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COMPARISION OF COLD FORMED BUILDING, CONVENTIONAL STEEL BUILDING AND PRE-ENGINEERING BUILDING

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Abstract
Cold-formed steel has been one of the most widely used building materials over a range of building applications. The use of cold-formed steel sections has become more common due to its lightness and high structural performance. Although formerly, cold- formed sections were only used as secondary members in concrete and steel structures, but it can be used as main structural elements, to reduce the cost in the construction as well as improve the structural function of a building, It is important to use a material that would provide high strength to weight ratio, and requires simpler and faster construction. It is very good choice over the conventional steel building for industrial purposes as well as residential purposes. Use of hot rolled shapes is often uneconomical because, the smallest available sections are more than sufficient. To achieve economy cold formed steel is a good option over conventional steel as it is light weight, easy to transport and recyclable. In this project, a comparative study is made between the conventional steel and cold formed steel..

Key words: Pre-Engineered Building, Convent Steel Building, Cold formed building .

1 INTRODUCTION

1.1 General

Two families of structural elements are typically available in steel construction. The first are the members constructed of plates and hot-rolled sections. The other, which is less well known to us but is becoming more significant, is made up of pieces that have been cold- formed using press-brake or bending brake procedures. These structural steel members were manufactured via cold-forming. Steel sheets are typically 0.5 mm to 4 mm thick for sheeting and 1 mm to 8 mm thick for profiles when used in cold-formed steel structural elements. Cold-forming steel plates up to 25 mm thick into structural forms is effective. While cold-formed steel sections are produced at normal temperature, hot-rolled steel sections are produced at extremely high temperatures. Economy is the main criteria for the industrial building. It is fact that hot rolled sections are available in wide variety but their practical use is limited. For moderate loading condition and moderate span replacement of hot rolled section is possible with cold formed Cold-formed shape, such as open sections, closed sections, and built-up sections, are easily accessible as structural elements. Typical cold-formed steel members used for carrying load are studs, track, purlins, girts. Whole structures as well as roof, floor, and wall systems are constructed using cold-formed forms. As joists, studs, and truss members, they can be employed as separate framing members (Bhambulkar et al., 2023). Main advantage using cold form system is it is recyclable. If the purpose of the building is fulfilled it can be it can be disassembled and reused for another function. Compared to hot rolled building materials, cold-formed steel offers a number of benefitsA typical stud wall only weights 10% to 15% as much as a stone wall, making it easier to handle during building and shipment. Cold-formed steel components may be precisely manufactured in shops before being assembled on-site, cutting down on assembly time(Sayyad, S. T., & Bhusare, V. , 2016). Cold-formed steel has one of the finest strength-to-weight ratios of any building material as a result of the cold-forming process. High strength and stiffness are the cause of higher design flexibility, broader spans, and better material utilization. Formwork is not needed when using cold- formed steel metal decks to pour concrete on the floor.

1.2 Categories Of Building

1. Cold-Formed Steel Building: Lightweight structure uses cold formed steel. Thin walled members are employed in low and mid-rise building construction because they ar expensive and structurally sound. Cold formed steel is being used in structures more and more frequently these days because to the accessibility of various creative and structurally sound Cold formed steel products. High strength and stiffness, mass manufacturing, simple and quick erection and installation, among other benefits of cold-formed steel. The cold formed steel products come in a variety of sizes and forms. several innovative and structurally efficient CFS products were easily available.

2. Conventional Steel Structures: Low-rise steel structures with truss-based structures and coverings are considered conventional steel buildings. The slope of the roof, manufacturing pitch, and transport methods are among the factors considered in the truss selection process. Hot rolled "T" type steel sections with standard spacing are used in conventional steel building designs, although they must be punched and fastened on location. The materials are put after being transported or manufactured at the factory. The demand for further economy in developing the region and designing the CSB is controlled by useful necessities. The members are used in typical constructions and are hot rolled. Steel roof trusses are typically utilised for industrial buildings, workshop structures, packing areas, warehouses, and for residential structures, academic institutions, and workplaces when construction projects must be finished quickly. The structural performance of these structures is well known in high wind areas, and for the most part, there are now code measures in place to ensure excellent behaviour. The whole portion of each and every component in the truss is put under uniform stress, requiring all of their strength. In order to create a system of triangles that are organised in a predetermined pattern according on the span, kind of loading, and functional needs of the structure, various elements are connected at their ends to create a truss frame structure.

Although there are many different Hot-Rolled section options, experience has revealed that only a small number of forms are actually useful and cost-effective. Figure displays a few CSB cross-sections. The cross-sections used in Hot-Rolled Steel (CSB) Industrial building have yield strength of 250Mpa,310 Mpa.

3. Pre-Engineered Buildings [PEB]: PEB Steel welcomes technical inquiries from architects and consultants. We are prepared to assist you in writing specifications for pre- engineered steel buildings and to recommend suitable solutions to your building requirements. No Limit to Architectural Imagination Many impressive architectural projects have used pre-engineered steel buildings. Nowhere has this been more evident than in the USA. Although this trend is developing in Asia and Africa, still not many architects on these continents have fully realized the economy, versatility and aesthetic features of pre-engineered steel buildings these are produced in the plant, itself. Here according to the requirements of the customer the manufacturing of the members is done. The components are made in completely ready condition for transportation.

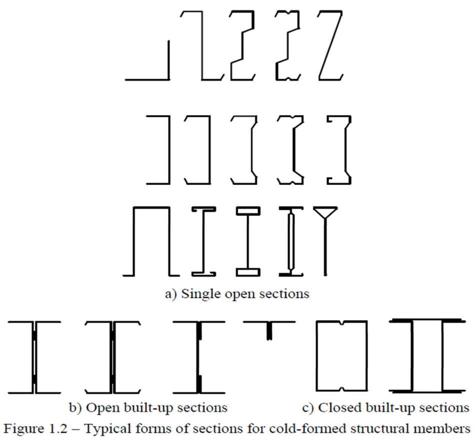

Figure 01. Cold formed steel sections

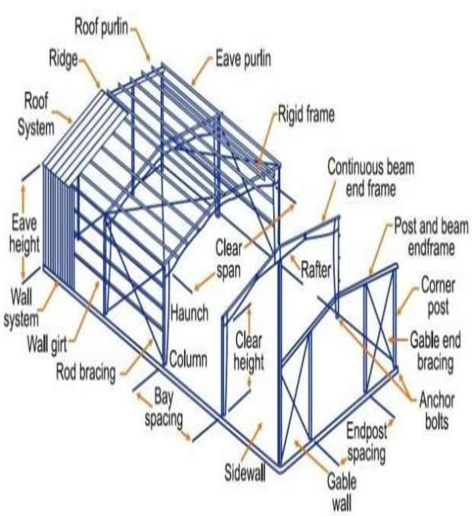

Figure 02. PEB Steel Structure

Fig.No.03. Conventional Steel Structure

1.3 Advantages Of Cold Formed Sections Over Hot Rolled Steel Sections

- Zero insect or fungal infection: This eliminates the issues with rotting and decomposed food brought on by insect and fungal infections.
- Consistency and Precision of Profiles: Cold-rolling's nature and manufacturing process allow for the maintenance and repetition of the intended profile over an extended period of time with a less-closed tolerance. The cold rolling technique, however, is perfectly suited to computerised operation, which helps to maintain precision.
- Flexibility of profile form: Cold-rolling may be used to create any desired cross- sectional shape, including Z-sections, C-sections, Z-sections with lips, and C-sections with lips.
- It can be pre-galvanized or pre-coated: To increase the material's resistance to corrosion and to provide a beautiful finish, it can be galvanised or coated with plastic materials.
- Best for site erection: Because it can be cut and built using a light machine or even just labour, cold-formed steel (CFS) may be preferable than hot-

rolled steel.

1.4 Aim

- Comparative analysis of Cold formed steel Warehouse, Pre-Engineering Warehouse and Conventional Steel for Industrial Warehouse.
- Comparative study of Steel consumption in Cold formed steel Warehouse, Pre- Engineering Warehouse and Conventional Steel

1.5 Objectives

- The Modeling of building for structural analysis and Sectional design of the members with hot rolled steel section.
- To analyze and design the industrial building with Pre-engineering Sections, Cold formed Steel section.
- To evaluate and compare the steel quantity of Industrial Building by using Cold formed steel section, PEB section and Conventional steel section.

2 LITERATURE REVIEW

For this project work, different research paper has been referred from various national and international journals. The following reviews have been done for each research paper

1.Hao Liang , et.al (2022)

The present research on CFS 1 section optimization and thermal performance of CFS structures is reviewed in this paper. It is discovered that several research have been done on how to improve the structural behavior of CFS by optimizing its cross-section. More and more limitations are taken into account throughout the optimization process in order to provide solutions that are more useful. Recent modifications to the loading conditions for cold-formed steel sections have altered them from pure bending/compression to combination loading, and new methodologies have been used throughout the optimizationprocess.

2. Pradeep Patidar, Komal Bedi (2019):

In order to determine the optimum material—cold formed or general steel section—that is stable, good in stiffness, cost-effective, affordable, and readily accessible, a comparison analysis is conducted on a three-dimensional warehouse for the same loadings using various sections. According to this study, cold-formed steel is more effective at withstanding ions, loads, and unbalanced pressures. Additionally, C.F.S. sections exhibit comparatively little deflection. Torsion and support response are considerably weaker in C.F.S, as may be shown.

3. Loragayle Doctolero & Mustafa Batikhah (Feb 2018)

Studied Cold formed steel section building and Conventional Steel Building concept of Design for Industrial building By estimating the construction costs of three building materials, this research investigates the use of CFS Sections in construction. RCC, hot rolled sections, and cold formed sections were used in the design of this four-story structure. According to the design codes for each material type, member portions for each were createdThe effectiveness of utilising CFS was then demonstrated by comparing and analysing the overall weight of the structure, material costs, construction expenses, and construction time for each building. According to the study, the overall cost of CFS is 61% less than that of RC structure and 35% less than that of HRS-material. It was discovered that CFS gains up to 38% less construction time than HRS and 164% less construction time than RC. Once more, HRS construction takes 126% less time than RC.

4. Mr. Shah Foram Ashokbhai, Et.al (Apr 2017)

The researchers will take into account utilising the STAAD-Pro V8i SS6 programme, the industrial shed structure's 15-meter span was examined and designed utilising hot-rolled and cold-formed sections. It is possible to draw the following conclusions from the findings and discussion: Industrial sheds with hot-rolled sections weigh 10435 kg more than those with cold-formed sections. When compared to an industrial shed structure made of hot rolled sections, the weight of cold formed sections is reduced by 32.03%. Researchers claim that an industrial shed with cold formed parts is more cost-effective than one with hot rolledsections.

5. Shabari Indhuja.A, Narendra Prasad.D(2017)

The differences in weight, quantity, and cost between hot-rolled steel and cold-formed steel industrial buildings are studied in this comparative research. Using the sectional properties of a cold-formed steel structure, the STAAD Pro programme creates a model of the cold- formed steel housing system. The software is used to develop the framework, and the direct strength approach is used to carry out the design. The structural weight of the CFS is 35% less than the CSB. The limiting ratio of the section is the cause of the increased weight in the IS code compared to AISC.Weight of CFS is dependent on the bay spacing up to a certain spacing, beyond which the weight decreases and the weight increases. Pre- engineered steel structures are 15% less expensive than traditional steel structures. Pre- engineered structures are inexpensive, strong, long-lasting, and recyclable. The comparison of conventional and pre-engineered buildings reveals that CFS is applicable to and advantageous for warehouses.

3 METHODOLOGY

A Comparative study between the hot rolled steel, PEB and cold formed steel industrial warehouse located at Pune is performed using Staad Pro software and the difference in weight, quantity and cost is discussed..

Following steps are followed as:

- Selection of building geometry
- Loading Calculation according to Building Geometry, location as per IS codes
- Selection of Load Combination as per IS design Codes
- Modeling:- As mentioned above geometry, loading calculation and combination 3d modeling is prepared in Staad-Pro. Preliminary assume the sections.
- Analysis of model is done.
- Design of structure is carried out by giving proper parameters to the structures
- Compare the strength and Displacement of structures.
- Calculate the Steel consumption to the building
- Compare the building according to the steel consumption.

4 THEOROTICAL CONTENTS

4.1 Building Geometry:-

following building layout plan of proposed warehoused is considered for the study

SR.NO	DESCRIPTION	
1	Location	Pune
2	Area	450 Sq.M
3	Length	30.00m
4	Width	15.00m
5	Height	6.00m
6	Bay Spacing	5.0m
7	No Of Bay	6 Nos.
8	Slope	5.71 Degree
9	Support	Fixed/Hinged
10	Wind Speed	39 M/S
11	Seismic Zone	III

4.2 Load Calculation

4.2.1 Dead Load :-

The load acting on the frame is calculated as per Indian Code – IS875- 1987 (Part-1). Load acting onto the roof consists of self-weight and components of structures like dead Load of roof sheeting, Sag rod, Purlin, bracing and insulation etc. also considered the self -weight of structure.

Weight of Roof sheeting (0.5mm thk) :- 5 kg/m2 Weight of Purlin :- 5 kg/m2 Bay spacing of structure is 6.0m

Total Weight in Rafter on middle rafter

= Total weight (kN/m2) x Bay spacing

= 0.10 x 6

=0.6 kN/m2 Total Weight in Rafter on End rafter

= Total weight (kN/m2) x Bay spacing

= 0.10 x 3

=0.3 kN/m2

4.2.2 Live Load

Live load acting on the inaccessible roof is carryout from the Indian standard code IS 875 (Part 2) – 1987. For the structure, it's taken as 0.75 KN/m2 with a reduction of 0.02 KN/m2 for each increase one degree above 10 degrees of the roof slope. The total uniformly distributed live load per running meter of rafter

Total Weight 0.75 kN/m2

Bay spacing of structure is 6.0m

Total Weight in Rafter on middle rafter

= Total weight (kN/m2) x Bay spacing

= 0.75 x 6

=4.50 kN/m2 Total Weight in Rafter on End rafter

= Total weight (kN/m2) x Bay spacing

= 0.75 x 3

=2.25 kN/m2

4.2.3 Wind Load

Wind load is calculated according to IS: 875 (Part3) –2015. The structure located at Pune, and Basic wind speed for the location is 39 m/s

Wind loads calculation as per IS : 875 (Part 3) –2015

Basic wind speed (Vb) = 39 m/sec for Pune (Table 1 of IS : 875 2015 (Part3)) Design wind speed (Vz) = Vb x K1 x K2 x K3 x K4 (Clause 6.3)

Where, K1 Probability factor (Risk Coefficient) = 1(Table 1 of IS : 875 2015(Part 3)Clause.3.1)

K2 Terrain Roughness and Height factor = 1.00 (Table 2 of IS : 875 (Part 3)) For Terrain Category 2

K3 Topography factor =1 ………(Clause 6.3.3)

K4 Importance factor for cyclonic region =1 (Clause 6.3.4)

Design wind speed

Vz = Vb x K1 x K2 x K3xK4 (Clause 6.3)

Vz = 39 x 1.0 x 1.0 x 1.0x1.0

Vz= 39.00 m/sec Design Wind Pressure

Pz = 0.6 Vz2 (Clause 7.2)

Pz = 0.6 (39.00)2

Pz = 0.912 kN /m2

Wind Pressure on Roof = (Cpe-Cpi)

4.3 LOAD COMBINATION :-

LIMIT STATE OF SERVICEABILITY

(DL+LL)

(DL+WL)

(DL+0.8LL+0.8WL)

LIMIT STATE OF STRENGTH

1.5(DL+LL)

1.5(DL+WL)

(0.9DL+1.5WL)

(1.2DL+1.2LL+0.6WL)

(1.2DL+1.2LL+1.2WL)

The application of load combinations, further design parameters are applied to the structure in accordance with the IS800 and the structures are analysed and design to determine normalized ratios and section sizes are varied accordingly. In general, serviceability Criteria for Structure as per IS code is as follow:

DEFLECTION LIMIT :

Vertical deflection = Span / 180

Horizontal deflection =Height / 150

5 ANALYSIS AND DESIGN

ANALYSIS AND DESIGN OF INDUSTRIAL WAREHOUSE USING CONVENTIONAL STEEL SECTIONS USING STAAD-PRO.

5.1 Staad Modeling For Conventional Structure:-

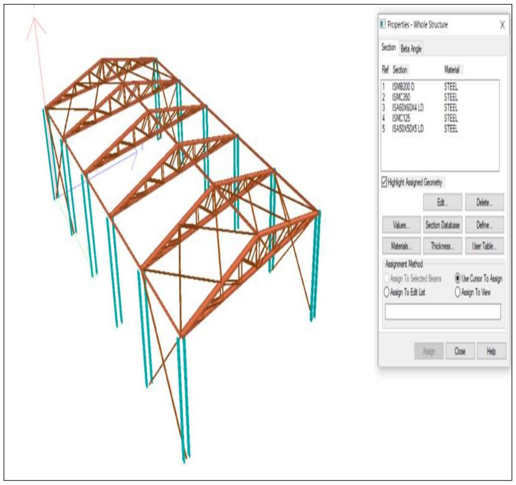

Fig. 04. – 3d view of Staad-Pro for Industrial Warehouse.

The load are applied to the structures as per load calculations:-

The Load Combination is added in the model as per IS code and Serviceability andStrength Envelop is Prepared

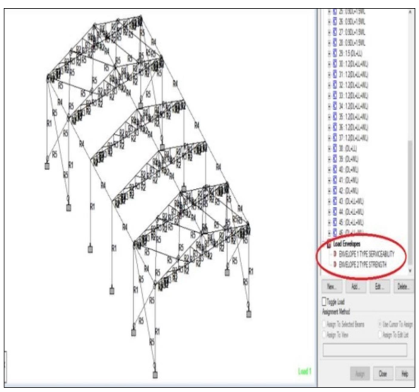

Fig. 05. Load Combination Envelop of Industrial Warehouse

5.2 Staad-Pro Analysis Of Structure:-

After completing the modelling analysis carried out

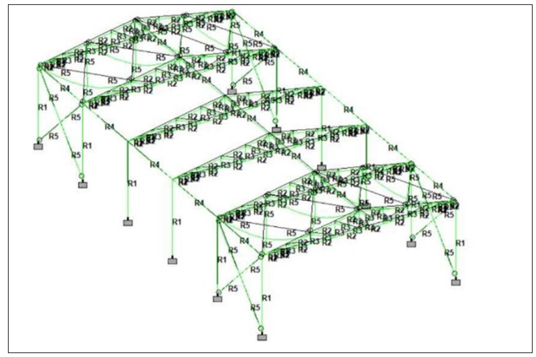

Fig. 06. Displacement of Industrial Warehouse

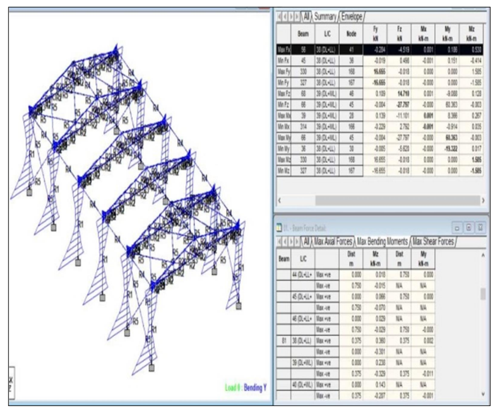

Fig.07–Bending Moment of Industrial Warehouse

5.3 STAAD DESIGN FOR CONVENTIONAL STRUCTURE

Design the structure as per IS800, by considering the Yield Strength of member is 310Mpa.

<u>DEFLECTION CHECK:-</u>

As per IS800, Allowed Horizontal Deflection,

Allowed Horizontal Deflection, Height/150 = 6000/150 = 40mm

Allowed vertical Deflection, Span/180 = 15000/180 = 83.33mm

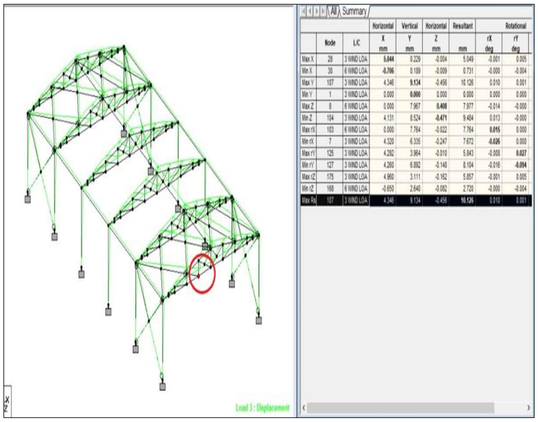

Fig.08– Horizontal Deflection of Industrial Warehouse (Wind Load)

Actual Horizontal Deflection is 5.044mm < 20mm Hence OK

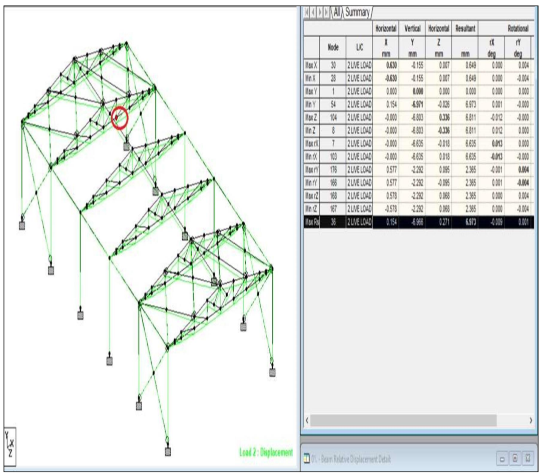

Fig. 9. – Vertical Deflection of Industrial Warehouse (Live Load)

Actual Vertical Deflection is 6.966 mm < 83.33mm

<u>**Unity Check:-**</u>

The ratio of all member is less than 1 Hence OK

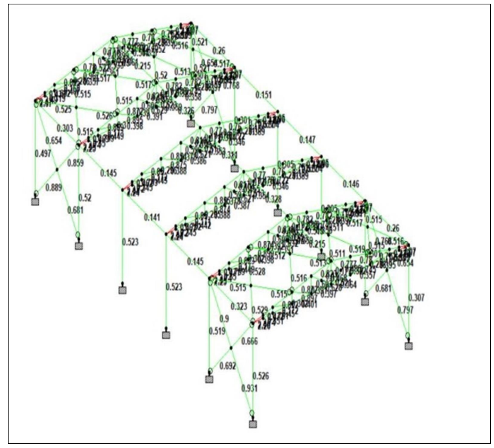

Fig. 10. – Unity Ratio of Industrial Warehouse

<u>Steel Weight:</u>

As per Staad- Pro Design Steel weight of conventional Structure:-

STEEL TAKE-OFF

PROFILE	LENGTH(METE)	WEIGHT(KN)
ST ISMC350	181.78	75.967
LD ISA60X60X4	127.58	9.232
ST ISMC125	90.00	11.477
LD ISA50X50X5	181.72	13.374
PRISMATIC STEEL	72.00	34.071
	TOTAL =	144.120

Fig. 11. – Structural Weight of Industrial Warehouse using Conventional Steel section

6 ANALYSIS AND DESIGN OF INDUSTRIAL WAREHOUSE USING PEB STEEL SECTIONS USING STAAD-PRO.

6.1 Staad Modeling For PEB Structure:-

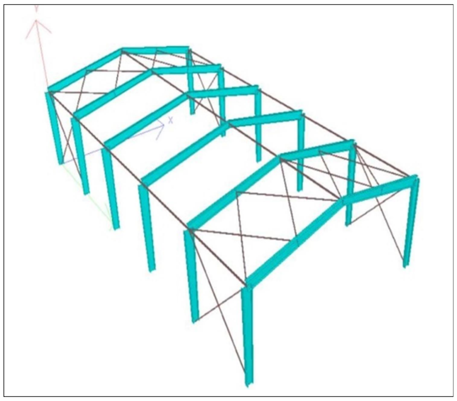

Fig. 12. – 3d view of Staad-Pro for Industrial Warehouse.

6.2 Staad-Pro Analysis Of Structure:-

After completing the modelling analysis carried out

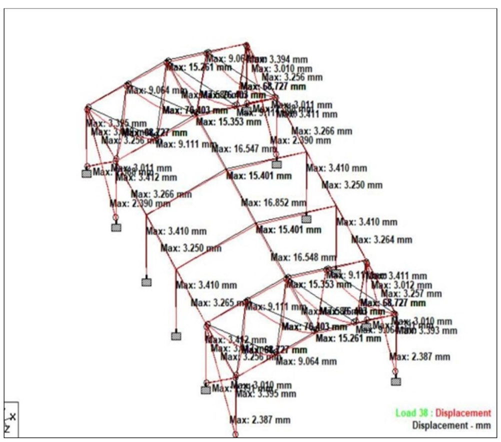

Fig. 13. Displacement of Industrial Warehouse

6.3 Staad Pro Design For PEB Structure

Design the structure as per IS 800:2007,

By considering the Yield Strength of member is 345 Mpa.

DEFLECTION CHECK:-

As per IS800,

Allowed Horizontal Deflection, Height/150 = 6000/150 = 40mm Allowed vertical Deflection,

Span/180 = 15000/180 = 83.33mm

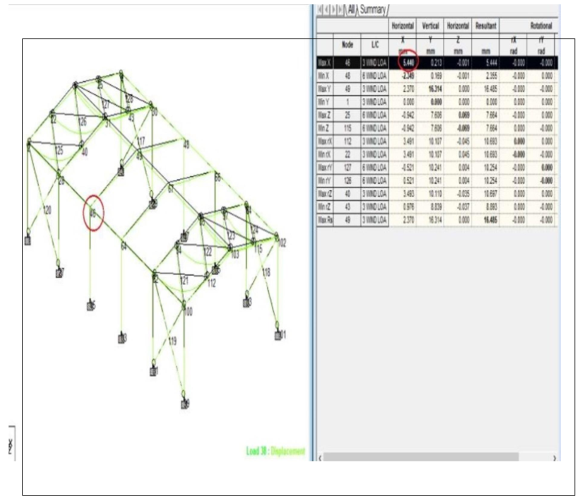

Fig. 14. Horizontal Deflection of Industrial Warehouse (Wind Load)

Actual Horizontal Deflection is 5.440 mm < 40mm Hence OK

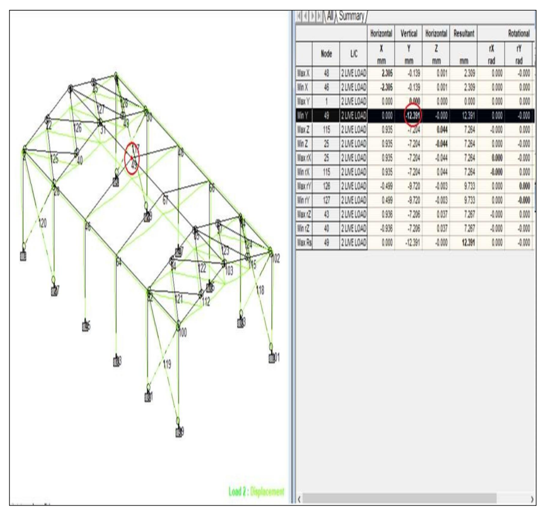

Fig. 14. Vertical Deflection of Industrial Warehouse (Live Load)

Actual Vertical Deflection is 12.391mm < 83.33mm Hence Ok

UNITY CHECK:

The ratio of all members is less than 1 Hence OK

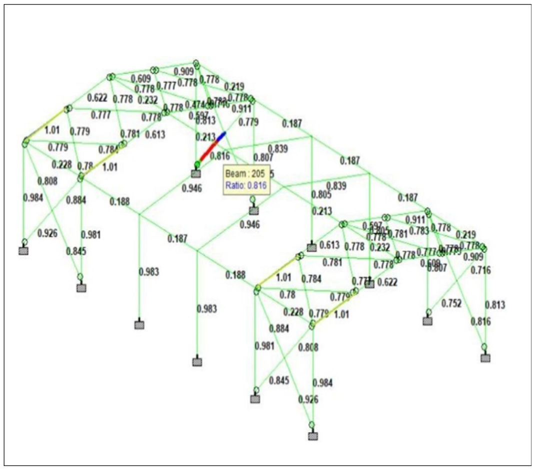

Fig.15. Unity Ratio of Industrial Warehouse

STEEL WEIGHT:-

As per Staad- Pro Modeling Steel weight of conventional Structure:-

STEEL TAKE-OFF

PROFILE		LENGTH(METE)	WEIGHT(KN)
Tapered MembNo:	1	72.00	40.266
Tapered MembNo:	6	30.59	13.984
Tapered MembNo:	68	30.59	13.396
ST PIP889M		90.00	7.398
ST PIP424M		181.72	5.179
Tapered MembNo:	253	30.59	12.809
		TOTAL =	93.031

Fig.16. Structural Weight of Industrial Warehouse using PEB section

7 ANALYSIS AND DESIGN OF INDUSTRIAL WAREHOUSE USINGCOLD FORMED STEEL SECTIONS USING STAAD-PRO.

7.1 STAAD MODELING FOR COLD FORMED STEEL STRUCTURE: -

As per mentioned building geometry and Specification the Staad-Pro Model is prepared using Cold Steel Sections as below and analyzed.

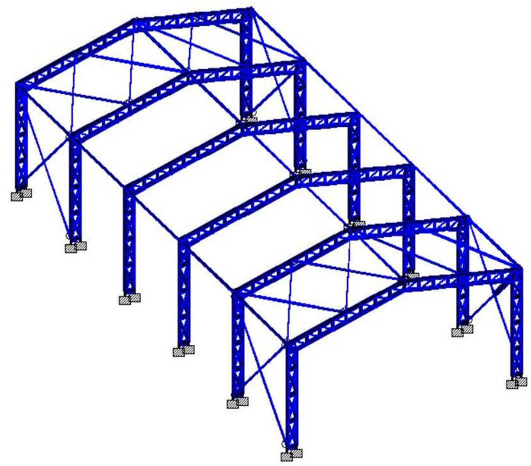

Fig.17. 3d view of Staad-Pro for Industrial Warehouse

7.2 STAAD-PRO ANALYSIS OF STRUCTURE: -

After completing the modelling analysis carried out for the industrial

warehouse and the displacement, beam stress shown by the warehouse is shown below in figures.

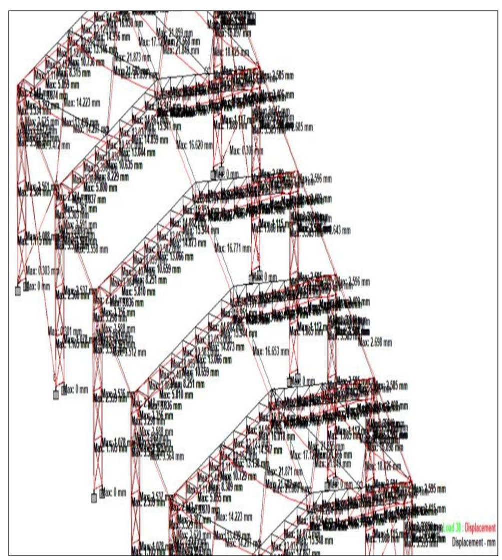

Fig.18. Displacement of Industrial Warehouse

7.3 STAAD-PRO DESIGN FOR COLD FORMED STRUCTURE

Design the structure as per IS 800:2007, By considering the Yield Strength of member is345Mpa.

DEFLECTION CHECK:-

As per IS801, Allowed Horizontal Deflection, Height/150 = 6000/150 = 40mm Allowed vertical Deflection, Span/300 = 15000/180 = 83.33mm

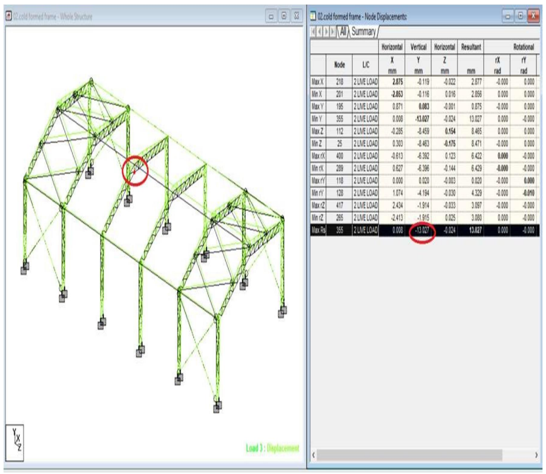

Fig.19. Horizontal Deflection of Industrial Warehouse (Wind Load) Actual Horizontal Deflection is 6.523 mm < 40mm Hence OK

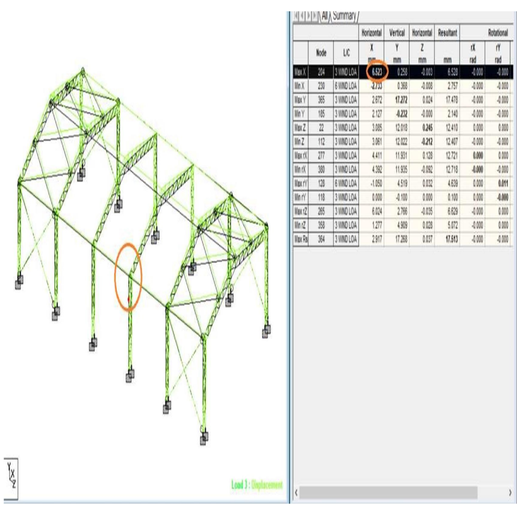

Fig.19. Vertical Deflection of Industrial Warehouse (Live Load) Actual Vertical Deflection is 13.027mm < 83.33mm Hence OK

UNITY CHECK:-

The ratio of all members is less than 1,Hence OK

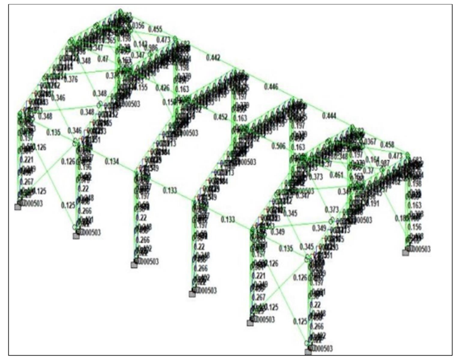

Fig.20. Unity Ratio of Industrial Warehouse

STEEL WEIGHT:-

As per Staad- Pro Modeling Steel weight of conventional Structure:-

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STEEL TAKE-OFF
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  PROFILE                LENGTH(METE)     WEIGHT(KN  )

535. 191 TO 261 263 264 266 267 269 270 272 273 275 276 278 279 281 282 284 285 -
536. 287 288 290 291 293 294 296 TO 370 374 375 378 383 385 TO 435 438 TO 440 -
537. 444 TO 450 456 TO 484 486 488 490 491 493 494 498 TO 501 503 504 506 TO 512 -
538. 514 515 517 TO 520 522 523 525 TO 533 535 536 538 TO 540 543 TO 546 548 549 -
539. 551 TO 574 576 577 579 580 582 TO 584 587 TO 590 592 593 595 TO 601 603 604 -
540. 606 TO 609 611 612 614 TO 622 624 625 627 TO 629 632 TO 635 637 638 -
541. 640 TO 663 665 666 668 669 672 676 TO 679 681 682 684 TO 690 692 693 695 -
542. 696 TO 698 700 701 703 TO 711 713 714 716 TO 718 721 TO 724 726 727 -
543. 729 TO 747 749 TO 751 753 755 758 TO 760 763 TO 766 768 769 771 TO 777 779 -
544. 780 782 TO 785 787 788 790 TO 797 799 TO 801 803 804 806 808 TO 811 813 814 -
545. 816 TO 834 836 838 840 842 845 TO 847 850 TO 853 855 856 858 TO 864 866 867 -
546. 869 TO 872 874 875 877 TO 885 887 888 890 TO 892 895 TO 898 900 901 -
547. 903 TO 1040
ST  250CS80X5                332.68           54.031
ST  120CS60X3.15              90.00            5.588
ST  100CS40X2                170.37            5.108
ST  250CS50X4                 84.06            9.564
ST  50CS50X2                  94.41            2.395
ST  120CS50X3.15             162.08            9.279
                                        ----------------
                             TOTAL =          85.964
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Fig.21 Structural Weight of Industrial Warehouse using cold formed steel section

8 RESULTS

For this study, Warehouse with Conventional Steel Section, PEB steel Section and Cold formed steel Sections are analysed and design To Study of Steel consumption in various sections also the Modelling of building for structural analysis and Sectional design of the members with hot rolled steel section, Pre-engineering Sections and Cold formed sections.

8.1 Horizontal Deflection (Wind Load):-
As per analysis done, The horizontal deflection of Warehouse by using Hot rolled steel Section (Conventional steel sections), Cold formed steel and PEB steel Section.

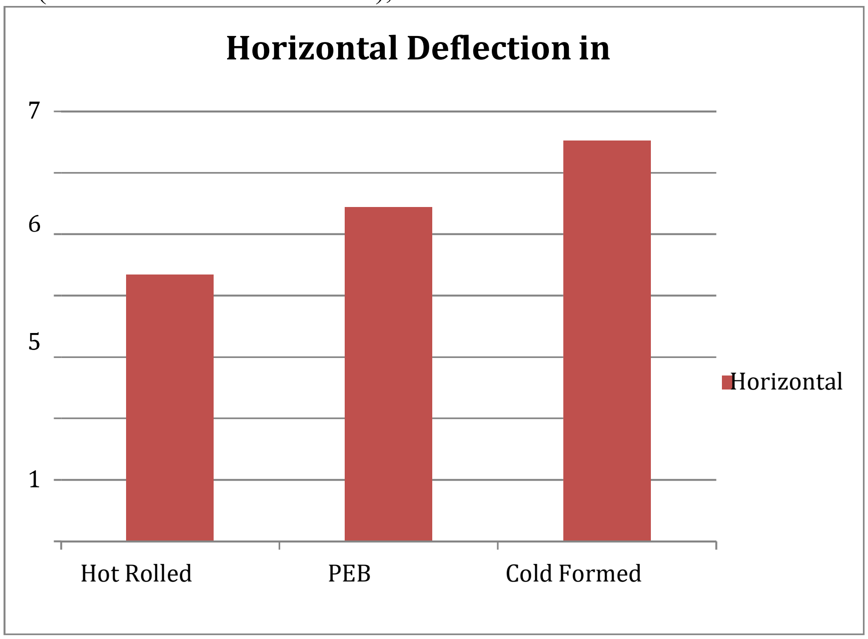

Chart 1. – Horizontal Deflection (Wind Load)

Actual Horizontal Deflection of Industrial Warehouse using Conventional Steel section is 4.346 mm, by using PEB sections is 5.440mm and Cold formed steel section is 6.523mm. All the deflection are within the Serviceability Condition (less than 20mm).

8.2 Vertical Deflection (Live Load):-
As per analysis done, The Vertical deflection of Warehouse are calculated.

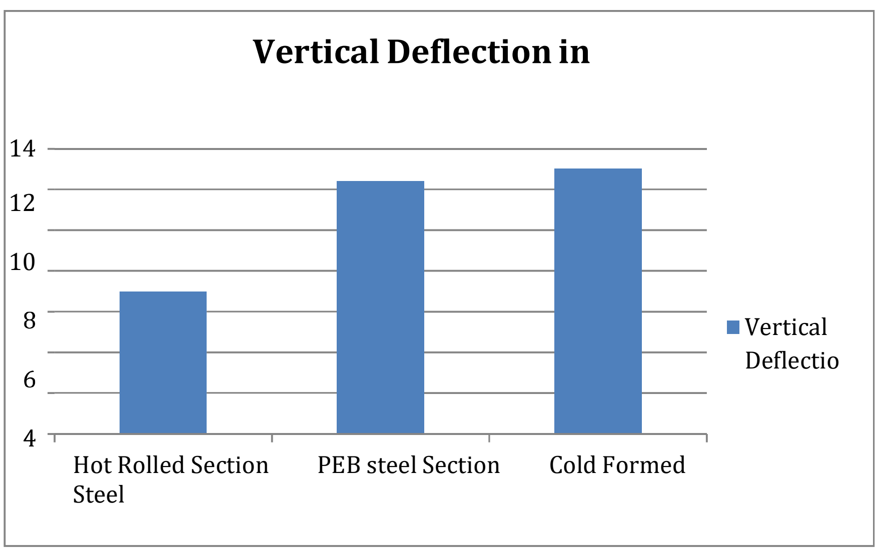

Chart 2. – Vertical Deflection in mm (Live Load)

Actual Vertical Deflection of Industrial Warehouse using Conventional Steel section is 6.966

mm , by using PEB sections is 12.391mm and for Cold formed steel section is 13.027mm , the vertical deflection are satisfied the serviceability criteria (vertical deflectionis less than 50mm).

8.3 Structural Weight :-

As per analysis and Design done,

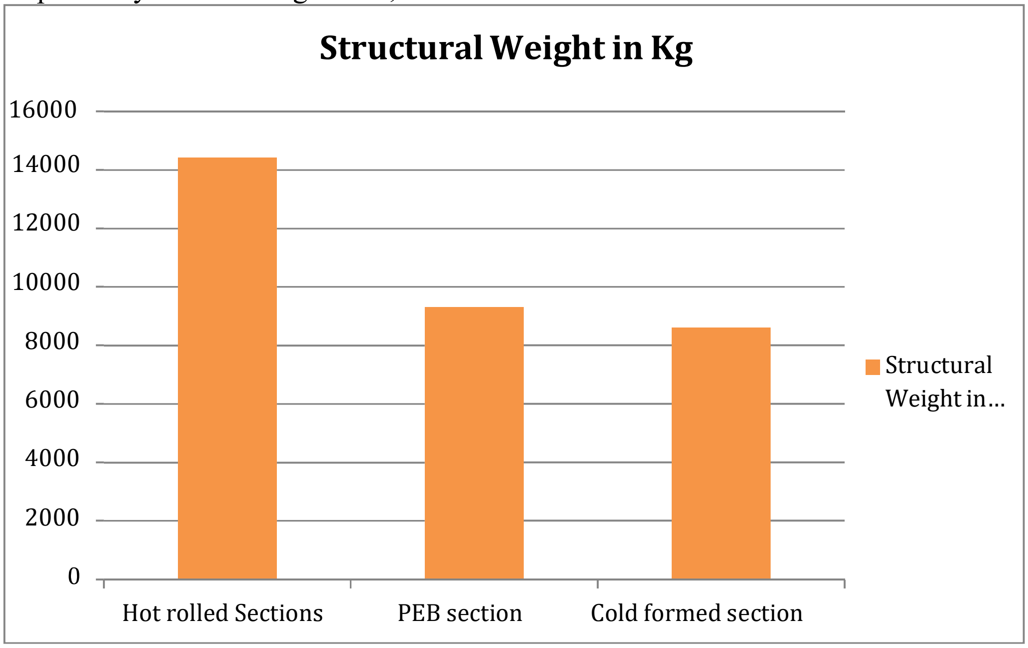

Chart 3. – Structural Weight in Kg

Structural Weight of Industrial Warehouse using Conventional Steel section is 14,412.00 Kg , by using PEB sections is 9,303.00 Kg and by using cold formed steel section is 8596.40Kg.

9 CONCLUSION

From the results following conclusions can be made as follows.

- Providing cold formed steel section for warehouse is reduced the steel consumption compared to Hot rolled section and PEB section.
- The PEB Steel consumption is 55% less than Conventional Steel section and Cold formed steel Consumption is 10% less than PEB steel Section.
- The horizontal deflection (Wind Load) for Hot rolled sections is reduced 25% compared to PEB section and 40% compared to Cold formed section.
- The Vertical deflection (Live Load) for Hot rolled sections is reduced 43% compared to PEB section and 46% compared to Cold formed section.

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