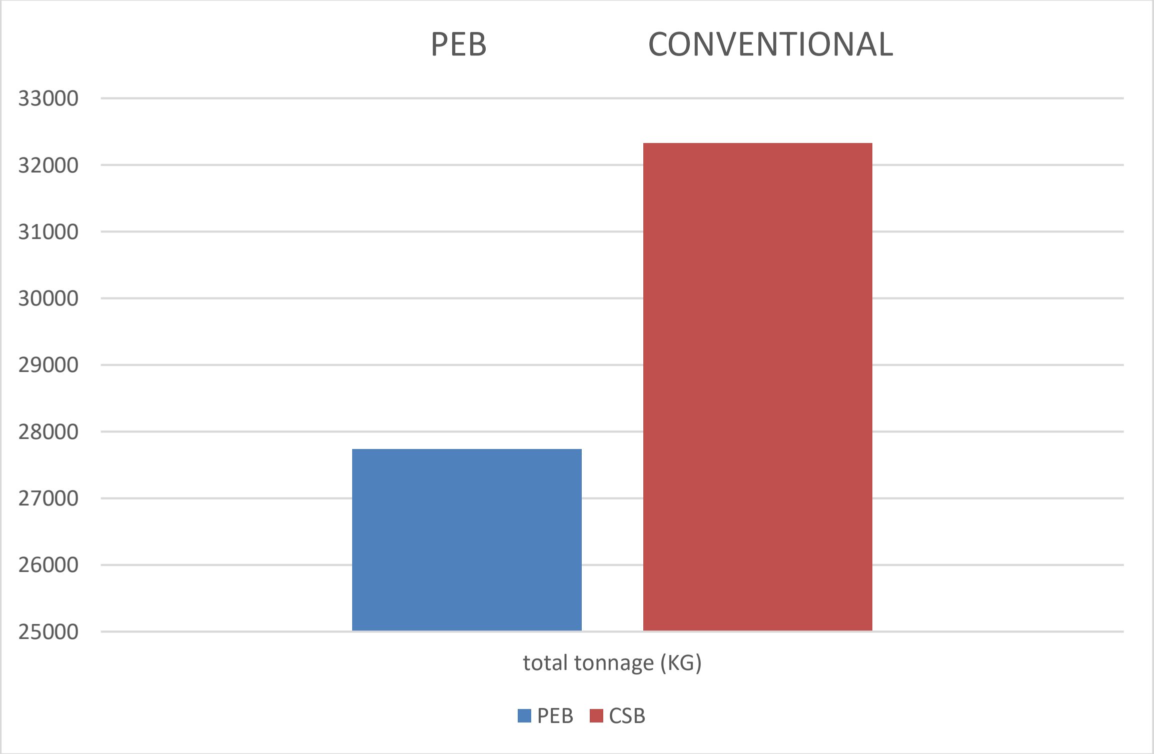


Fig. 6.4 Application of wind load



Graph-1 Comparison between steel take off (Single frame)



Graph-2 Comparison between total tonnage

Further, the material used for the construction of the pre-engineered building is not only environmentally friendly but it is reusable and well as recyclable. After the requirement is fulfilled the material of dismantled pre-engineered building can be reused for a further new type of construction. This factor indirectly affects the cost parameters of the construction of the pre-engineered building.

7. CONCLUSION

In this work, Analysis and design of Conventional Steel Building and Pre-Engineering Building has been carried out and comparison between both has been done. Following are the conclusion of this project.

1. Displacement
- CSB model gives more displacement then PEB model for same loading condition due to less weight of structure.

2. Support reactions
- After analysis of PEB and CSB frame it is concluded that the support reaction is more for CSB as compared to PEB and CSB.

3. The study of self-weight of the models showed that the self-weight for PEB is less than that of CSB for the same geometry. With reduction in self-weight, the loads and hence the forces on the PEB will be relatively lesser, which decreases the effective sizes of the structural members.

4. Steel quantity depends on primary members and purlins. As spacing of frame is increased steel consumption decreased for primary members and increased for secondary members.

5. Also, material wastage plays a significant role in reducing steel quantity and cutting the cost of structure as all fabrication work for conventional steel frames are performed at site results in lots of wastage in material.

6. The overall tonnage difference between Pre-engineered building & Conventional building are 14.23%. In PEB, the tonnage lighter is 14.23 % as compared to CSB. [1]

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