Analysis and Design of Industrialized Building Using Cold Formed Steel by Sap2000

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Abstract— Increasing world population and natural resource limitations has led to a growing demand for more efficient structural systems to achieve a sustainable economy and society. Cold-formed steel CFS) Structural systems are increasingly adopted as primary or secondary structural members in modern building construction because of their light weight, speed of construction, recyclability, and sustainability. The pre-engineered steel building system construction has great advantages to the single storey buildings, practical and efficient alternative to conventional buildings, the System representing one central model within multiple disciplines. Pre-engineered building creates and maintains in real time multidimensional, data rich views through a project support is currently being implemented by packages for design and engineering. In this research work we will design Industry using analysis tool SAP 2000 and use Novel cold formed steel structure and compare it with general steel available in Indian market. Here we will compare both in terms of strength and weight of structure with bolted and welded connections.

Keywords: Cold Formed Steel, Analysis, SAP2000, Industrial Building, Cost Analysis, Forces

I. INTRODUCTION

A. *Background of the Study*

A large steel structures being built are only single storey buildings for industrial purpose. Secondary structural members span the distance between the primary building frames of metal building systems. They play a complex role that extends beyond supporting roof and wall covering and carrying exterior loads to main frames. Secondary structural, as these members are sometimes called, may serve as flange bracing for primary framing and may function as a part of the building's lateral load–resisting system. Roof secondary members, known as purloins, often form an essential part of horizontal roof diaphragms; wall secondary members, known as girts, are frequently found in wall bracing assemblies. The majority of steel structures being built are only low-rise buildings, which are generally of one storey only. Industrial buildings, a sub-set of low-rise buildings are normally used for steel plants, automobile industries, light, utility and process industries, thermal power stations, warehouses, assembly plants, storage, garages, small scale industries, etc. These buildings require large column free areas. Hence interior columns, walls and partitions are often eliminated or kept to a minimum.

Most of these buildings may require adequate headroom for use of an overhead traveling crane. A third type of secondary framing, known by the names of eave strut, eave purling, or eave girt, acts as part purloin and part girt—its top flange supports roof panels, its web, wall siding. Grits, purloins, and eave struts exhibit similar structural.

This investigation is focused on the utilization of cold formed steel structures over general hot rolled steel structures to prepare base for utilizing an economical, stable and light weight material for its fast assembling and transportation. For analysis and design process we are using analysis tool SAP2000.

B. *Cold Formed Steel Structures*

Cold formed steel (CFS) sections are manufactured from steel sheets, strips or plates at room temperature. The thickness of the steel sheets, strips or plates used in cold formed steel sections is mostly in a range from 0.4mm to 6.4mm, and in exceptional cases, a steel plate with a thickness of up to 25mm can be cold formed into a section (Yu, 2000).

It Is the common term for products made by rolling or pressing steel into semi- finished or finished goods at relatively low temperatures (cold working). Cold- formed steel goods are created by the working of steel billet, bar, or sheet using stamping, rolling (including roll forming), or presses to deform it into a usable product.

The use of cold-formed steel construction materials has become more and more popular since its initial introduction of codified standards in 1946. In the construction industry both structural and non-structural elements are created from thin gauges of sheet steel. These building materials encompass columns, beams, joists, studs, floor decking, built-up sections and other components. Cold-formed steel construction materials differ from other steel construction materials known as hot-rolled steel (see structural steel). The manufacturing of cold-formed steel products occurs at room temperature using rolling or pressing. The strength of elements used for design is usually governed by buckling. The construction practices are more similar to timber framing using screws to assemble stud frames.

C. *Advantages of Cold Formed Steel Structures*

– Cold forming has the effect of increasing the yield strength of steel, the increase being the consequence of cold working well into the strain-hardening range.
– These increases are predominant in zones where the metal is bent by folding. The effect of cold working is thus to enhance the mean yield stress by 15% - 30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15%.
– Cross sectional shapes are formed to close tolerances and these can be consistently repeated for as long as required.
– Cold rolling can be employed to produce almost any desired shape to any desired length.
– Pre-galvanized or pre-coated metals can be formed, so that high resistance to corrosion, besides an attractive surface finish, can be achieved.
– They are usually light making it easy to transport and erect.

- High strength to weight ratio is achieved in cold-rolled products.

Fig. 1: Cold formed steel structure

D. Wind Analysis

Most wind damage to buildings occurs during strong winds. The wind loads specified here are applied to the design of buildings to prevent failure due to strong wind. The strong winds that occur in this country are mainly those that accompany a tropical or extra tropical cyclone, and down-bursts or tornados. The former are large-scale phenomena that are spread over about 1000km in a horizontal plane, and their nature is comparatively well known. Down-bursts are gusts due to descending air flows caused by severe rainfall in developed cumulonimbus. Since the scale of these phenomena are very small, few are picked up by the meteorological observation network. It is known that tornados are small-scale phenomena several hundred meters wide at most having a rotational wind with a rapid atmospheric pressure descent. The characteristics of the strong wind and pressure fluctuation caused by tornados are not known. The number of occurrences of down-bursts and tornados is relatively large, but their probability of attacking a particular site is very small compared with that of the tropical or extra tropical cyclones. However, the winds caused by down-bursts and tornados are very strong, so they often fatally damage buildings. These recommendations focus on strong winds caused by tropical or extra tropical cyclones. However, the minimum wind speed takes into account the influence of tornadoes and down-bursts.

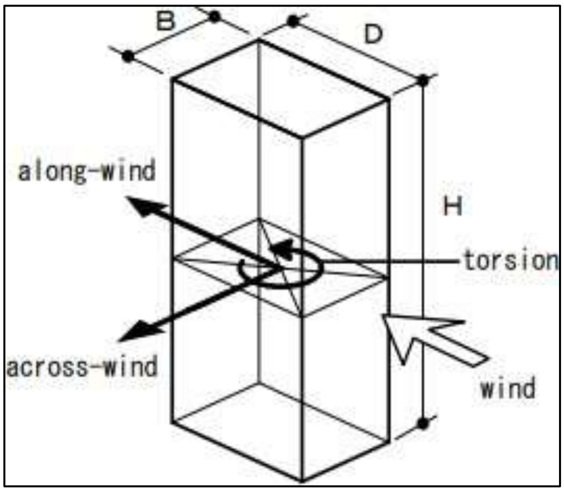


Fig. 2: wind load effect on components

E. SAP-2000

SAP2000 speaks to the most modern and easy to understand arrival of the SAP arrangement of PC programs. At the point when at first discharged in 1996, SAP2000 was the main adaptation of SAP to be totally coordinated inside Microsoft Windows. It includes an intense graphical UI that is unmatched as far as usability and profitability. Creation and adjustment of the model, execution of the analysis, and checking and advancement of the outline, and generation of the yield are altogether refined utilizing this single interface. A solitary auxiliary model can be utilized for a wide range of sorts of analysis and plan.

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally requires the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large system into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

II. METHODOLOGY

A. General

In this research work our motive is to justify the variation in strength and cost of both the cases of industrial building for same loading and site conditions to carry out the best of them.

In this study, I am focusing the analysis using finite element method using analysis tool SAP 2000, which is capable of applying all conditions and methods with respect to preferred I.S. code.

B. Methodology

1) *Step-1 first step of our study is to select building geometry*

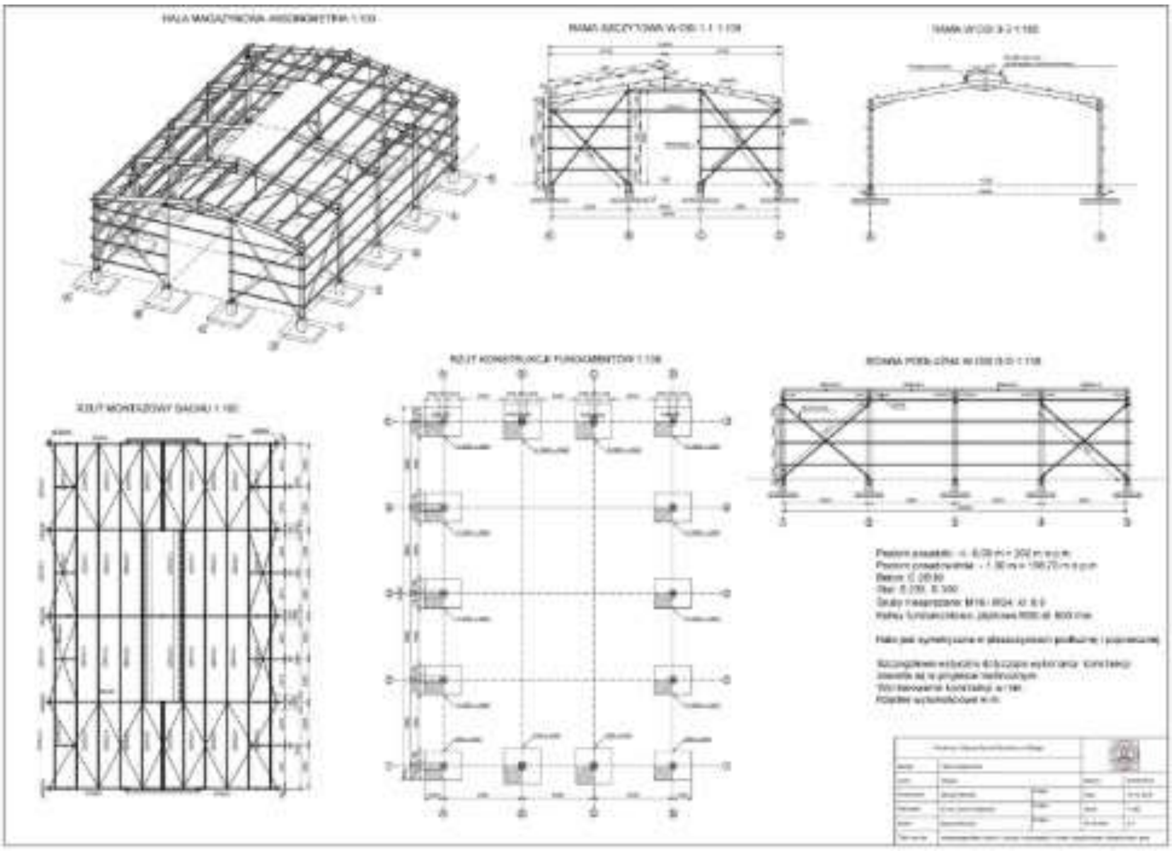
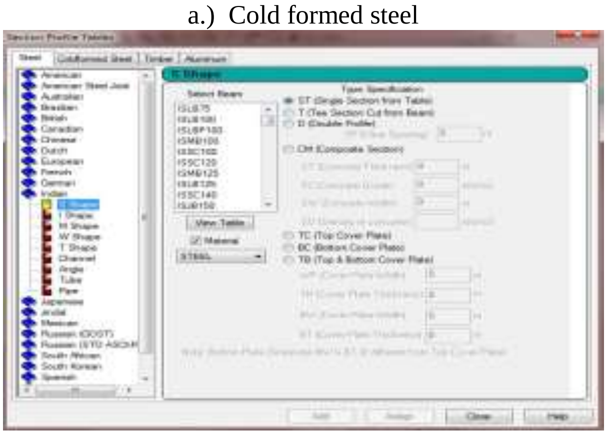


Fig 3 Plan of ware house

2) Step-2 Selection of different materials (CFS & STEEL) can be use.

a.) Cold formed steel



b.) General steel section

Fig. 4: Sectional properties as per Indian steel table

Hot rolling is a plant procedure which includes rolling the steel at a high temperature (commonly at a temperature over 1700° F), which is over the steel's recrystallization temperature. At the point when steel is over the recrystallization temperature, it very well may be molded and shaped effectively, and the steel can be made in a lot bigger sizes. Hot moved steel is commonly less expensive than virus moved steel because of the way that usually made with no deferrals all the while, and along these lines the warming of the steel isn't required (all things considered with virus rolled). At the point when the steel chills it will contract marginally accordingly giving less control on the size and state of the completed item when contrasted with virus rolled.

Cold moved steel is basically hot moved steel that has had further handling. The steel is handled further in chilly decrease plants, where the material is cooled (at room temperature) trailed by strengthening as well as tempers rolling. This procedure will create steel with nearer dimensional resiliences and a more extensive scope of surface completions. The term Cold Rolled is erroneously utilized on all items, when really the item name alludes to the moving of level moved sheet and loop items.

3) Step-3 Selection of wind zone (39m/s) as per IS- 875 (part-III):1987, Appendix – A for Bhopal region.

As a structural designer one ought to consider exceptionally precisely all heaps influencing structures. One of the essential burdens following up on structures is the breeze stacks, whose assurance is critical to choose the level of security and economy of the structures. In past structural specialists don't typically think about the heaps of twists, yet amid the ongoing years since the pattern to manufacture higher and lighter structures the breeze loads turned into a critical factor influencing the basic plan. In Oman the typical practice is to receive structure proposals of remote codes of training, which can be very insignificant, because of contrasts in climatic and geographic conditions. The breeze powers just as the breeze weight following up on the rooftops, dividers and claddings depend on the breeze speed Vs. This essential breeze speed will have an arrival time of 50 years as most structures are intended for a real existence time of 50 years.

IS : 875 (Part 3) - 1987			
City/Town	Basic Wind Speed (m/s)	City/Town	Basic Wind Speed (m/s)
Agra	47	Jhansi	47
Ahmadabad	39	Jodhpur	47
Ajmer	47	Kanpur	47
Almora	47	Kohima	44
Amritsar	47	Kurnool	39
Asansol	47	Lakshadweep	39
Aurangabad	39	Lucknow	47
Bahraich	47	Ludhiana	47
Bangalore	33	Madras	50
Barauni	47	Madurai	39
Bareilly	47	Mandi	39
Bhatinda	47	Mangalore	39
Bhilai	39	Moradabad	47
Bhopal	39	Mysore	33
Bhubaneshwar	50	Nagpur	44
Bhuj	50	Nainital	47
Bikaner	47	Nasik	39
Bokaro	47	Nellore	50
Bombay	44	Panjim	39
Calcutta	50	Patiala	47
Calicut	39	Patna	47
Chandigarh	47	Pondicherry	50

Table 1: Wind speed as per Indian standards

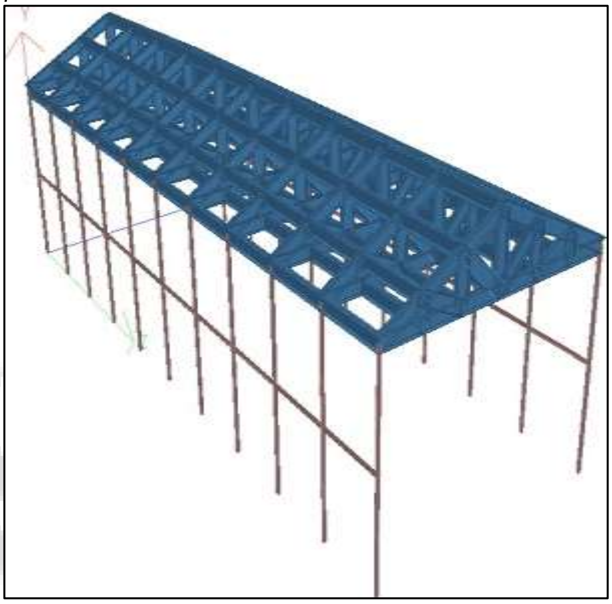
IS : 875 (Part 3) - 1987			
City/Town	Basic Wind Speed (m/s)	City/Town	Basic Wind Speed (m/s)
Coimbatore	39	Port Blair	44
Cuttack	50	Pune	39
Darbhanga	55	Raipur	39
Darjeeling	47	Rajkot	39
Dehra Dun	47	Ranchi	39
Delhi	47	Roorkee	39
Durgapur	47	R ourkela	39
Gangtok	47	Simla	39
Gauhati	50	Srinagar	39
Gaya	39	Surat	44
Gorakhpur	47	Tiruchchirrappalli	47
Hyderabad	44	Trivandrum	39
Imphal	47	Udaipur	47

4) Step-4 Formation of load combination (8 load combinations in x & z-direction)

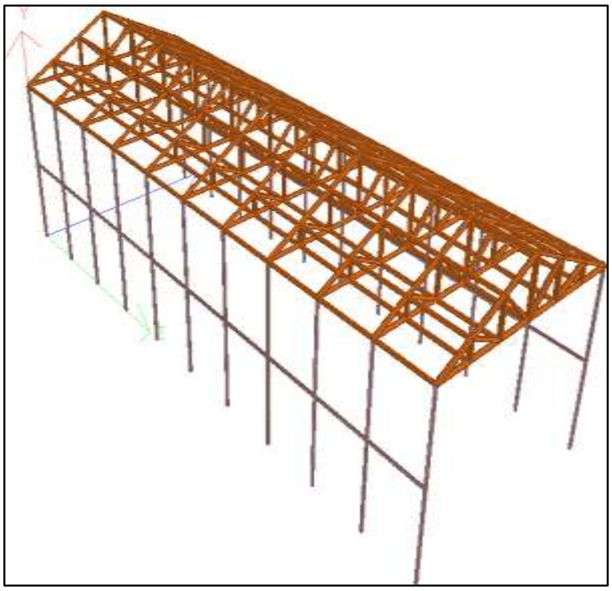
S.No.	LOAD CASE NO.	LOAD CASES
1	1	D.L
2	2	L.L
3	3	W.L
4	4	(D.L+L.L)
5	5	(D.L+W.L)
6	6	1.5(D.L+L.L)
7	7	1.5(D.L+W.L)
8	8	1.2(D.L+L.L+W.L)

Table 2: Load combinations as per I.S. 875-III

5) Step-5 Modeling of building frames using SAP2000 software.



General Steel structure



C.F.S. Structure

Fig. 5: Modeling of ware house frame using SAP2000

6) Step-6 Analysis of truss considering same loading

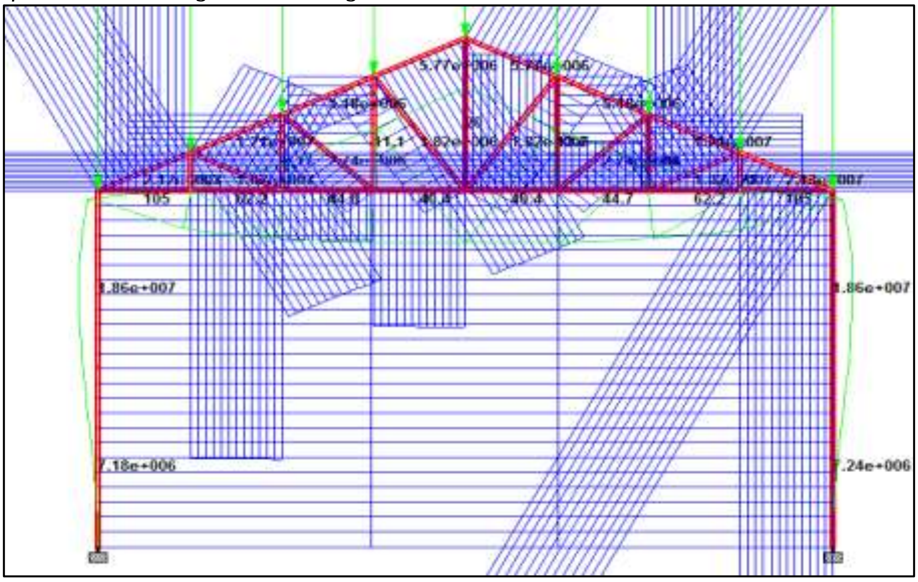


Fig 6: Stress Distribution

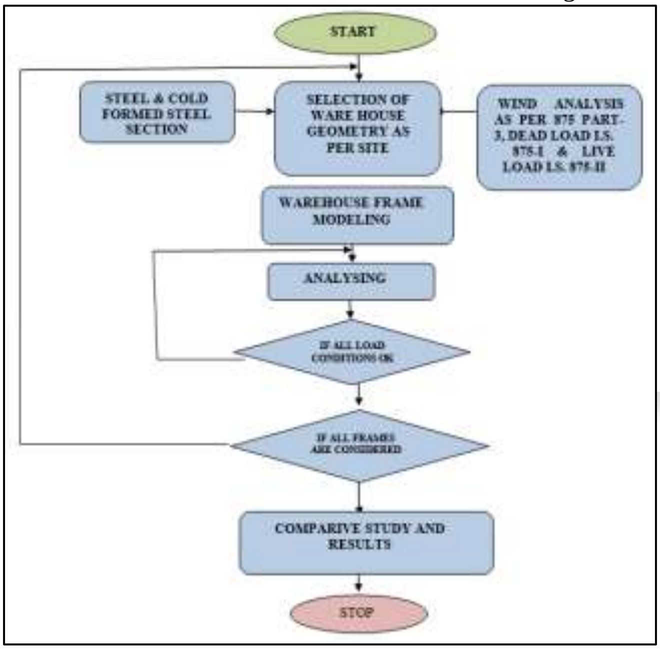


Fig. 7: Flow chart of the study

C. Geometrical data & Load Calculations

S.No.	Geometrical details	
1	Type of roof truss	Doublehowe
2	Section Size	Indian Standard Sections
3	Support Condition	Fixed Support
4	Length	36 meter
5	Bays in Z direction	10 spans
6	Width	12 meter
7	Bays in X direction	6 spans
8	Column height	7 meter

Table 3: Geometrical properties of the structure

S.No.	Material properties	Values
1	Density of STEEL	7480 kG/ m3
2	Density of Cold Formed Steel	8000 kG/ m3
3	Young's modulus of STEEL	2.17 x 104 N/mm2
4	Poisson ratio, μ (Steel)	0.17
5	Poisson ratio, μ (C.F.S)	0.3
6	Tensile strength of Steel	415 N/mm2
7	Elastic Modulus of C.F.S.	3447.3 MPa
8	Tensile Strength of C.F.S.	550 N/mm2

Table 4: Material properties

D. Components Load calculations:

Following loading is adopted for analysis: -

1) Dead Loads:

Self wt. of truss
Floor Finish load = 1 kN/m2
Roof Load = 1.5 kN at joints

2) Live Loads:

a. Live Load as per 875 part-2 on typical Sections =0.75 kN/m2

3) Wind load:

Calculation of wind load as per IS-code 875 (part-III):1987.Calculation of wind pressure on the windward face of building. Effective area is calculated on the windward face of building frame to determine the wind force act on junction of structures

E. Panel Load

Concentrated load applied at the interior panel point of the truss in kN is called Panel Load (P).

It is calculated by multiplying the roof load (load per unit area) by the horizontal area of the roof contributing load to interior panel point of the truss.

It is separately calculated for dead, live and wind loads.

The truss is analyzed for unit gravity loads, unit wind force on left side of truss and unit wind force on the right side of the truss.

Principle of superposition is then used to calculate member forces due to actual loads.

Suppose that the deflection at any point of the truss, called point A, due to unit load acting at some other point B of the truss is Δ.

According to the principle of superposition, for structures within elastic range, the deflection of the structure due to combined action of two sets of loadings is equal to the sum of deflections due to individual loads acting separately.

If another unit load is applied at A, deflection at point B will become Δ +Δ or 2Δ.

Similarly for P number of unit point loads, the deflection will be P x Δ. The same principle is also valid for member forces.

Panel load multiplied with the unit load member forces gives the magnitudes of member forces for the actual loads.

This explains the use of calculating the panel loads for dead, live and wind loads.

1) Load at interior

Panel point = P = load intensity over horizontal plan area (w)

x area supported by the panel point (p x s) = w x p x s

Load at exterior panel point = P/ 2

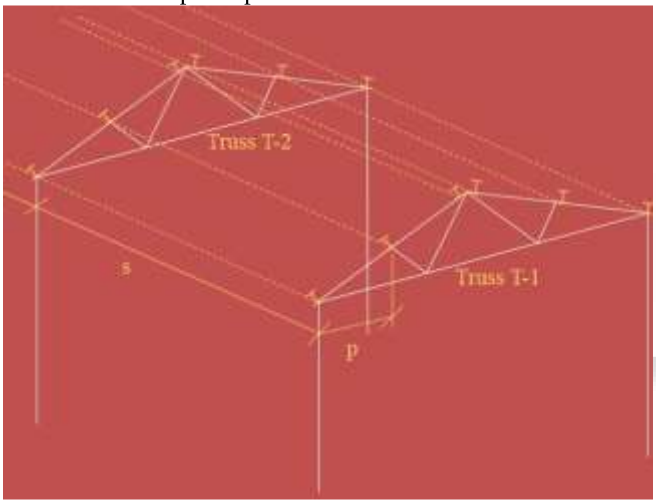


Fig. 8: Inclined panels

For panels:

UDL (ww) N/m2 is converted Into Panel concentrated load

Pww= ww x s x p/cosθ

Angle of top chord = 30 0

Dead load of roofing = 17 kg/m2

Insulation boards = 5 kg/m2

Self-weight of purlins = 10 kg/m2

Self-weight of bracing elements = 3 kg/m2

Miscellaneous = 5 kg/m2

Panel Length, p = 2.5 m

Span length of truss, L = 20 m Spacing of trusses, center-to-center, S = 5.5 m

Total dead load except truss self-weight = sum of given dead loads = 40 kg/m2

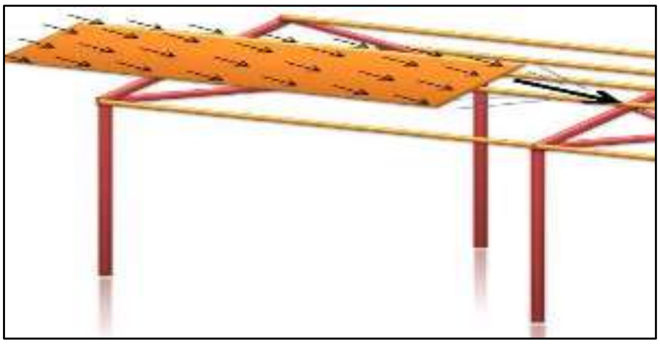


Fig 9: Panels load

a. Assembling of inclined members (Site work of Nahar Industry Mandideep)

b. Assigning joint connections(Site work of Nahar Industry Mandideep)

Fig. 10: Site working of ware house

III. RESULTS & DISCUSSION

A. F.E.M. Analysis

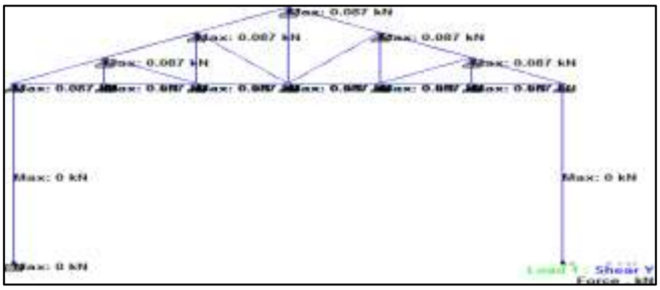


Fig. 11: F.E.M. Analysis

B. Shear Force at different Nodes

Shear Force kN		
Node	C.F.S.	Steel
38	207.44	301.254
32	240.65	317.507
29	273.86	312.45
33	281.92	309.85

37	277.45	307.25
35	273.34	304.65
39	269.23	302.05

Table 5: Shear Force at different nodes

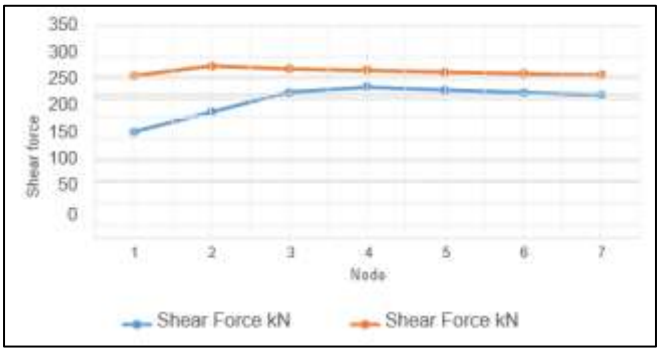


Fig. 12: Shear force at different nodes kN

C. *Axial Force*

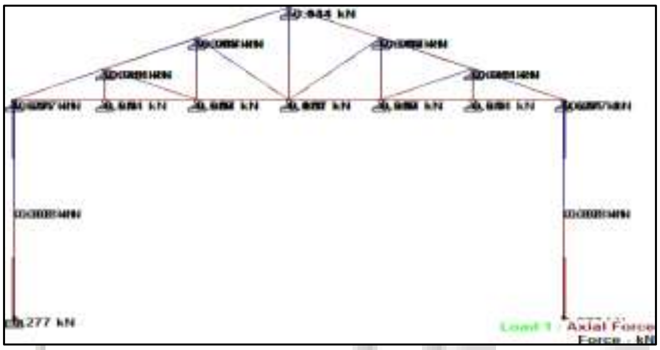


Fig 13 Axial Force

Axial Force kN		
Node	Steel	C.F.S.
54	3400.05	3005.766
58	2809.87	3189.08
53	3000.23	3372.394
55	4688.627	4583.729
57	3298.09	3739.022
58	3898.98	3922.336
52	4499.87	4105.65

Table 6: Axial Force at Different Nodes

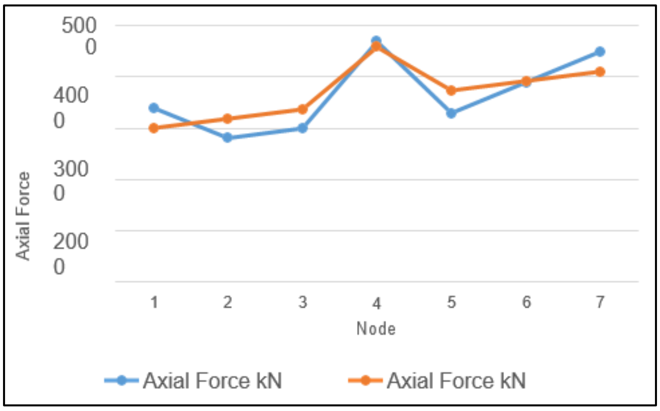


Fig. 14: Axial force at different nodes

D. *Deflection at different joints*

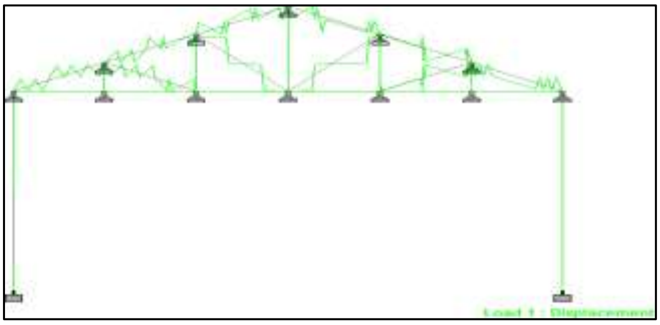


Fig. 15: Displacement

Deflection in (mm)		
Beam	C.F.S.	Steel
112	2.935	5.204
113	2.87	5.02
114	2.805	4.836
115	2.74	4.652
116	2.675	4.468
117	2.61	4.284
118	2.545	4.1
119	2.48	3.916
120	2.415	3.732

Table 7: deflection at different joints

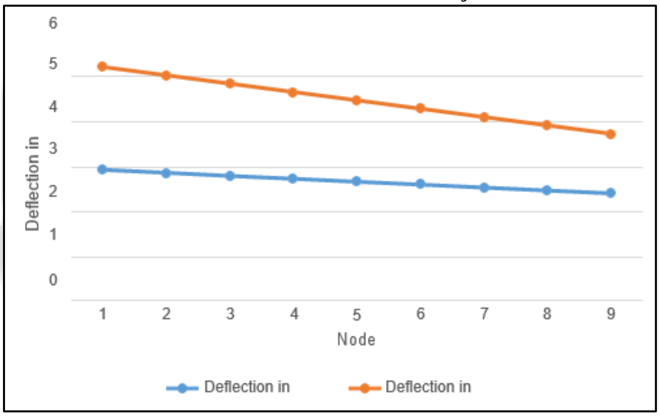


Fig. 16: Deflection at different nodes in mm

E. *Support reaction:*

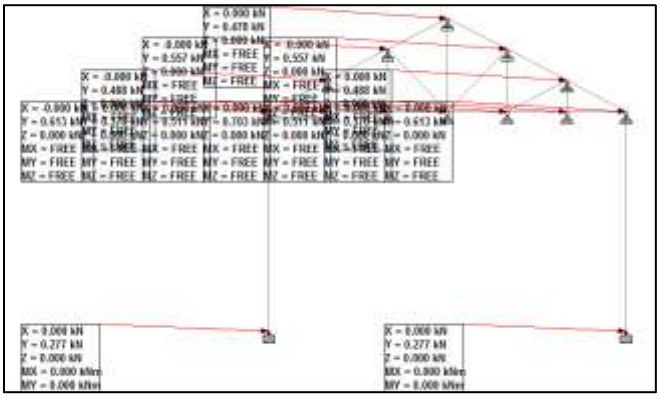


Fig. 17: Support reaction at nodes

support reaction y direction	
Cold formed steel	Steel
1538.305	1538.252

Table 8: Support reaction

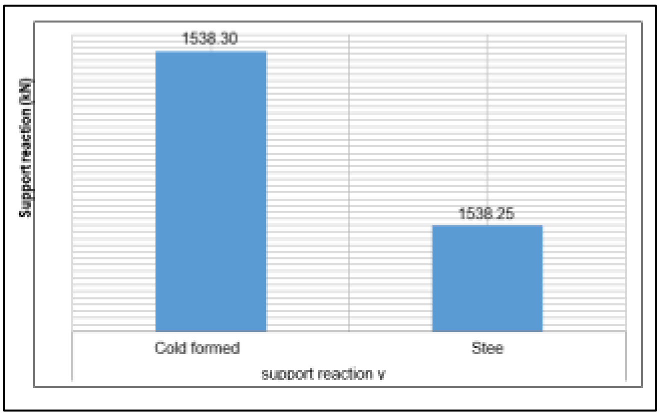


Fig. 18: Support reaction

F. Maximum forces

1) Maximum shear force

Maximum shear force KN	
Cold formed steel	Steel
281.92	317.507

Table 4.5: Maximum Shear Force

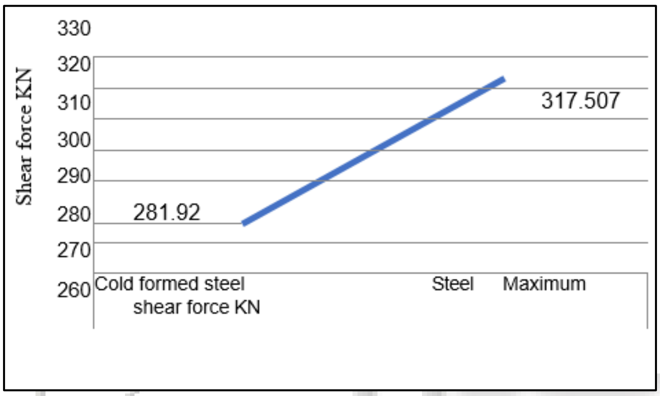


Fig. 19: Max. Shear Force kN

2) Maximum Axial Force:

Maximum Axial force KN	
Cold formed steel	Steel
4583.729	4688.627

Table 9: Maximum Axial Force kN

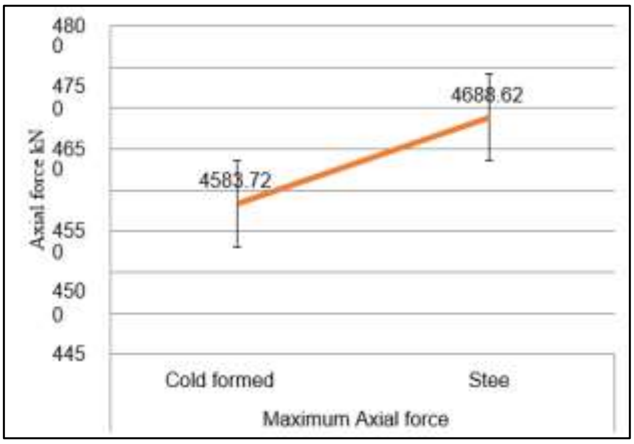


Fig. 20: Max. Axial force kN

3) Maximum Deflection mm

Maximum deflection mm	
Cold formed steel	Steel
2.935	5.204

Table 10: Deflection mm

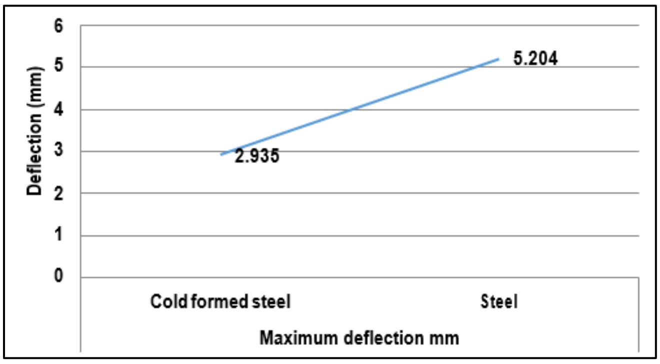


Fig. 21: Max. Deflection mm

4) Optimization of Sections

SECTIONS	General STEEL	CFS
Angle section	ISA 150 ×150×8 DOUBLE ANGLE SECTION	80LU80×4
Channel Section	ISMC 250 Area – 39cm sq	120CU60×6 Area – 12.90cm sq
PIPES / HAT	65MM(NB) M D - 76.1mm t - 3.6mm	50HU50×3.15 D – 50mm t – 3.15mm

Table 11: Cost Optimization sections:

5) Cost Analysis:

Cost Analysis in Rupees				
Type	Qty. Kg	Rate	Total	Remark
Steel Section	10380	136	1411680	14% Cost reduction is observed in C.F.S. structure
C.F.S. Sec	8700.43	140	1218060	

Table 12: Cost Analysis

IV. CONCLUSIONS

In present study comparative study is done on a 3-dimensional ware house for same loadings with different section to find out the best material either cold formed or general steel section which will be stable, good in stiffness, cost effective, economical and easily available.

1) Shear force: As shear force is generated due to unbalancing at the joints connecting different members, here in above chapter it is observed that C.F.S structure can minimize the forces unbalancing by approximately 22% thus making structure more stable.
2) Axial force: In building with truss structures like (ex: Consider an Mobile Communication Tower structure, ware house, industrial frame). Every truss element of the structure is designed to take only Axial forces (Either Tension or Compression). Axial forces can cause Buckling in long slender members. In our study ist is observed that minor variation of 4-5% is obtained in C.F.S. frame.
3) Support reactions: A support reaction is the reaction force/forces that are attributed to a support for the system. In our study it is observed that distribution of forces to the support and support to the below ground is more effective in C.F.S. frame.

4) Deflection: The deflection distance of a member under a load is directly related to the slope of the deflected shape of the member under that load, and can be calculated by integrating the function that mathematically describes the slope of the member under that load. In results above it is observed that C.F.S. frame structure is resisting deflection comparing to general structure
5) Cost Analysis: As India is a developing nation thus development of new construction with cost effectiveness is important for its proper and budgeted development. Here results shows that using C.F.S. one can minimize the cost by 14% of the total cost.
6) It is determined in this study that cold formed steel is better resisting load, and unbalanced forces. here it is concluded that deflection in C.F.S. sections are relatively less. It can be determine that torsion and support reaction is comparatively less in C.F.S.

V. FUTURE SCOPE:

Following future aspects can be consider are as follows

- C.F.S. analysis of heavy and tall structure can be proceed in future.
- Seismic analysis can be proceed.
- Study of connections can be investigate in future.

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