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Seismic Performance of Cold Formed Steel and Conventional Steel of Industrial Structures Using Splice Connections

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Abstract: ***In this project it is proposed to carry out the design of industrial roof truss of conventional steel as well as the cold formed steel structures using splice connections. Splices are therefore most often used when the structural element is required in longer length and also resistant the seismic force in structural elements. Industrial roof truss is designed manually for both conventional and cold formed steel as per codal provisions. Experimental Investigation is finally done for the Splice Connections with a specimen. The project is all about how the section is deduced and economical while using splice connections. Experimental and theoretical results indicate the significant reduction in member and deflection with incremental increase of ultimate load carrying capacity. Finally a comparative study will be done based on seismic performance, cost and weight of steel member for cold formed section & conventional steel section with and without splice connection.***

Key words: Splice Connection, Howe Type roof truss, Limit state method, ConventionalSteel, Cold Formed Steel

I. INTRODUCTION

Cold formed steel members are widely used in the civil engineering field, particularly in industrial residential, and commercial buildings. Design of industrial roof truss of conventional steel as well as the cold formed steel structures using splice connections. Splices are therefore most often used when the structural element is required in longer length and also resistant the seismic force in structural elements. Industrial roof truss is designed manually for both conventional and cold formed steel as per codal provisions.It is frequently required to connect structural members along their span due to the available length of sections being inadequate and also due to carrying and erection constraints. Such joints are called splices. Splices have to be designed so as to spread all the member forces and at the same time provide enough stiffness and simplicity in erection Splices are generally located away from significant sections. complementary forces arising due to in immovability effects. In all cases, the supplies of the code should be fulfilled. Trusses are mainly used in railway bridges ,roofs of industrial buildings, long length floors , vehicle car shad, and roofs of multi-storey buildings, to resist gravity loads .

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Trusses are also used to architecture purpose in building walls and horizontal planes of industrial buildings to resist lateral loads. The analysis and design of Fink type of roof trusses by working stress method and limit state method. The cold formed steel sections are better moment resistance varies from 36 % to 97% of measured by bolted moment connections feasibility and economically. Furthermore development in cold formed steel channel section back to back connection using medium and large span structures by M F Wonlf (et al) [1]. Previous literature suggested by K.K. Sangle (et al) [2] the bracing system used in steel structures prevented the lateral displacement at roof level, to control the seismic behaviour of structures and control the vibration of the system. The displacement reduces about 43% to 60% of at the roof level bracing system, time period is also reduced up to 65 % .The effective and economical design of bracing system obtained by diagonal B – style bracing system.R. B. Kulkarni (et al) [3] reported that increase the load carrying capacity in cold formed steel sections at the joints with single and multiple number of bolted connections by effect of in filled different grade conventional concrete and Geopolymer concrete.The ultimate load carrying capacity of the bolted connection percentage is increases from 8.95% to 57.25% by infilling conventional concrete or geopolymer concrete at the joints only.The performance of connections any with conventional concrete or geopolymer concrete in filled at joints are nearly same and small variations are observed. The paper presented working stress method is most economical compare with the limit state method. But most flexural strength, minimum shear, minimum local buckling& distortional buckling and maximum load carrying capacity compare with working stress method by A Jayaraman(et al) [4] nowadays most widely used cold formed steel section for all fields. The cold formed steel section used in different size and various shape of the section used in structures. A Jayaraman(etal) [5] reported that comparison and behaviour of cold formed steel channel section and built up section are used similar cross sectional area. Channel section has high bending moment, minimum deflection, load carrying capacity is high and distortional buckling also less & local buckling compare with channel built up section by same cross sectional area.Shah ForamAshokbhai (etal) [6] reported that the weight of industrial shed is 10435 kg reduced by cold formed sections compare with hot rolled sections. The weight of industrial structures with cold formed steel sections is reduced with 32.03% compare with industrial structure with hot rolled sections. So from the above conclusion, Industrial structures with cold formed steel sections are most economical than industrial structures with hot rolled sections.

II EXPERIMENTAL INVESTIGATION

A. Materials:

a. Steel Section: Steel ISMC100 and ISMC75 with modulus of elasticity 200GPa is used and their thermal expansion is about $11.07\times 10^{-6}/^{o}$ C

b. Bolts and nuts: The grade M 4.6 bolts have yield stress about 60% and ultimate material strength of 400N/mm^2 and the same are used as nuts

c. Principal rafter: Principal rafter is a sloping member of a roof trusses and supporting the purlins on which the common rafter rest.

d. Stanchion: The roof truss and column stanchion system is basically an addition of the beam and column resolution, providing an cost-effective means of increasing the useful span.

e. Strut: Strut it is widely used in industrial truss and railway steel bridges. The major reason of strut is to sustain the stiffness of the structure and to get axial forces .it is not designed to get and static .

.f. Purlins: Purlins used in steel construction, the term purlin normally refers to steel roof truss members that distance equivalent to the building eaves, and prop up the roof decking or sheeting. The purlines are in revolve supported by rafters or walls

Loads on the roof truss:

Roof truss are subjected to dead load, live load, wind load and snow loads etc.

a. ***Dead load:*** The theoretical investigation of dead load of the truss is as shown in Figure 1

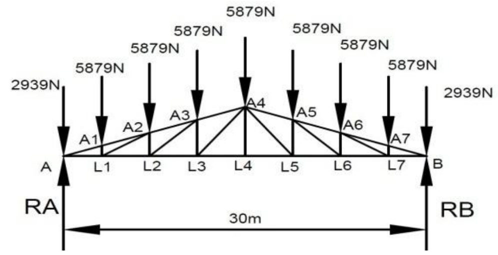

Figure 1. Theoretical investigation of Dead load

b. ***Live load:***

The live load on inclined roofs with swill up to 10 degree is to be occupied as 0.75kN/m^2 of plan area .for roofs with slopes greater than 10degree,an live load 0.75kN/m^2 less than 0.02 kN/m^2 for each amount increase in slope over 10 degree, subject to a minimum of 0.4 kN/m^2 is to be occupied for roof covering. The theoretical investigation of live load of the truss in given in Figure 2

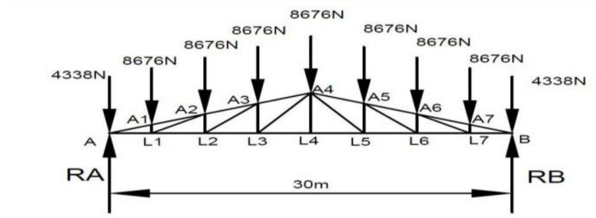

Figure 2. Theoretical investigation of Live load

c. *Wind load:*The theoretical investigation of live load of the truss in shown in Figure 3.

The following equation is used for the calculation of wind load

Wind load (Ww) = ($Cp_e - Cp_i$) area x basic wind pressure

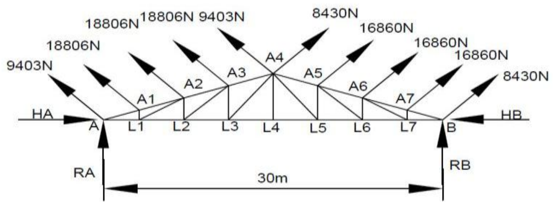

Figure 3. Theoretical investigation of wind load

d. ***Snow load:***
Snow load is the sliding force on a steel roof by the load of accumulate **snow** and ice

e. ***Spacing of roof trusses:***
4 m to 8m for the economical spacing of roof trusses. Using spacing of roof trusses 4m, the span up to 18m used. For length of spans from 18m to 25m the spacing have to not go beyond 6m.

f. ***Splice plate***:
A thick metal plate used to make connections between structural steel members. The arrangement of column splices connection as shown in Figure4.

g. **Design of splice connection**

Based on references cited [7] to [13]

ISHB 250@547N/m

Sectional Area A = 6971mm^2

Depth of section D =250mm,

Thickness of web tw = 8.8mm

Width of flange bf = 250mm, Thickness of flange tf = 9.7mm,

Section modulus Zez = 708.43x10^{3}mm^3 Zpz = 638.7x10^{3}mm^3

Factored axial load = 248+260 =508kN

Factored bending moment = w × l ^{2}/ 8 = 1587.5kN.m

Factored shear force V = w × l /2 = 508×5/2 = 1270kN

Area of web =(250-2 ×9.7) ×8.8 =2029.28mm^2

Design of web splice

Position of load carried by web = 508 × (2029.28/6971) = 147.88kN Using two M20 HSFG bolts in double shear

Slip resistance of M20 bolt in Single shear = 52.6mm Slip resistance of M20 bolt in double shear = 105.2mm

Provide two plates of 120×120×8mm web splice

Design of Flange Splice

Portion of load carried by each flange = (508-147.8) /2 = 180.1kN

Using four M20 HSFG bolts in double shear

Total slip resistance = 4×52.6 = 210.4kN

Total bearing resistance = 4×2.5×0.5×20×9.7×(410/1.25) = 318.160kN

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Total bolt strength = 210.4kN>80.1kN
Hence the connection is safe
Thickness of the flange plate $=180.1 \times 10^3 / [(250/1.1) \times (250-2(22))] = 3.84$mm
Splice plate for flange = 220×250×10mm

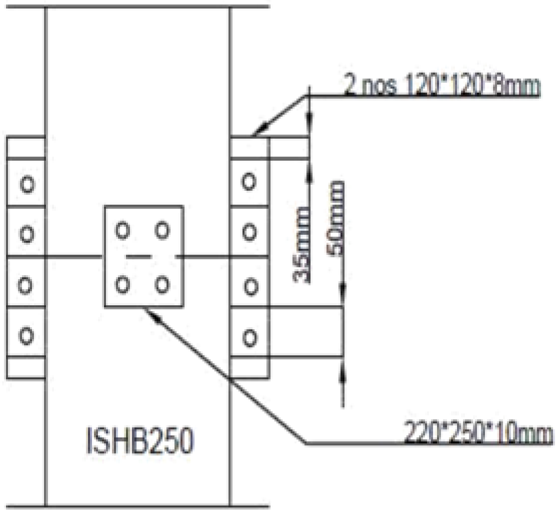

Figure 4.ColumnsSplices Connection

F.BASE SHEAR CALCULATION
Fundamental natural period of vibration

The approximate fundamental natural period of vibration (Ta) in seconds of moment resisting

Framed building: $T_a = 0.085h^{(0.75)} = 0.085(15)^{0.75} = 0.647$s

The building is located on hard soil site Sa/ g = $1.00/T = 1.00/0.647 = 1.54$

The design horizontal acceleration spectrum value: $A_h = Z\, I\, S_a / 2\, R_g$

Zone factor Z =0.16 Importance factorI = 1.0

$$A_h = Z\, I\, S_a / 2\, R_g = 0.16 \times 1.0 \times 1.54 / 2 \times 5 = 0.0246$$
$$A_h = 0.0246$$
Base shear = Ah W = 0.0246×65415.4 = 1569 kN
Base shearVb = 1569 kN

III. EXPERIMENTAL PROCEDURE

In this research it is proposed to carry out the design of industrial roof truss of conventional steel as well as the cold formed steel structures using splice connections. Splices are therefore most often used when the structural element is required in longer length and also resistant the seismic force in structural elements. Industrial roof truss is designed manually for both conventional and cold formed steel as per codal provisions.Consider the rolled steel channels section and cold formed steel section ISMC100& ISMC75. A 1m length of ISMC100 and ISMC75 is taken respectively. For the design of splice connection the design load to be carried by the section and the length of the section is reduced. The corresponding sections are reduced to 0.5m length and their bolted connections are made with splice plates. The testing is carried out in computerized universal testing machine of capacity 400kN. The result is occupied as a load carrying capacity and deflection of the rolled steel section, cold formed steel section and their properties are compared with the sections with and without splice connections of rolled steel and cold formed steel sections.

V. RESULT AND DISCUSSION

Experimental investigation of specimens without and with splice connections and experimental set up are given Figure 5.

Figure 5. Experimental set up for specimens with and without splice connections

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A. *The Experimental investigations ofload carrying capacityrolled and cold formed steel sectionswith and without splice connectionsare obtainable in Table1*

Different Types of Section	Rolled steel section	Rolled Steel using Splice Connection	Cold formed Steel section	Cold formed section with splice connection
ISMC 100 (1m length)	110	140	75	90
ISMC100 (0.5 m length)	80	100	40	65
ISMC75 (1m length)	80	100	45	70
ISMC75 (0.5m length)	94	112	30	55

Table 1.Load carrying capacity of cold formed steel and rolled steel section

a. *Load Carrying Capacity of rolled and cold formed steel sections of ISMC 100 mm, with and without splice connections for 1m length.*

The experimental investigations of the load carrying capacity of rolled steel sections and cold formed steel sections with splice connection ISMC100 mm is 20 % is higher than the without splice connection ISMC100 mm for 1m length. Both the rolled steel sections and cold formed steel sections valus are as given in Figure 6. From that results cold formed steel section both the connections with and without splice connections the load carrying capacity is 55.55 % and 46.67 % of lesser than the conventional steel section.

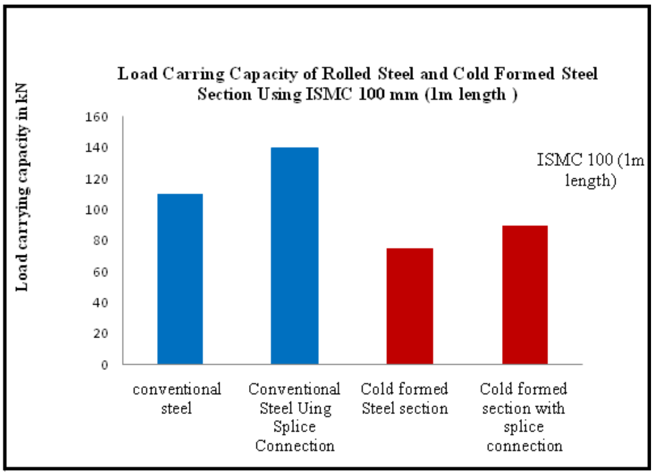

Figure 6. Load carrying capacity of rolled and CFS sections using-ISMC100 mm for 1m

b. *Load convey Capacity of rolled and cold formed steel sections of ISMC 100mm, with and without splice connections for 0.5 m length.*

The Experimental investigations of load carrying capacity of rolled steel section and cold formed steel section ISMC 100 mm for 0.5m length with and without splice connection have been made. The obtained results shows that the load carrying capacity of rolled steel section with splice connections the ISMC100 mm is greater than the without splice connections ISMC100 by 27% for 0.5 m length. The load carrying capacity of cold formed steel sections with splice connection ISMC100 mm is 30 % higher than the without splice connections ISMC100 for 0.5m length. Both the rolled steel section and cold formed steel sections value are as given in Figure 7.From that result cold formed steel sections both the connections with out and with splice connections the load carrying capacity is 53.85 % and 50.00 % of lesser than the conventional steel sections.

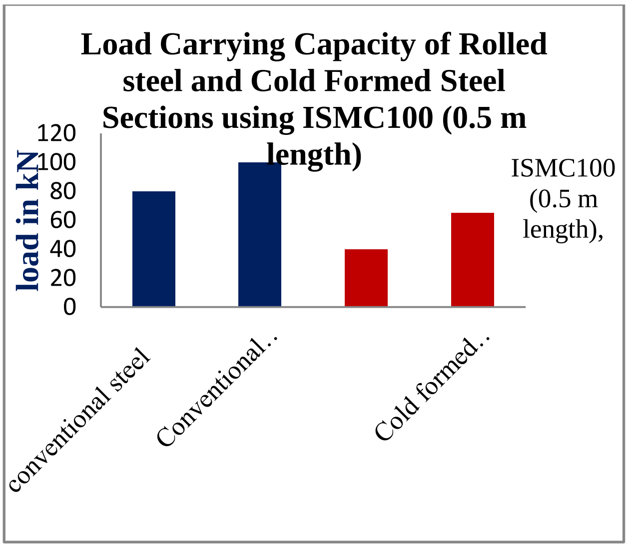

Figure 7. Load carrying of rolled and CFS section using-ISMC100 mm for 0.5m length

C .Load Carrying Capacity of rolled and cold formed steel sections of ISMC 75mm, with and without splice connections for 1m length.

The experimental investigations of load carrying capacity of rolled steel sections and cold formed steel sections ISMC 75mm, with and without splice connections for 1m length .The obtained results shows that the load carrying capacity of rolled steel sections with splice connections the ISMC 75 mm is greater than the without splice connections ISMC 75 by 25% for 1m length. The load carrying capacity of cold formed steel sections with splice connections ISMC 75 mm is55.55 % higher than the without splice connections ISMC 75 mm for 1m length. Both the rolled steel sections and cold formed steel sections results are as shown in Figure 8.From that result cold formed steel sections with and without splice connection the load carrying capacity is42.85.55 % and 77.77% of lesser than the conventional steel sections.

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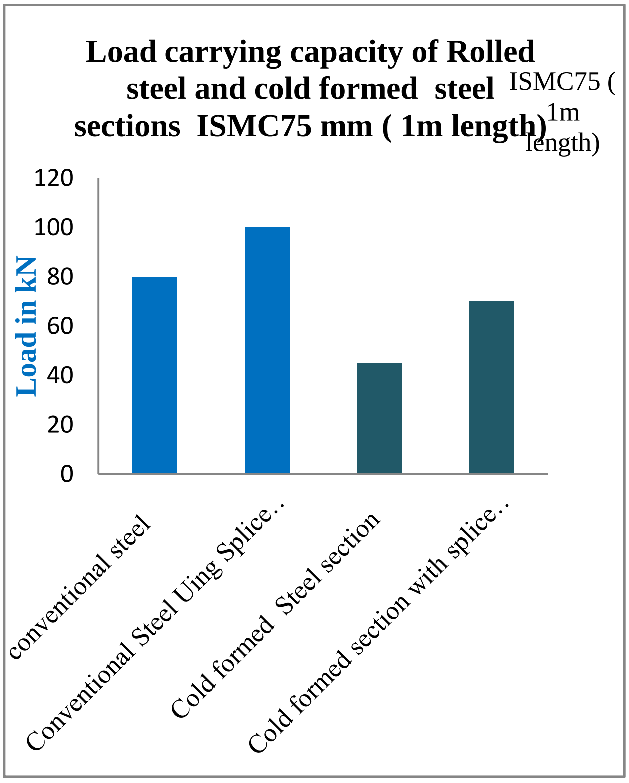

Figure 8. Load carrying capacity of rolled and CFS sections using-ISMC 75 mm for 1m length

D. Load Carrying Capacity of rolled and cold formed steel sections of ISMC 75mm, with and without splice connections for 0.5m length.

The experimental investigation of load carrying capacity of rolled steel sections and cold formed steel sections ISMC 75mm, with and without splice connections for 0.5m length .The obtained results shows that the load carrying capacity of rolled steel sections with splice connections the ISMC 75 is greater than the without splice connections ISMC 75 by 19.14% for 1m length. The load carrying capacity of cold formed steel sections with splice connections ISMC 75 mm is 45.45 % higher than the without splice connections ISMC 75 for 0.5m length. Both the rolled steel sections and cold formed steel sections results are as shown in Figure 9**.** From that result cold formed steel sections both the connections with and without splice connections the load carrying capacity is 68.08 % and 49.10 % of lesser than the conventional steel sections.

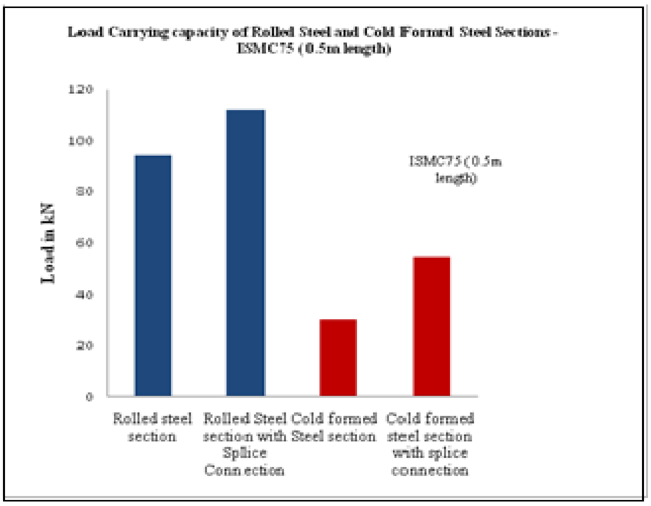

Figure 9.Load carrying capacity of rolled and CFS sections using-ISMC75mmfor 0.5m length

A. Deflection ofrolled steel sections and cold formed steel sections with and without splice connections are presented in table 2.

Table 2.Deflection of cold formed steel and rolled steel section

Different Types of Section	Rolled steel sections	Rolled Steel using Splice Connections	Cold formed Steel sections	Cold formed Steel section with splice connections
ISMC 100 (1m length)	6.8	5.4	3.2	2.5
ISMC100 (0.5 m length)	4.9	4	2.8	2.3
ISMC75 (1m length)	3.7	2.8	2.4	1.9
ISMC75 (0.5m length)	3	2.5	2.1	1.1

The experimental investigations has been made with the deflection of rolled and cold formed steelsectionswith and without splice connections, the ISMC100 and ISMC75 for 1m length are used .The obtained results shows that the deflection of rolled steel sections and cold formed steel sectionsISMC100 mm, the splice connections is lesser than the without splice connectionsby 25.92% and 28% . The deflection of rolled steel sections and cold formed steel sectionsISMC 75 mm, and withsplice connectionsis lesser than the without splice connections by 32.14% and 26.31 %. Both the rolled steel sections and cold formed steel sections with and without splice connections results are as shown in Figure 10.From that result cold formed steel sections both the connections without and with splice connections the deflection is 53.70 % and 52.94 % of lesser than the conventional steel sections ofISMC100 mm. The cold formed steel sections both the with and without splice connections the deflection is 56 % and 54.16 % of lesser than the conventional steel sections of ISMC75 mm.

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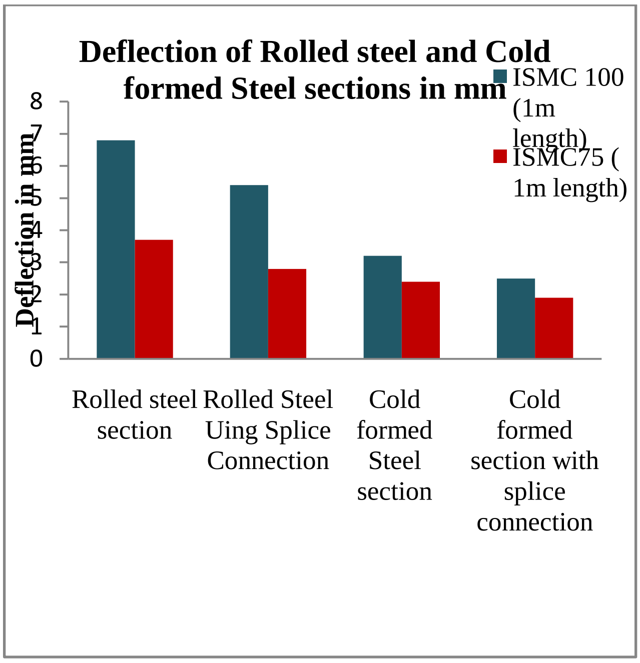

Figure 10.Deflection of rolled and CFS section using-ISMC100 mm and ISMC75mm

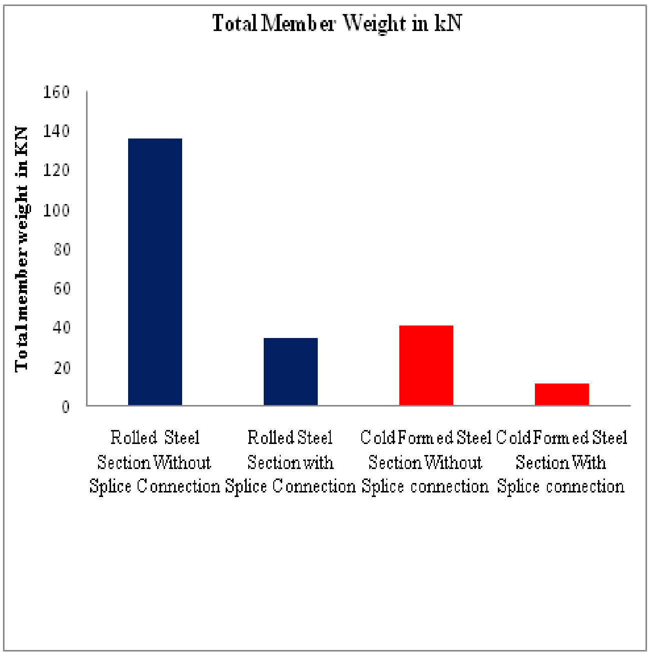

Figure 11.Member weight of rolled and CFS section with and without splice connections

B. Member weight of rolled steel section and cold formed steel section with and without splice connections are presented in table 3.

Table 3. Member weight of cold formed steel and rolled steel section

Different Types of Section	Total member weight in kN
Rolled Steel Section Without Splice Connection	135.91
Rolled Steel Section with Splice Connection	34.52
Cold Formed Steel Section Without Splice connection	40.74
Cold Formed Steel Section With Splice connection	11.712

The theoretical investigation on weight of the member of rolled and cold formed steel sections with and without splice connections have been made. The obtained results shows that the member weight of rolled steel sections with splice connection is lesser than the without splice connections by 74.60 %. The obtained results shows that the member weight of cold formed steel sections, with splice connections is lesser than the without splice connections by 71.25%. Both the rolled steel sections and cold formed steel sections with and without splice connections results are as shown in Figure 11.From that result cold formed steel sections both the connections with and without splice connections the total member weight is 66.60 % and 70.00 % of lesser than the conventional steel sections.

C.Total weight of conventional ste el structures and cold formed steel section with and without splice connections are presented in table 4.

Table 4.Total weight of cold formed steel and rolled steel section

Different Types of Section	Total Weight of Structures in kN
Rolled Steel Section Without Splice Connection	42490
Rolled Steel Section with Splice Connection	32163.4
Cold Formed Steel Section Without Splice connection	6940.2
Cold Formed Steel Section With Splice connection	3710.22

The theoretical investigation of the total weight of conventional steel structures and cold formed steel structures with and without splice connections. The obtained results shows that the total weight of conventional steel structures, with splice connections is lesser than the without splice connections by 32.10 %. The obtained results shows that the total weight of cold formed steel sections, with splice connections is lesser than the without splice connection by 87.05 %. Both the rolled steel sections and cold formed steel sections with and without splice connections test valus are as given in Figure 12. From that results cold formed steel sections both the connections with and without splice connection the total weight is 88.88 % and 51.22% of lesser than the conventional steel sections.

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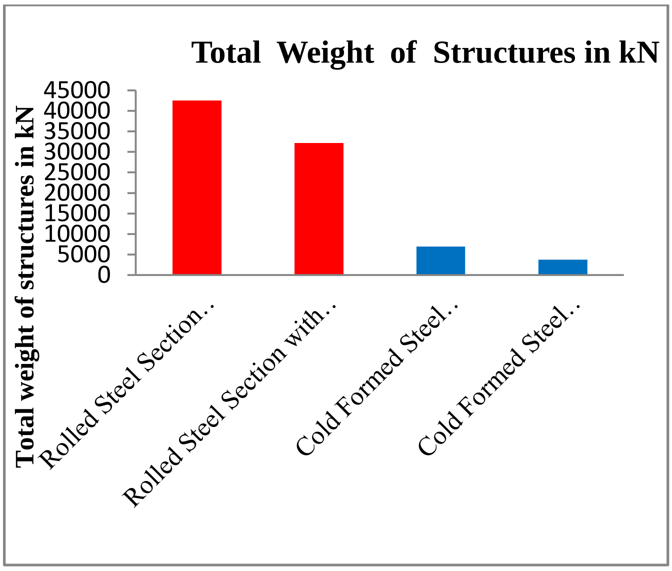

Figure 12.Member weight of rolled and CFS sections with and without splice connections

D.Base shear of Conventional steel structures and cold formed steel sections with and without splice connections are presented in table 5.

Table 5. Base shear of cold formed steel and rolled steel sections

Different Types of Section	Base shear in kN
Conventional Steel Section Without Splice Connection	1569
Conventional Steel Section with Splice Connection	1319
Cold Formed Steel Section Without Splice Connection	714.49
Cold Formed Steel Section With Splice Connection	636.26

The theoretical investigations of the base shear of conventional steel structures and cold formed steel structures with and without splice connections. The obtained results shows that the base shear of conventional steel structures, with splice connections is lesser than the without splice connections by 19 %. The obtained results shows that the base shear of cold formed steel sections, with splice connections is lesser than the without splice connections by 12 %. Both the rolled steel sections and cold formed steel sections with and without splice connections results are as shown in Figure 13. From that results cold formed steel sections both the connections with and without splice connections the base shear is 51.79 % and 54.46 % of lesser than the conventional steel sections.

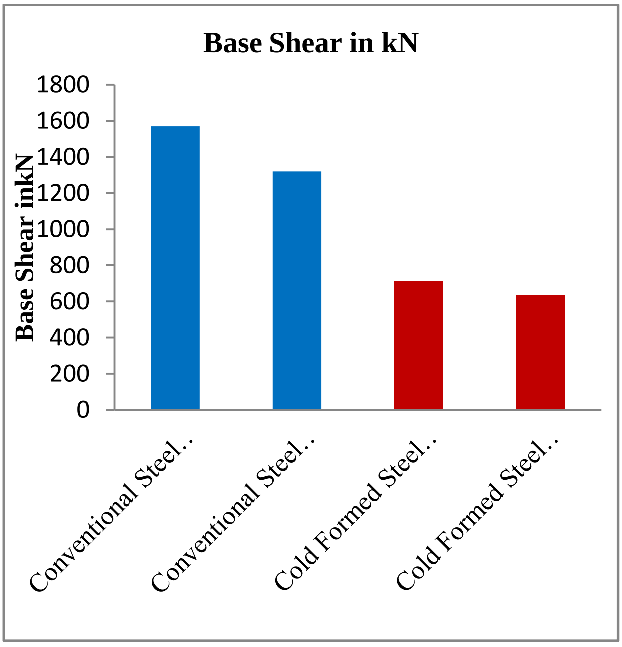

Figure 13.Base shear of rolled and CFS section with and without splice connections

E. Total cost of Conventional steel structures and cold formed steel section with and without splice connection are presented in table 6.

Table 6. Cost estimation of cold formed steel and rolled steel section

Different Types of Section	Total cost (Rs)
Rolled Steel Section Without Splice Connection	2549400
Rolled Steel Section with Splice Connection	1929804
Cold Formed Steel Section Without Splice connection	416412
Cold Formed Steel Section With Splice connection	222612.2

The theoretical investigations of the total cost of conventional steel structures and cold formed steel structures with and without splice connections have been made. The obtained results shows that the total cost of conventional steel structures, with splice connections is lesser than the without splice connections by 24.30 %. The obtained results shows that the total of cold formed steel sections, with splice connections is lesser than the without splice connections by 87.05%. Both the rolled steel sections and cold formed steel sections with and without splice connections test results are as given in Figure 14. From that results cold formed steel section both the connections with and without splice connections the total cost estimation is 88.46 % and 83.66 % of lesser than the conventional steel sections.

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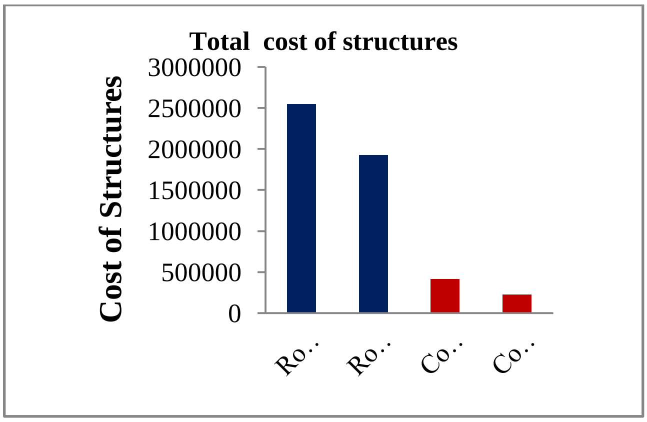

Figure 14.Total cost of rolled and CFS sections with and without splice connection

V. CONCLUSIONS

In this research work, the design based on IS 800:2007, IS 801:1975 and IS811:1975 the study is carried out to earthquake code book IS1893 (Part1):2002 and analysis is done by a industrial structure in both conventional steel and cold formed steel using splice connections. The parameters mainly focused in this study is the deflection and load carrying capacity of industrial structures, member reduction, cost of steel structures, seismic performance in both conventional and light gauge cold formed steel with or without splice connections.

The following are the conclusions obtained from this research

- In ISMC 100 mm for 1m length and 0.5 m length , the cold formed steel section both the connection with & without splice connections have the load carrying capacity is 55.55 % & 46.67 % and 53.85% & 50.00 of lesser than the conventional steel sections .
- In ISMC 75 mm for 1m length and 0.5 m length , the cold formed steel sections both the connection with & without splice connections have the load carrying capacity is 42.85.55 % & 77.77 % and 68.08 & 49.10 % of lesser than the conventional steel sections.
- In cold formed steel sections both the connection with & without splice connections the deflection is 53.70 % & 52.94 % and 56 % & 54.16 % of lesser than the conventional steel section ISMC100 mm and ISMC 75 mm.
- The cold formed steel sections both the connection with & without splice connections the total member weight and total weight of structures is 66.60 % & 70.00% & 88.88 % and 51.22% of lesser than the conventional steel section respectively.
- In cold formed steel sections both the connection with and without splice connections the total cost estimated is 88.46 % and 83.66 % of lesser than the conventional steel sections.
- In cold formed steel sections both the connections with and without splice connections the base shear is 51.79 % and 54.46 % of lesser than the conventional steel sections.

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