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Behaviour of Cold Formed Steel Sigma Purlins Using ANSYS

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ABSTRACT
Popularity of the Cold-formed steel is increasing in the recent years due to the high strength of weight ratio. The performance of the Cold Formed Steel (CFS) sections is affected due to various buckling modes. To overcome this limitation, the Webs are stiffened by means of intermediate stiffeners. Stiffeners in the web of the C-section increase the local buckling stress, distortional buckling stress of the section.In the present investigation, two different forms of purlins were studied numerically. The web stiffened channels named as Sigma section is used as a purlin and their effects is analysed using a commercially available Finite Element Software ANSYS 14.0. Two boundary conditions with open and closed distortional buckling restraint around the edges were assumed for analysis. Specimens are non-linearly analysed in simply supported condition for three varying d/t ratio. The stress and deformation contours were plotted to determine the yield load and ultimate load.

Keywords
Cold formed Steel, stiffeners, sigma section, non-linear analysis, yield load and ultimate load

1. INTRODUCTION
The Cold-formed steel sections are widely used in construction and building industries. The popularity of these products has dramatically increased in recent years due to their wide range of application, easy of fabrication and high strength-to-weight ratios. With the advance of the science and technology, the yield strength of the cold-formed steel can now reach as high as 550MPa. Based on the strength design, the cold-formed steel member can have a very thin thickness. However, the thinner the section, the easier the member can buckle. Efforts have been made to increase the buckling resistance by designing sections that have intermediate folds in the flange and/or in the web[3]. The folds are named as web stiffeners which are used to reduce the local buckling of the member. Two types of web stiffeners are introduced in the model to increase the flexural capacity and to reduce the local buckling, they are triangular and trapezoidal. The shape and dimensions of the web stiffeners are explained in the later phase. Modelling is done for three d/t ratio and two boundary conditions. 3-Dimensional model is created using AUTOCAD 2014 and commercially available Finite Element Software ANSYS 14.0 Workbench version is used to analyze and study the behaviour of the various sections. A material model in finite element model should inevitably be capable of representing both elastic and plastic behaviour of steel in compression and tension. Therefore, the development of a finite element model (FEM) may need intensive material testing to incorporate into the material model in any of the finite element [FE] packages available. There are quite large numbers of numerical material models available in the literature which is analyzed using ABAQUS and CUFSM. However, ANSYS has not been used for the analytical purpose. Therefore, this paper presents twelve numerical models that can be easily modeled and analyzed using ANSYS 14.0. Six models for open boundary condition andclosed boundary condition were employed for various d/t ratios. These models were loaded and their stress-strain characteristics are studied. This material model presented in the paper is capable of representing the buckling shape and stress-straincontour, yield load and the ultimate load of the specimens. Twelve numerical non-linear specimens in ANSYS are briefly discussed in the section.

2. Developing The Material Model
2.1 Modelling and Meshing
The modelling is done using AutoCAD 2014 as a solid element. The thickness is assumed very smoothly over the area of the element. Verification of the model is done using Design Modeller and Multiphysics were used to mesh the element.

3. MATERIAL PROPERTIES USED IN ANSYS
3.1 Element type
Specimens were modelled as SOLID186 a element which is shown in Fig 1.The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions and rotations about the x, y, and z-axes. This element is well-suited for linear, large rotation, and/or large strain nonlinear applications because of plasticity, creep, stress stiffening, large deflection, and large strain capabilities.

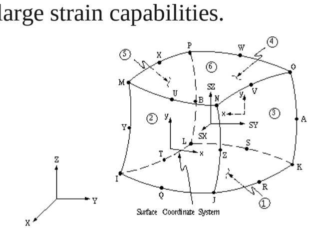

Figure 1. Solid Element 186

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3.2 Element type
For all the specimens both linear and Non-linear material properties were given. The details of the linear properties are given in the Table 1 and the details of the non-linear properties are shown in the Figure 2.

Table 1. Linear properties of the specimen

Description	Value
Young's modulus	2.06 x 10^5 N/mm^2
Poisson's ratio	0.3
Yield stress	240 N/mm^2

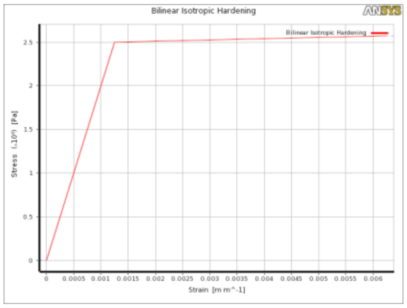

Figure 2. Non-linear property of the specimen.

3.3 Meshing

Multiphysics was used to mesh the element. It was found that good simulation results could be obtained by using the element (Hexagonal mesh) size of approximately 20mm for the web, flanges and stiffeners.

3.4 Loading and boundary condition

The boundary conditions were modelled and analysed for the load carrying capacity and buckling performance for 12 specimens of 1.5 m length and 1.6mm, 2mm and 2.5mm thickness for varying parameters. The ends of the specimens were simply supported, both ends were restrained against distortion for closed boundary condition and in open boundary condition it is not restrained against buckling. Beam specimens were loaded at its one fourth spans till failure and results were obtained by non-linear analysis. The solver method is set to Newton Raphson (Iterative process) with the maximum no. of iterations set to program controlled. The support and loading condition for both open profile is shown in Figure 3. The support and loading for closed boundary condition were shown in Figure 4.

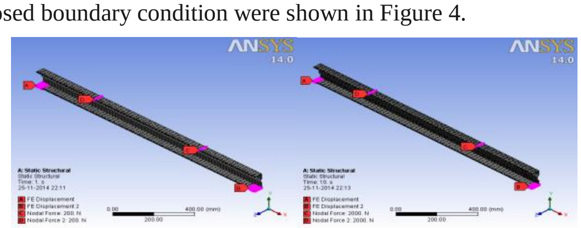

Figure 3. Mesh view of Profile 1 and 2 with loading, support and boundary condition

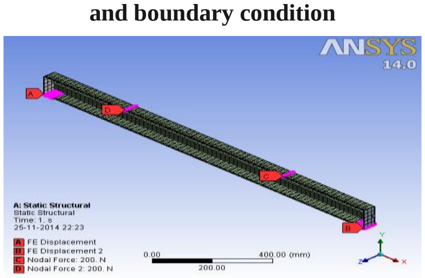

Figure 3. Mesh view of profile 1 with closed boundary condition

4. GEOMETRICAL SPECIFICATION

4.1 Size of beam

- Cross section of Beams = 50mm x 100mm
- Length = 1500mm

Sigma section of height 100mm, flange width 50mm and having thickness of 1.6mm, 2mm and 2.5mm were used for a length of 1.5m. Web is stiffened by proper cold forming process. Two boundary conditions were also included in which open boundary condition refers to the member without distortional restraint, whereas closed boundary condition refers to the member with distortional restraint. Sectional dimensions are shown in Figure 5, 6.

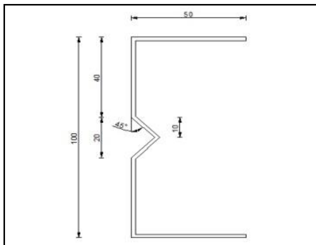

Figure 5: Profile 1 (Elevation)

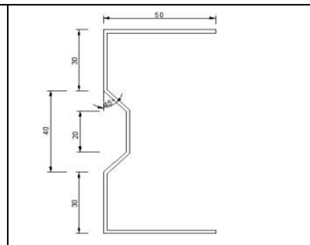

Figure 6: Profile 2 (Elevation)

Table 2. Geometric details of specimen

Beam No	SIZE hxb (mm)	Thickness (mm)	d/t	b/t	Boundary conditions
P1t1_O	100x50	1.6	62.5	31.25	open
P1t2_O	100x50	2.0	50	25	open
P1t3_O	100x50	2.5	40	20	open
P1t1_C	100x50	1.6	62.5	31.25	closed
P1t2_C	100x50	2.0	50	25	closed
P1t3_C	100x50	2.5	40	20	closed
P2t1_O	100x50	1.6	62.5	31.25	open
P2t2_O	100x50	2.0	50	25	open
P2t3_O	100x50	2.5	40	20	open
P2t1_C	100x50	1.6	62.5	31.25	closed
P2t2_C	100x50	2.0	50	25	closed
P2t3_C	100x50	2.5	40	20	closed
P2t3_C	100x50	2.5	40	20	closed

Where, h - Depth of web

b - Width of flange

t -Thickness of beam

Open – without distortional restraint

Closed – with distortional restraint

5. RESULTS AND DISCUSSION

ANSYS 14.0 was used for numerical analysis to web stiffened sigma sections in transverse two point loading with simply supported condition. Loading was applied gradually till failure.

Ultimate values of the vertical displacement, Von mises stress, Von mises strain, yield load and ultimate load were calculated using ANSYS 14.0 in the incremental loading for all 12 beam specimens (d/t=62.5,50,40). Non-linear analysis was done and the obtained results were tabulated below.

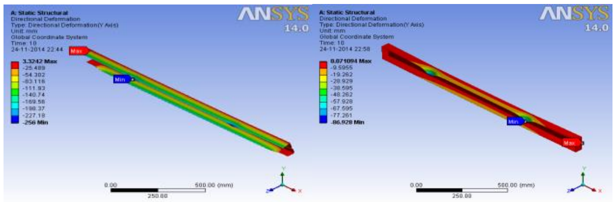

Figure 7. Deformation for P1t1_O and P1t1_C

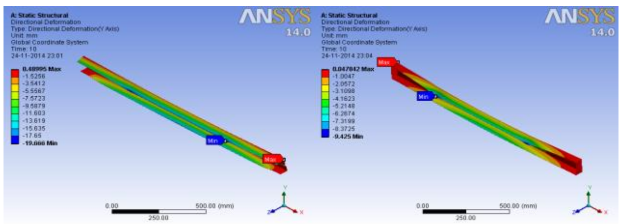

Figure 8. Deformation for P1t2_O and P1t2_C

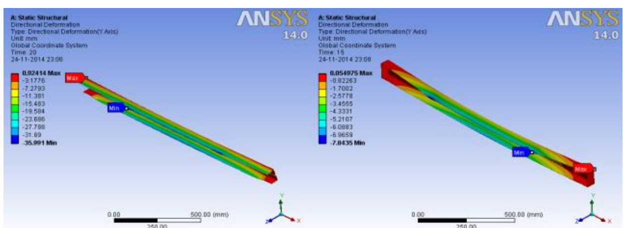

Figure 9. Deformation for P1t3_O and P1t3_C

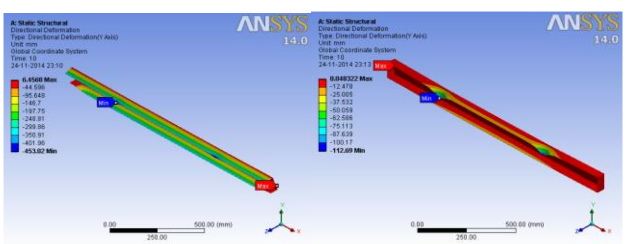

Figure 10. Deformation for P2t1_O and P2t1_C

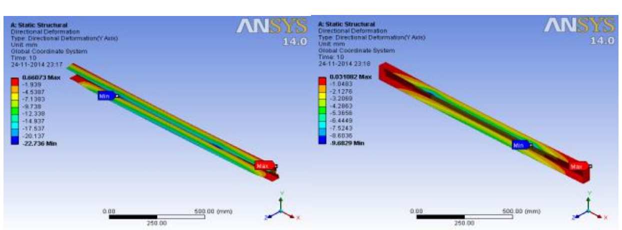

Figure 11. Deformation for P2t2_O and P2t2_C

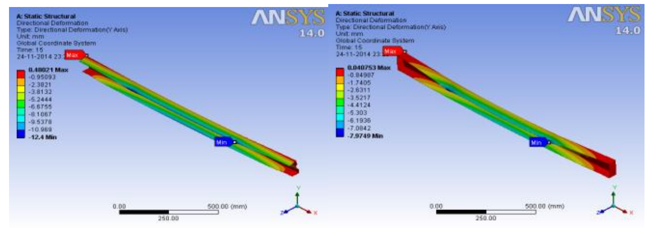

Figure 12. Deformation for P2t3_O and P2t3_C

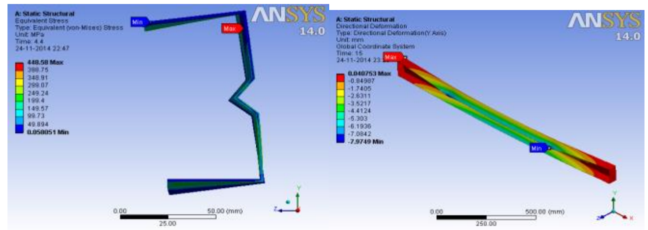

Figure 13. Side Deformation for P1t1_O and P1t1_C

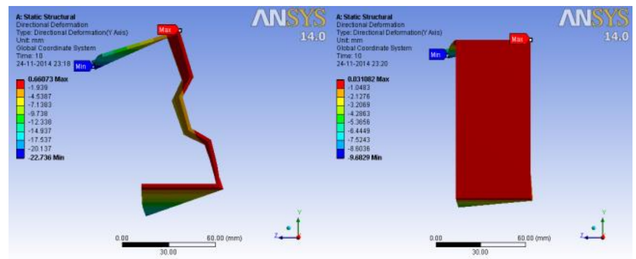

Figure 14. Side Deformation for P2t2_O and P2t3_C

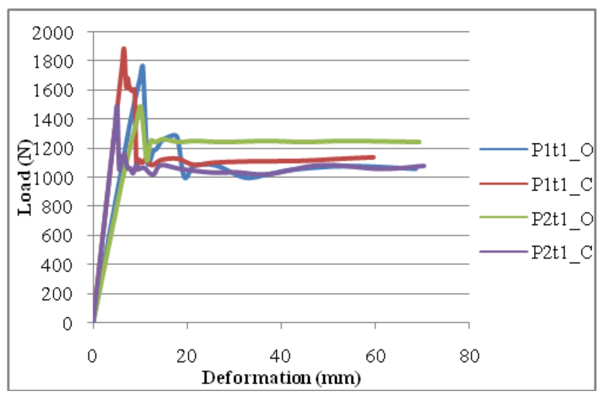

Figure 15. Load vs Deformation for d/t=62.5

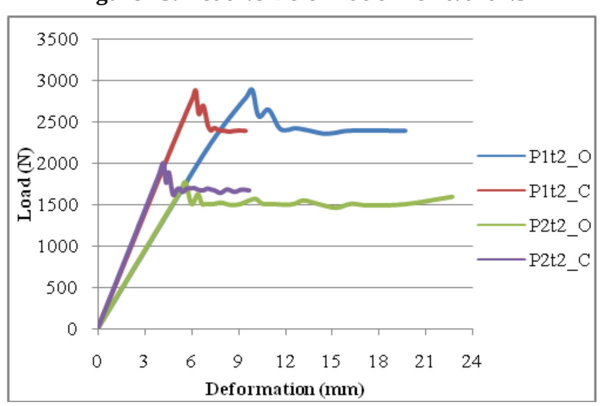

Figure 16. Load vs Deformation for d/t=50

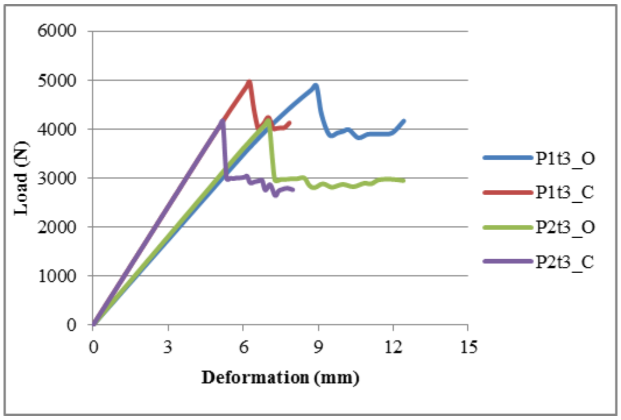

Figure 17. Load vs Deformation for d/t=40

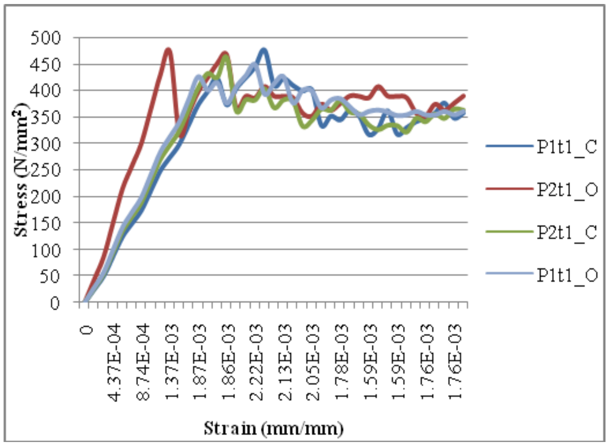

Figure 18. Von-misess stress vs Von-mises strain for d/t=62.5

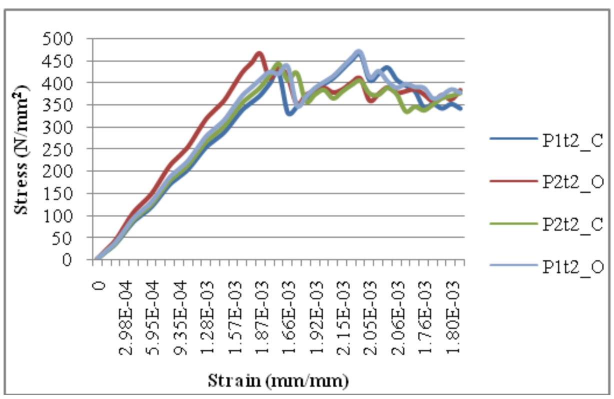

Figure 19. Von-misess stress vs Von-mises strain for d/t=50

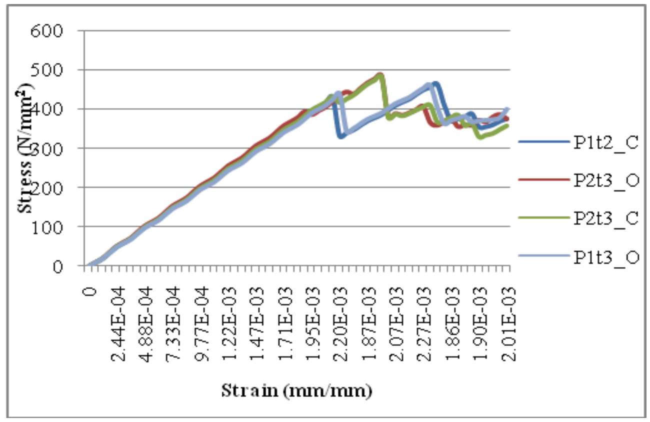

Figure 20. Von-misess stress vs Von-mises strain for d/t=40

Table 3. Numerical results for Sigma section specimens

Sl. No	Specimen	Thickness 't' (mm)	Deflection at failure (mm)	Von mises stress (N/mm²)	Von mises strain (mm/mm)	Yield load (N)	Ultimate load (N)
			Vertical				
1	P1t1_O	1.6	10.581	448.5	0.0022	804.9	1760
2	P1t1_C	1.6	6.602	475.3	0.0023	1080	1880
3	P2t1_O	1.6	5.5747	473.3	0.0023	464.8	880
4	P2t1_C	1.6	5.1246	462.4	0.0023	740.3	1480
5	P1t2_O	2	9.8965	468.9	0.0028	1080	2880
6	P1t2_C	2	6.2543	464.5	0.0023	1182	2880
7	P2t2_O	2	5.6368	463.9	0.0023	948	1760
8	P2t2_C	2	4.2071	443.9	0.0023	1126	2000
9	P1t3_O	2.5	8.9254	460.2	0.0021	2052	4880
10	P1t3_C	2.5	6.2555	464.1	0.0023	2017	4960
11	P2t3_O	2.5	7.0191	485.6	0.0024	1955	4160
12	P2t3_C	2.5	5.1805	483.4	0.0024	2008	4160

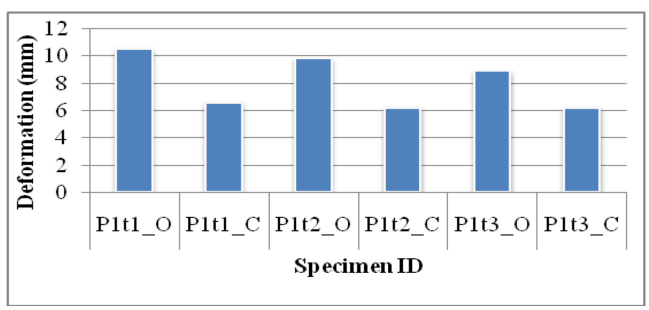

Figure 21. Deformation(Profile-1) for various specimens

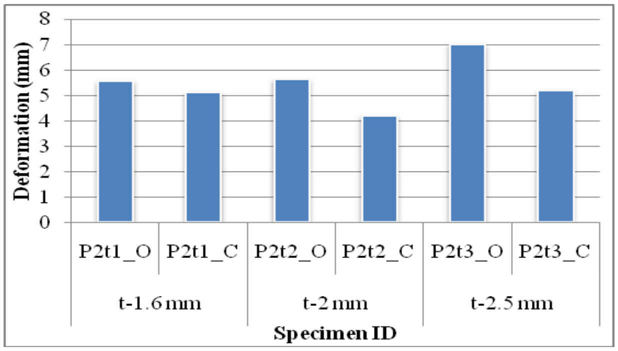

Figure 22. Deformation(Profile-1) for various specimens

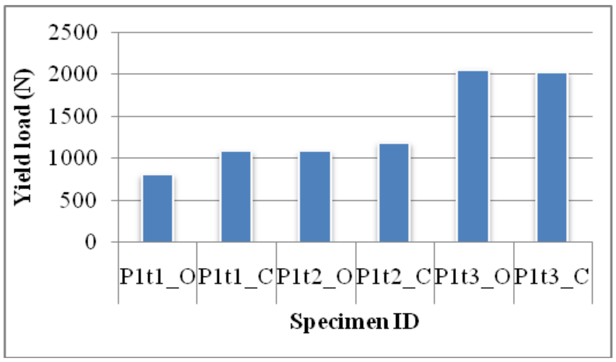

Figure 23. Yield load(Profile-1) for various specimens

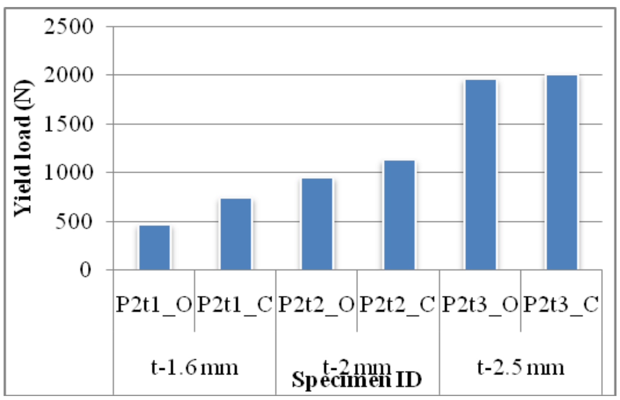

Figure 24. Yield load(Profile-2) for various specimens

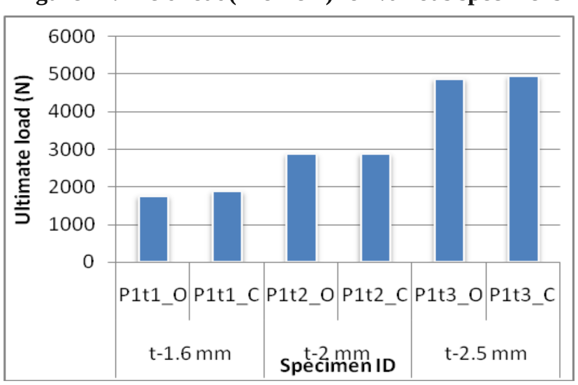

Figure 25. Ultimate load(Profile-1) for various specimens

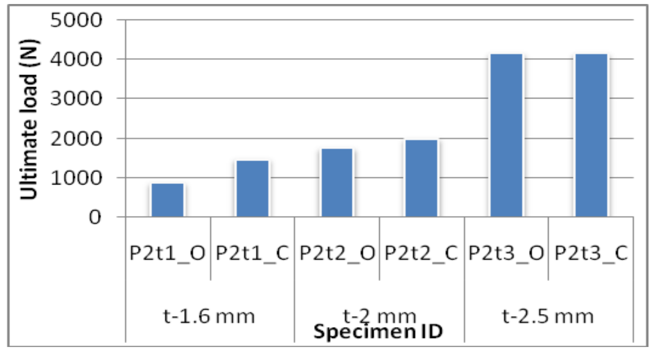

Figure 26. Ultimate load(Profile-2) for various specimens

6. CONCLUSIONS

ANSYS 14.0 was used to determine non-linear analysis of the web stiffened Sigma sections. The sections are tested for pure bending with simply supported condition. Deflection, stress and strain were measured and the contours were plotted. The members were investigated for yield load capacity, ultimate load capacity and deflection. The following conclusions can be made based upon the numerical results.

- Higher value of h/t ratio in the section, have low load carrying capacity. They have shown an increase in load carrying capacity from 35.13% to 372% when compared with the lesser h/t ratio sections.
- The results obtained from numerical analysis shows that the ultimate load carrying capacity of Profile 1 of Sigma section is increased to an average of about 60.63% than the Profile 2 of the sigma section.
- Ultimate load carrying capacity of the section with distortional restraint is more than the open section by an average of 4% for profile 1 and 41% for profile 2.
- Load carrying capacity was increased for the Profile 1 of the sigma section compare to the Profile 2 of the sigma section, due to provision of stiffeners in the web of the Sigma section.
- Lateral and vertical displacements for Profile 1 of sigma section are more than Profile 2 of the sigma section.
- Yield load capacity of the profile 1 of the sigma section is increased to an average of 23.83% when compared with profile 2 of the sigma section.
- When the h/t ratio decreases, the %increase of yield load capacity also decreases.
- For the h/t ratio 62.5 and 50, the yield load capacity of profile 1 is increased when the distortional restraint is provided to an average of 21.84%, but for the h/t ratio of 40 the yield load capacity decreased by 1.73%.
- Hence the provision of full distortional restraint not only decreases the deflection but also increases

the yield load and ultimate load capacity of the section for both the profiles 1 and 2.

- As per the numerical analysis, the capacity of the section in profile with triangular stiffener is greater in all aspects when compared to profile with trapezoidal stiffener, so significant cost reduction in the construction can be made when profile 1 is used.

REFERENCES

[1] Long-yuan Li, "Analyses of distortional buckling of cold-formed sigma purlins using EN1993-1-3", Journal of Constructional Steel Research,Volume 65, Issue 12, December (2009) Pages 2099‑2102.

[2] Jian Yang, Qiang Liu, "An experimental study into flexural behaviour of sigma purlins attached with roof sheets", Engineering Structures,Volume 45, December (2012) Pages 481-495.

[3] Long-yuan Li, Jian-kang Chen, "An analytical model for analysing distortional buckling of cold-formed steel sections" Thin-Walled Structures,Volume 46, Issue 12, December (2008) Pages 1430-1436.

[4] Dhammika Mahaarachchi, Mahen Mahendran,"Lateral Distortional Buckling Behaviour of a New Cold-formed Hollow Flange Channel Section" Eighteenth International Specialty Conference on Cold-Formed Steel Structures, Orlando, Florida, U.S.A, October 26 & 27 (2006).

[5] P. Keerthan, M. Mahendran, "Shear Strength of Hollow Flange Channel Beams with Stiffened Web Openings", 21st International Specialty Conference on Cold-formed Steel Structures, Missouri University of Science and Technology, St. Louis, Mo. (2012).

[6] P. Keerthan, M. Mahendran, "Shear strengths of lipped channel beams with stiffened web openings using numerical studies",5th International Conference on Structural Engineering, Mechanicsand Computation, Cape Town, South Africa. (2012).

[7] Jian Yang, Qiang Liu, "Sleeve connections of cold-formed steel sigma purlins", Engineering Structures,Volume 43, October (2012) Pages 245–258.

[8] Cheng Yu, Benjamin W. Schafer, "Distortional Buckling Of Cold-Formed Steel Members In Bending", American Iron and Steel Institute,Baltimore, Maryland, January 2005.

[9] Wei-Wen Yu, and Roger LaBoube, "Cold-Formed Steel Design", Fourth Edition, WILEY, John Wiley & Sons, Inc.

[10] Maria. E. Moreya and Pekoz T., "Experiments on lipped channel flexural members", Proceeding of 12th international specialty conference on cold-formed steel structures , St. Louis, Missouri, USA Oct 18-19 (1994) pp 41-56.

[11] Chi-Ling Pan, and Wei-Wen Yu, "Yield moment of cold-formed steel beams under different strain rates, "Journal of Structural Engineering, Vol.127, No.3 (2001) pp264-270.

[12] Chong, K.P., and D.M. Mosier, "Non linear behavior of continuous cold-formed beams" Proceedings of the 3rd international specialty conference on cold-formed steel structures, W.W.Yu and J.H. Senne Eds, University of Missouri-Rolla (1975) pp 227-250.