Use of Cold Form Section for Low Cost Housing

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Abstract - *As per ministry of housing, 1.77 million number of peoples don't have one of basic amenities i.e. house. Basically Cold Formed Steel are Pre-Engineered Building structures which can enhance easy and faster mode of construction which can overcome this concern. These structures are designed using semi rigid connections which makes the system earthquake resistant in addition to the safety, durability, performance and long-term low operational costs for the 50-year design life of a typical low-rise residential house. When a purpose of building is fulfilled or no longer needed it can be disassembled, stored or moved to another place and re-erected since major joints used are bolted connections. The design of section is based on the compressive nature (Flange) of the C-section provided and the model is executed on the ANSYS. This study is made using IS801 and AISI code equations subjected to maximum allowable stress, with effective section properties of C section with different b/t ratios of flange. The model is created and analysis & design part was carried out on STAAD. Pro as well as manually. This study helps to understand the behaviour of cold formed steel sections under compression subjected to loading conditions for different b/t ratios and fulfill the requirement of economical housing scheme.*

Key Words – Low Cost Housing, Cold Form Sections, Channel Lipped section, b/t Ratio, Flange of section, Pre-Engineered Building.

1. INTRODUCTION

According to a report of a Ministry of Housing and Urban Poverty Alleviation (MHUPA), India's urban housing shortage is estimated at nearly 18.78 million households in 2012. Besides those living in obsolescent houses, 80 percent of these households are living in congested houses and are in requirement of new houses. Some report also says that nearly one million households are living in non-serviceable low strength houses, while over half a million households are in homeless conditions. Growing concentration of people in urban areas has resulted in an increase in the number of people living in slums and squatter settlements. It is apparent that substantial housing shortage looms in Urban India and a wide gap exists between the de-mand and supply of housing. Hence, traditionally, low cost housing has been the domain of the government [11]. India's urban housing shortage is being primarily driven by the EWS and LIG categories. However, majority of the housing supply that has been built across urban India is beyond the affordability of the EWS and LIG segment [9]. Further, high land costs, archaic building bye laws, stringent licensing norms, delay in project ap-proval and unfavourable banking policies made low cost housing projects uneconomical that too for disaster prone areas like earthquakes, Wind, etc, for private developers [4]. So constructing a low cost house with affordable prices and low maintenance could help eradicating such major concerns [1].

2. PRE ENGINEERED BUILDING

In PEB structures there are basically two types of structural steel: hot-rolled steel shapes and cold-formed steel shapes. The hot rolled steel shapes are formed at elevated temperatures while the cold-formed steel shapes are formed at room temperature. Cold-formed steel structural members are shapes commonly manufactured from steel plate, sheet metal or strip material. The manufacturing process involves forming the material by either press-braking or cold roll forming to achieve the desired shape. Press-braking is often used for production of small quantity of simple shapes. Cold roll forming is the most widely used method for production of roof, floor and wall panels. It is also used for the production of structural components such as Cees, Zees, and hat sections. Sections can usually be made from sheet up to 60 inches (1.5m) wide and from coils more than 3,000 feet (1,000m) long [12].

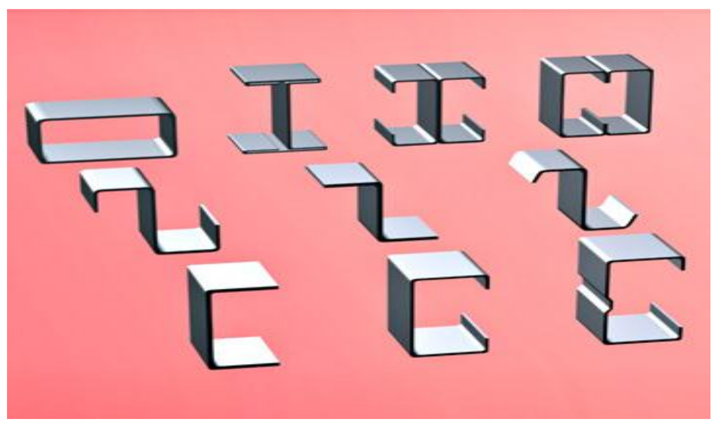

Figure 1: Types of Cold Form Steel Section

In terms of physical characteristics, cold rolled steels are typically harder and stronger than standard hot rolled steels. As the metal is shaped at the lower temperatures, the steel's hardness, resistance against tension breaking, and resistance against deformation are all increased due to work hardening. These additional treatments, however, can also create internal stress within the material. This can cause unpredictable warping but were not applicable to cold–formed sections because of their relatively thin steel walls which were susceptible to buckling. Cold-formed steel members maintain a constant thickness around their cross-section, whereas hot-rolled shapes typically exhibit tapering or fillets [11].

2.1 Stiffened & Unstiffened Elements

Plates that had a stiffening element on only one edge were called "unstiffened." These did not require calculation of an effective width, but were designed on the basis of a reduced stress. The stiffener could be "edge" or "intermediate," In a section such as a channel that has a flange stiffened by a web on one side and a lip on the other, the flange was considered a stiffened element. Now, there is a distinction between the flange of a channel and the flange of a hat section which is attached to webs on both sides. The channel flange is now called an edge-stiffened element, while the flange of the hat is still called a stiffened element. The edge stiffener usually produces effective widths distributed along the element. [10]

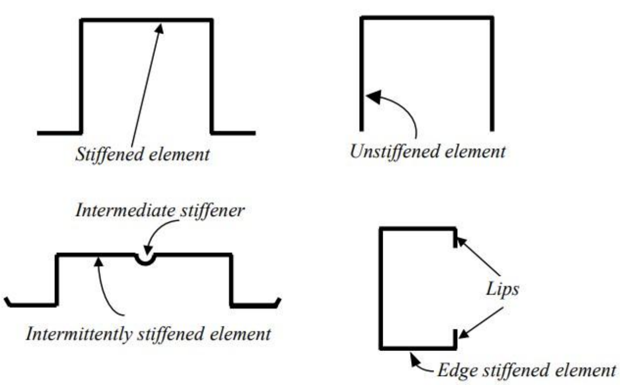

Figure 2: Stiffened & Unstiffened Elements

2.2 Effective Width Concept

Because cold-formed members typically have very high width-to-thickness ratios, they tend to buckle elastically under low compressive stress. However, the stiffened edges of the plate remain stable and a certain width of the plate close to the corners is still "effective" in resisting further compressive load. The inability of the centre of the plate to carry compressive load is caused by out-of-plane deformations in the shape of the fundamental elastic buckling mode. These deformations reduce the axial stiffness, concentrating the compressive force at the edges of a plate. The ultimate load is reached when these edge stresses, carried by the "effective width", exceed the yield stress of the plate material. The "effective width" method provides an approximation to the complex non-uniform stress distribution in a thin buckled plate under compression. [12]

3. METHODOLOGY

3.1 Assumptions

The research has been focused on the following assumptions,

1. For analysis of member, C-section with lips is considered.
2. Section is predominantly in flexure.
3. Only compression flange shall undergo buckling.
4. Though compression flange undergoes buckling shift in neutral axis towards tension. [2]

3.2 Neutral Axis Concept

In case of flexural members, only top flange undergoes buckling and concentration i.e. neutral axis shifts from centre towards bottom tension fibre with certain amount of eccentricity (δ) as shown below. Therefore, with change in stress distribution Centre of Gravity also changes and shift towards bottom flange. [2]

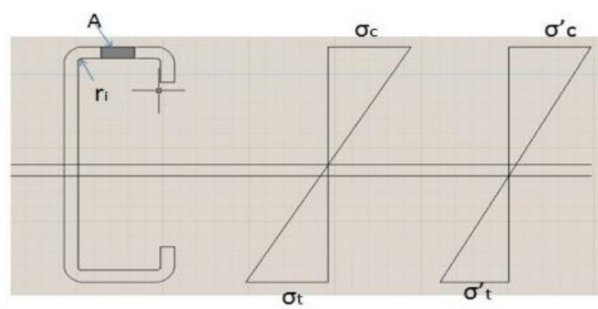

Figure 3: Shifting of Neutral axis stress and distribution

3.3 Buckling effects

Global buckling designed is based on flexural torsional buckling equation by considering the interaction of major, minor and torsional buckling modes as well as Reduction in width of cross sectional area to account for buckling effects [3].

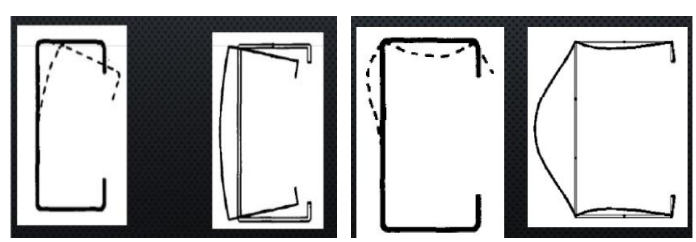

Figure 4: Types of Buckling, Local buckling of compressive member, Inward distortional buckling & Global buckling (Flexural/Distortional)

The compressive flange of the beam acts like an axially loaded. Therefore, in long-span of beams, the tension flange may tend to buckle. Since we had considered only Flange member instead of Complete section. Edges between the plate elements rotates without translation [10]. Rotation of the flange occurs at web junction and lateral bending of the section. It depends on the ratio of width of flange to depth of web. Since we had considered Flexural members, only Flange is allowed to deflect while other members will not undergo any change in properties as well as remain in their original positions [6].

3.4 Section Properties

The basic parameters such as area of cross section, moment of inertia, section modulus, etc. were calculated. To know the parameters of particular section, Excel sheet was made which can be used for any typical section. For more accuracy centre line method is used which is more conventional than normal one [3]. For instance, section of 200 x 80 x 20 x 1.5mm is considered and properties are evaluated with both the methods viz. AISI Cold Form Steel Design [15] & Indian Standards [13].

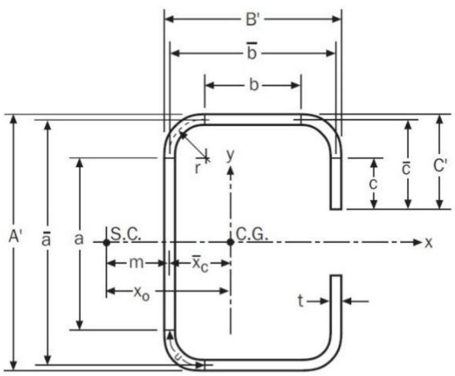

Figure 5: Centre line method as per AISI-CFS Manual

Gross Section Area	Ag	588.75	mm2	5.8875	cm2
Area of Effective Sect	Ae	580.65	mm2	5.81	cm2
Mass/unit length	m	4500040	kg/mm	4.5	kg/m
Centre of gravity	Cy	48.89094	mm	4.89	cm
Moment of Inertia	Ixx	3660804	mm4	366	cm4
	Iyy	525963.3	mm4	52.60	cm4
Radius of gyration	Rxx	79.4019	mm	7.94	cm
	Ryy	30.0968	mm	3.01	cm

Table 1: Basic parameters calculated by Indian Standards method.

Dimensions	Area of Section	Ax	588.585729 (mm2)	5.88586 (cm2)	
	Moment of Inertia	Ix	3740048.4 (mm4)	374.005 (cm4)	
	Dist. B/n Centroid & Web C/line	xc	23.2455 (mm)	2.32455 (cm)	
	Moment of Inertia	Iy	514093.777 (mm4)	51.4094 (cm4)	
	Dist. b/n SC & Web C/line	m	35.9138 (mm)	3.59138 (cm)	
	Shear Centre	Xo	-59.159325 (mm)	-5.91593 (cm)	
	Torsion Constant	J	441.439297 (mm4)	0.04414 (cm4)	
	Warping Constant	Cw	4140761358 (mm6)	4140.76 (cm6)	
	Radius of Gyration	Rxx	79.713843 (mm)	7.97138 (cm)	
		Ryy	29.5540028 (mm)	2.9554 (cm)	
	Section Modulus	Zxx	37400.484 (mm3)	37.4005 (cm3)	
		Zyy	5140.93777 (mm3)	5.14094 (cm3)	

Table 2: Basic parameters calculated using AISI Cold Form Steel Manual. [15]

The structural parameters namely effective width to thickness, effective width to gross width, effective moment of inertia to gross moment of inertia is calculated from AISI S100-2007 as well as Indian codes IS:811-1987. C-section was considered with different dimensions. For a particular section, the effective properties were calculated. Several iterations were made to calculate the exact value with minimal percentage of errors. [7]

Element	L	y from top fiber (in.)	Ly	Ly^2
Top Flange	51.491	0.750	38.618	28.9636
Bottom Flange	76.625	199.250	15267.531	3042055.602
Web	196.625	100	19662.500	1966250.000
Negative web element	1.726	34.171	58.99	2015.862
Top Inside Corner	1.473	0.469	0.690	0.324
Bottom Inside Corner	1.473	199.531	293.834	58629.069
Top Outside Corner	1.473	0.469	0.690	0.324
Bottom Outside Corner	1.473	199.531	293.834	58629.069
Top Lip	8.983	6.179	55.502	342.937
Bottom Lip	18.313	189.156	3463.924	655222.842
Sum Σ	359.653		39136.118	5783174.991
$\bar{y}$	108.82	mm	from Top fiber	

Table 3: Effective section properties by AISI method. [16]

3.5 Compatibility of Section

After the section properties are calculated, the designed section is executed on ANSYS. We had considered the model of channel lipped section, with following properties, [5]

Property	Value	Unit
Dimension	180CS80x1.5	mm
Yield Stress	345	Ksi
Poisson's ratio	0.3	-
Allowable Stress	572	ksi
Support Condition	S. S.	-
Pressure	10^{-3}	Mpa

Table 4: Sectional properties used in ANSYS. [14]

Once the properties are assumed, analysis of the section is executed with various loading and support conditions. Various types of Sections considered from which 200CS80x2 is shown below. [5]

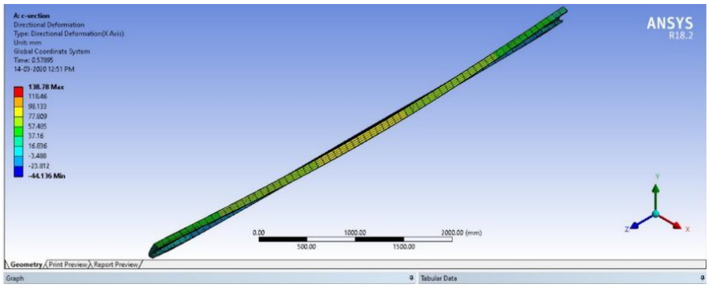

Figure 6: Deformation of section without Sag Rod

3.6 Structure Plan

After Finalizing the section, i.e. Structural as well as secondary members a plan for low rise residential house is considered. By adopting the norms of Ministry of Housing (MoH) and Nagpur Metropolitan Area (NMA) Development Plan (Maharashtra, India), a two-room sized house is plotted with minimal required space [9] & [4].

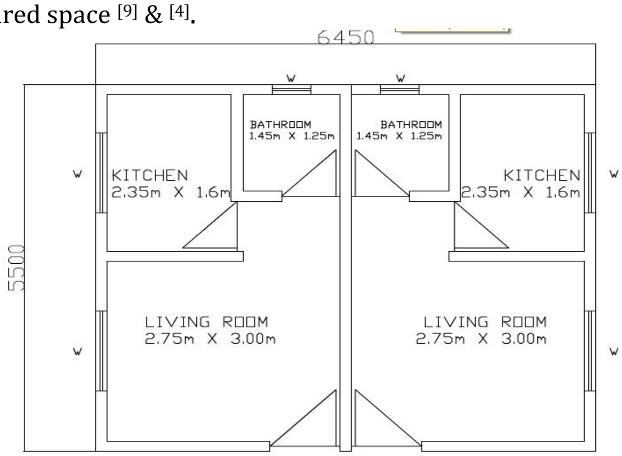

Figure 7: Nominal Room Size according to Ministry of Housing

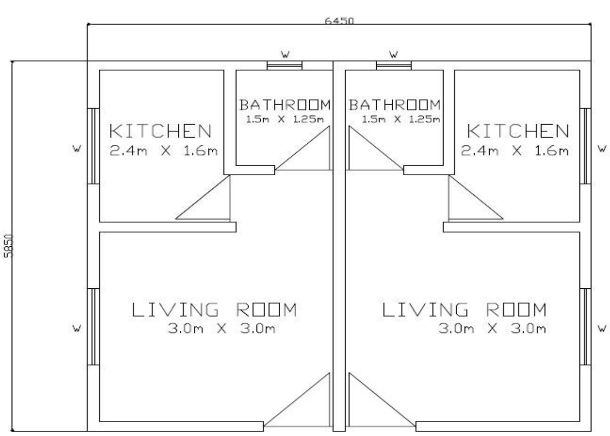

Figure 8: Nominal Room Size according to Nagpur Metropolitan Area

3.7 Models

Three building models were considered, using various parameters. The three structures were made with different specification and based on their modelling, data is interpreted.

1) RCC Framed Structure (RCC + CFS Roof)

A low rise residential building was considered called as Roof System, made of RCC columns having size of 230 x 230 mm and Roof made up of PEB structure namely, Rafters with designation of ISMB150 & purlins of ISMC75 with sheeting thickness of 1mm. Sloped Footing is used in Foundation with a size of 800 x 800 mm with a depth of 1500 mm. Plinth beam of 230 x 230 mm was taken with Clear height of the structure kept 3 m. At joint splice plate is used and connected by bolted connection of 12 mm diameter bolts [8]. Purlins was placed at a distance of 1.5 m centre-to-centre and frames are placed at 3.15 m apart. Brick work is used for Partition walls. The model was tested with various loading conditions including Wind load, Collateral load, etc. 7 Pinned condition were used for end supports on STAAD. Pro [11].

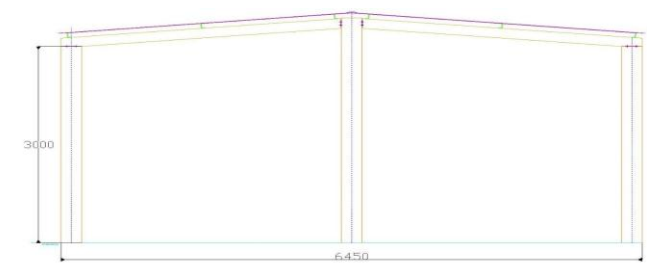

Figure 9: Elevation of RCC Framed Structure

2) Load Bearing Structure

A model is created made of Brick masonry having a column size of 230 x 230 mm and R.C.C. slab of 125 mm. Footing was made of 3 layers, 1st layer consist of Murom having a depth of 225 mm. 2nd layer was laid of P.C.C. and after that, stepped footing was made of Bricks masonry with a depth of 230 mm each. Then Plinth slab was laid with a thickness of 125 mm and above that Load Bearing structure with designated dimesnions were considered.

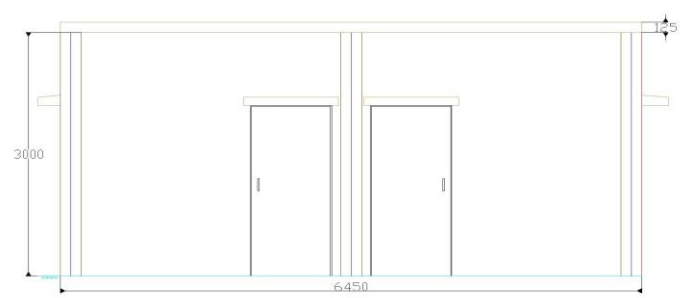

Figure 10: Elevation of RCC Framed Structure

3) Cold Form Steel Structure

A model of Cold Form Steel structure was made, consisting of two different sections, viz. Columns & Rafters made of lipped C-section with designation of 200CS60x2 with lip depth of 20 mm and Purlins & Girts with a designation of 120CS50x1.2 with a lip depth of 12 mm. Bolted connection was used with a size of 12 mm Diameter bolts [8]. Welding was preferred at very rare conditions where ever it is necessary. Splice plate is used at joints and connection was made back to back & pinned end conditions were used [6]. Plinth beam of 230 x 230 mm size was considered with a column placed centre to centre fixed with a support of splice plate and anchorage bolts of 12 mm [1].

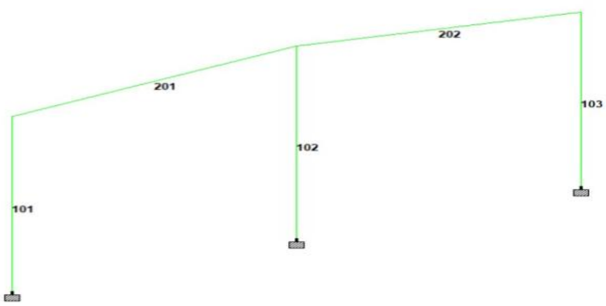

Figure 11: Analysis of 2D model of section 200CS60x2 [4]

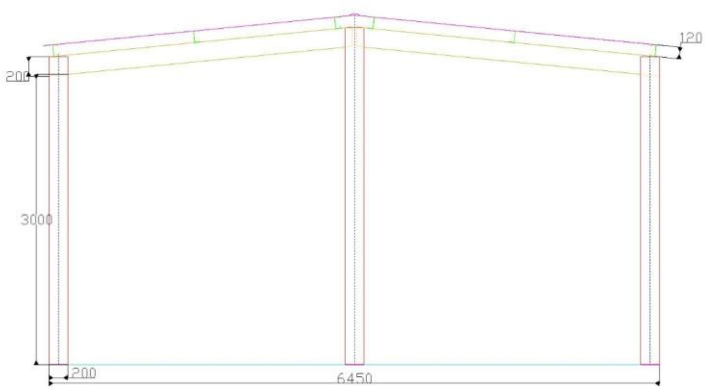

Figure 12: Elevation of Cold Form Structure

4. RESULTS AND DISCUSSION

1) RCC Framed Structure

The figure shows the connection of middle column used in RCC Framed structure. The anchor bolts were used of 12 mm diameter connected by a splice plate b/n column and rafter. The splice plate is welded to the rafter and purlins were connected with bolted connection. The base model was created and the analysis of rafters as well purlin was done in STAAD. Pro. A section of ISMB150 was used for rafters and ISMC75 for purlins.

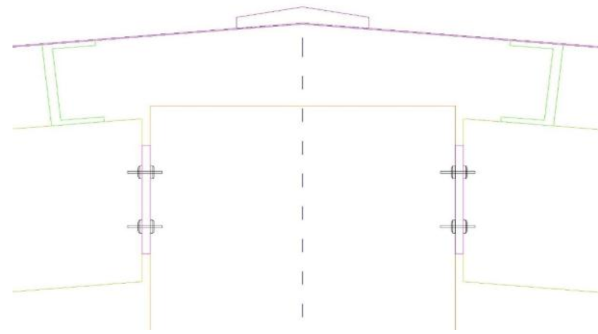

Figure 13: Bolted connection between Column and Rafter

Sr.	Description	Quantity	Rate	Pricing
1	Foundation	400 Sq. ft.	400/-	1.60 L
2	Plinth Beam	120 R. ft.	250/-	0.30 L
3	Slab	400 Sq. ft.	80/-	0.32 L
4	Column	9 nos.	4000/-	0.36 L
5	Brick Work (inc. Plastering)	360 Cu. ft.	120/-	0.43 L
6	Rafter	280.72 kg.	50/-	0.15 L
7	Purlin	236.23 kg.	50/-	0.12 L
8	Sheeting	220 kg.	51/-	0.11 L
9	Bolts & Welding			0.10 L
10	Miscellaneous		10 %	0.35 L
			Total	4.00 L

Table 5: Estimated cost for constructing RCC Framed Structure

Therefore, it can be said that an amount of 4.0 Lakh rupees is required to construct a Framed structure.

2) Load Bearing Structure

A plan was made with specifications listed above. The analysis and manual calculations was done for which re sults listed below.

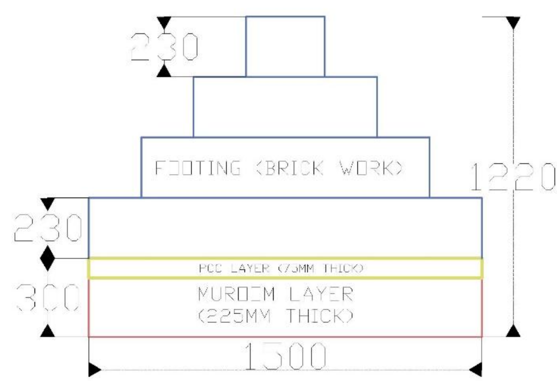

Figure 14: Model of Footing for Load Bearing Structure

Table 6: Estimated cost for constructing Load Bearing structure

Sr.	Description	Quantity	Pricing
1	Foundation	30.71 Cu. mt.	2.25 L
2	Plinth Beam	120 R. ft.	0.30 L
3	Slab	800 Sq. ft.	0.64 L
4	Column	9 nos.	0.16 L
5	Wall	1100 Sq. ft.	1.10 L
6	Miscellaneous	10 %	0.45 L
		Total	4.90 L

Therefore, it can be said that an amount of 4.90 Lakh rupees is required to construct a Framed structure.

3) Cold Form Steel Structure

The figure shows the connection of middle column used in Cold Form Steel structure. The splice plate is used between column and rafter and connection made was back to back. For connection, 12 mm diameter bolts were used. Purlins were placed at a distance of 1.5 m centre to centre and connected with the help of bolts.

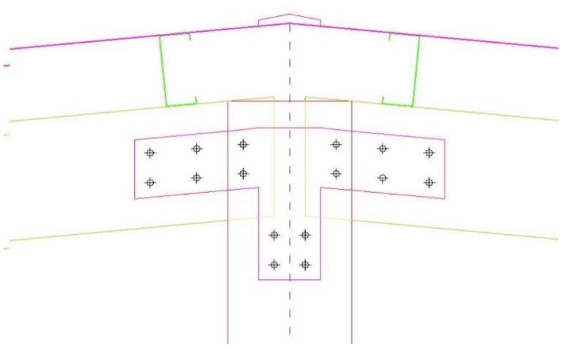

Figure 15: Bolted connection of Column and Rafter in CFS Structure

Step 5)	Classify the section							
	€	0.85						
			Check					
a)	width/thickness	25.000	28.006	THE SECTION IS PLASTIC				
b)	depth/thickness	95	107.258	THE SECTION IS PLASTIC				
Step 6)	Shear Capacity							
	Vdz	316453.1941	Check			Vdy	83277.15635	Check
	Fyz	189871.9165	SAFE			Fyy	49966.29381	SAFE
Step 7)	Bending Design Strength							
	Mdz	3089723.41	n-mm			Mdy	10647358.52	n-mm
Step 8)	Moment Capacity							
		0.426	≤ 1					
			SAFE					
Step 9)	Deflection Check							
a)	Permissible	16.25	mm					
b)	Actual	0.01	mm					

Table 7: Result of Designed section 120CS50x1.2

Therefore, the section was initially analysed in Staad. Pro and the design of Cold Form Steel section was done manually. In this process the section passed and can be used for Practical purpose.

Sr.	Description	Quantity	Rate	Pricing
1	Foundation	400 Sq. ft.	400/-	1.60 L
2	Plinth Beam	120 R. ft.	250/-	0.30 L
3	Slab	400 Sq. ft.	80/-	0.32 L
4	Frame (Columns & Rafters)	264.24 kg.	55/-	0.14 L
5	Purlins & Girts	186.31 kg.	55/-	0.10 L
6	Sheeting	570 kg.	51/-	0.29 L
7	Welding & Bolts			0.20 L
8	Miscellaneous		10 %	0.30 L
			Total	3.25 L

Table 8: Estimated cost for constructing Cold Form Steel Structure

Therefore, it can be said that an amount of 3.25 Lakh rupees is required to construct a Cold Form Steel structure.

5. CONCLUSIONS

This analytical study of, "Using cold form section for low cost housing" helps better understand the compatibility and uses of Section & from this it can be concluded that,

1) With different b/t ratios, the gross effective properties can be calculated depending upon the use and compatibility of section. It can be said that with effective width concept, a lesser dimension section can withstand a larger amount of deflection if optimised perfectly.
2) The analysis of section was carried out as per Indian Standards as well as American Standards. It is found that AISI code gives a better accuracy in respect to sectional properties as well as in behaviour. An approximate, 15% more optimised result was found as per AISI.
3) A low rise residential house can be constructed by using Cold Form Steel which can give higher efficiency of cost as well as can be erected with a span of 3 days (excluding substructure).
4) As per the study, a cost of 3.25 Lakh is required to construct a low rise residential house for 2 beneficiaries, which means it will cost you for a sum of 8,690/- per sq. mt.
5) It can be preferred not only for permanent construction but also as temporary purpose, especially in Seismic prone areas.

6. REFERENCES

[1] Vidal P. Paton-Cole and Emad Gad. "Understanding the benefits of constructing a residential house with a heart of cold-formed steel", EPiC Series in Education Science. 2017, Australia.

[2] Kushalkumar Yadav, Dr. Prashant D. Hiwase and Dr. Ramesh V. Meghrajani. "Study the behaviour of cold form c-section purlins under bending", International Journal of Civil Engineering and Technology (IJCIET). Volume 9, Issue 5, May 2018, pp. 964–968, Article ID: IJCIET_09_05_106.

[3] Nikhil N. Yokar and Pratibha M. Alandkar. "Comparison of compression capacity of cold formed steel channel sections under concentrated loading by analytical methods", Journal of Civil Engineering and Environmental Technology. Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, No. 2; August, 2014 pp. 28-32.

[4] S. M. Hardwani and A. V. Patil. "Low cost earthquake resistant house using cold formed steel [cfs] member- a case study" International Journal of Engineering Research & Technology (IJERT). ISSN: 2278-0181Vol. 2 Issue 9, September-2013.

[5] Ashish Kumar, Sanjay Kumar, Keshav Priyadarshi, Ashutosh Kumar & Rajan Kumar "Cold formed steel stiffened web sections behaviour" International Journal for Innovative Research in Science & Technology. Volume 3, Issue 04, Sept 2016 ISSN (online): 2349-6010.

[6] Prof. Morgan Dundu. "Buckling of short cold‑formed lipped channels in compression" Journal of The South African Institution of Civil Engineering. Vol 56 No 2, August 2014, Pages 46–53, Paper 1044.

[7] Colin A. Rogers & R. M. Schuster. "Cold formed steel flat width ratio limits, d/t and di/w" Scholars' Mine. (1996) - 13th International Specialty Conference on Cold-Formed Steel Structures.

[8] Rahima Ummi Kulsum Nadya and Fathoni Usman. "Bolted connection of cold-formed steel section- A Review" ARPN Journal of Engineering and Applied Science. Vol. 13, No. 17, September 2018 ISSN 1819-6608 Malaysia.

[9] Mr. Roshan S Satpute, Dr. Valsson Varghese. "Building design using cold formed steel section" International Refereed Journal of Engineering and Science (IRJES). (Online) 2319-183X, (Print) 2319-1821 Volume 1, Issue 2 (October 2012), PP.01-16.

[10] M. Meiyalagan, M. Anbarasu, and Dr. S. Sukumar. "Investigation on cold formed c section long column with intermediate stiffener & corner lips – under axial compression" International Journal of Applied Engineering Research, Dindigul Volume 1, No1, 2010 ISSN 09764259.

[11] Shabari Indhuja, and Narendra Prasad. "Development of a cold formed steel housing system" International Journal of Innovative Research in Science, Engineering and Technology. ISSN(Online): 2319-8753 ISSN (Print): 2347-6710 Vol. 6, Issue 3, March 2017.

[12] Helen Chen "An overview of cold-formed steel structures" PDH Online Course S101 (2 PDH).

[13] Indian Standards IS 801:1975

[14] Indian Standards IS 800:2007

[15] American Standards AISI Manual of Cold Form Steel Design

[16] American Standards AISI S100-2007