Numerical Analysis of Buckling Behavior of Cold Formed Steel Angles With Intermediate Stiffener

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Abstract

This project is mainly focused on the study of buckling behavior of cold formed steel angles. As column is a vertical compression member, it may affected by buckling, namely, local buckling, global buckling, torsional buckling, and distortional buckling. To enhance the buckling load capacity, the stiffeners were placed at the following positions : i) buckling axis ii) to connect the outer legs of the angle section iii) both buckling axis and the line connecting outer legs iv) triangular plate from corner to the buckling axis and v) triangular plate on the full cross section. In addition to that the length of columns are altered as 600 mm, 900 mm, and 1200 mm and the stiffener spacing as 100 mm, 150 mm, and 200 mm. Finite element analysis has been carried out by ANSYS Workbench 15.0 by creating the model using CATIA V5 software for the fixed ended cold formed equal angles with same thickness having five different sizes that makes the total number of specimens as 240. The column sections are analyzed by applying load on the top surface of the angle section. The analytical results obtained from FEM are compared with unstiffened column. By observing the results, it was found that the stiffener plate placed on the full section gives the better buckling load capacity compared to all others, but the stiffener provided at both the buckling axis and the line connecting outer legs fetches the optimum load capacity with economy in material and weld.

Keywords: Cold formed steel angles, buckling load, buckling axis, line connect the outer legs of the angle, finite element analysis

I. INTRODUCTION

Cold formed steel sections are widely used in low rise buildings, transmission towers and trusses. Cold formed steel members having less weight at the same time they give enough strength [12]. Various shaped elements are made using cold formed steel. In this paper angle section was selected for study. Angle section may be used as vertical member in low rise buildings and transmission towers. The vertical members of low rise buildings and transmission towers are affected by buckling namely local buckling, global buckling, torsional buckling, and distortional buckling. In this study, the buckling behavior of cold formed steel with and without stiffeners was compared.

II. MODELING USING CATIA

CATIA is mechanical software was used for model making. The model making in the ANSYS is somewhat difficult because the stiffeners at various locations, various spacing, and curves and bends also difficult. So the CATIA V5 has been used for making the model. 240 numbers of specimens are modeled using CATIA V5 Software. Fig. 1 showed the conventional (without stiffener) column and the column with stiffeners at buckling axis as shown in Fig. 2, connect the outer legs of the angle section as shown in Fig. 3, both buckling axis and the line connecting outer legs as shown in Fig. 4, triangular plate from corner to the buckling axis as shown in Fig. 5 and triangular plate on the full cross section as shown in Fig. 6.

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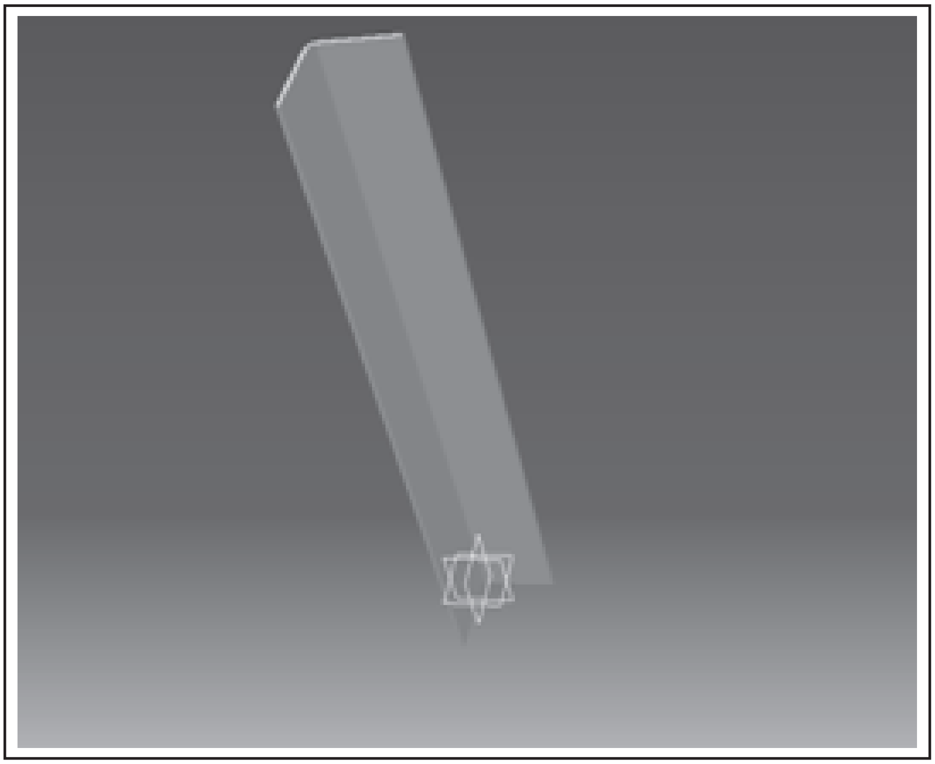

Fig. 1. Conventional Column Model

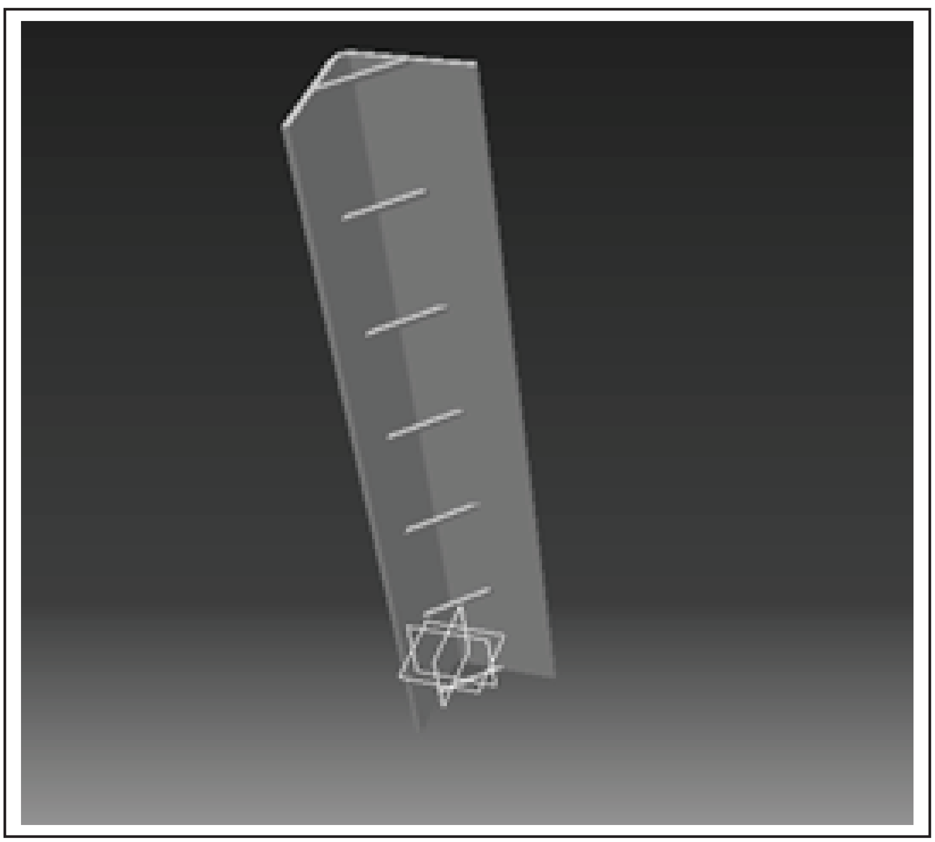

Fig. 2. Column Model With Stiffener at Buckling Axis

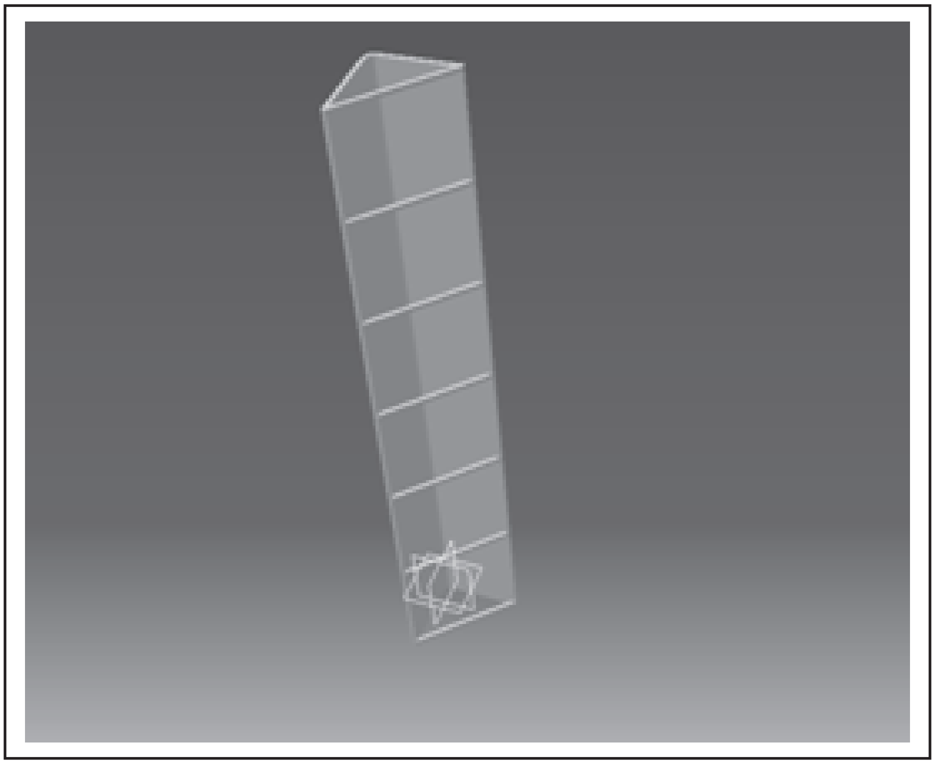

Fig. 3. Column Model With Stiffener at Line Joining the Outer Legs of an Angle

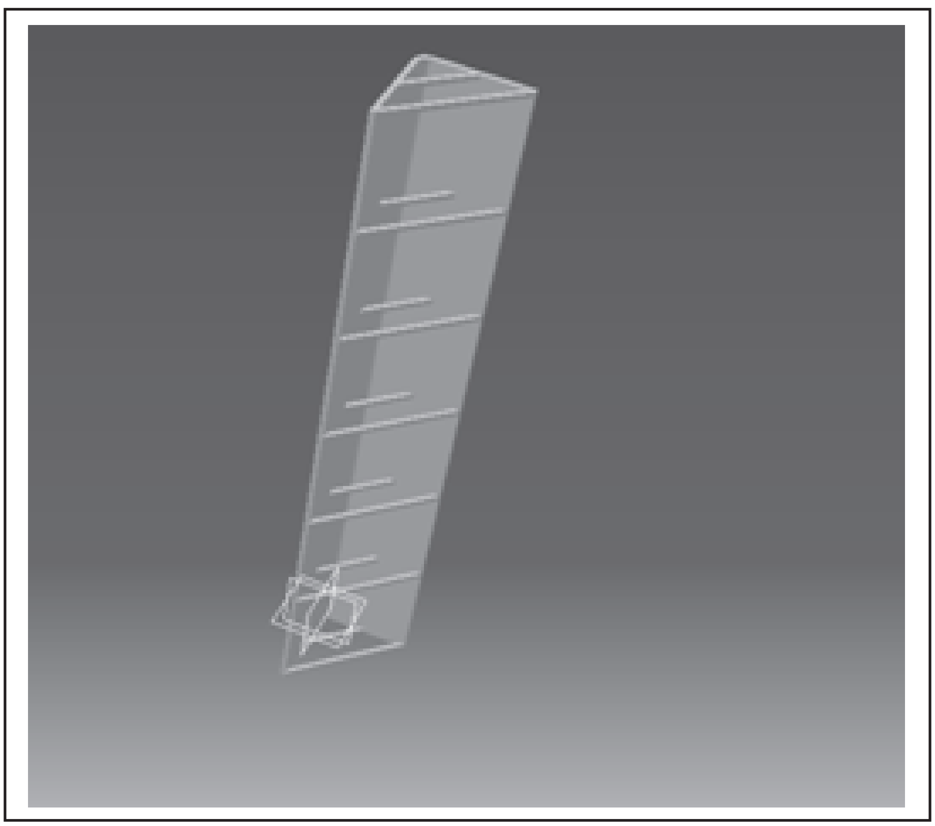

Fig. 4. Column Model With Stiffener at Both Buckling Axis and Line Joining the Outer Legs of an Angle

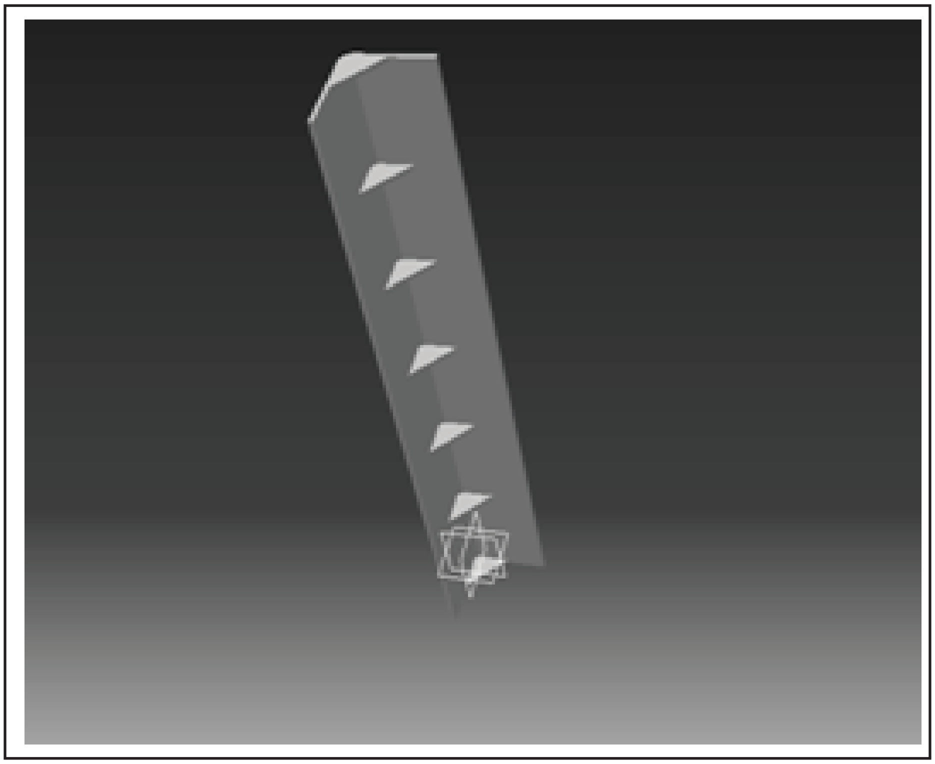

Fig. 5. Column Model With Triangular Stiffener Plate From Corner to Buckling Axis

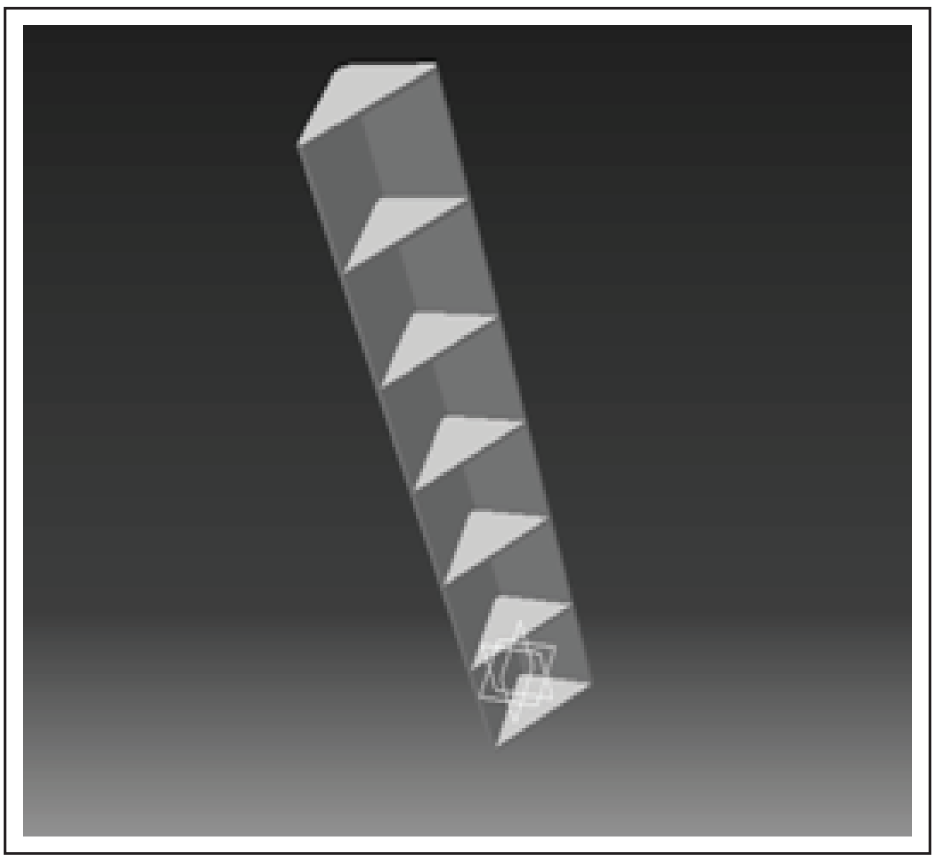

Fig. 6. Column Model With Triangular Stiffener Plate on Full Cross Section.

III. ANALYSIS BY ANSYS WORKBENCH

The model was analyzed by ANSYS with fixed support on one side and remote displacement on the other side (Y component only free, others are constant). The linear buckling analysis was done on the models. Material property of cold formed steel was Young's modulus: $2.034X10^5$ MPa and Poisson's ratio: 0.3. The unit load was applied on the top surface of the column.

Fig. 7 showed the imported model from CATIA to ANSYS and Fig. 8 showed the meshed model. Fig. 9 to Fig. 11 showed the three different mode shapes of the beam [10].

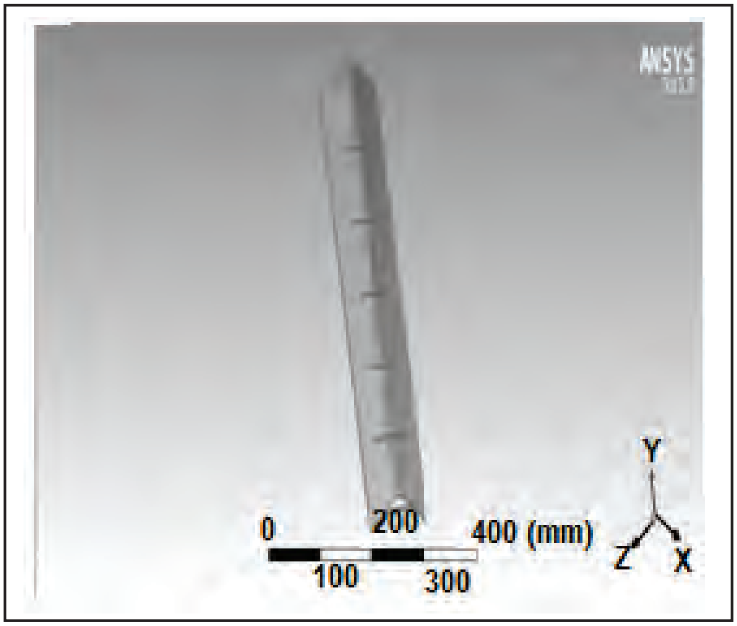

Fig. 7. Model Imported in ANSYS

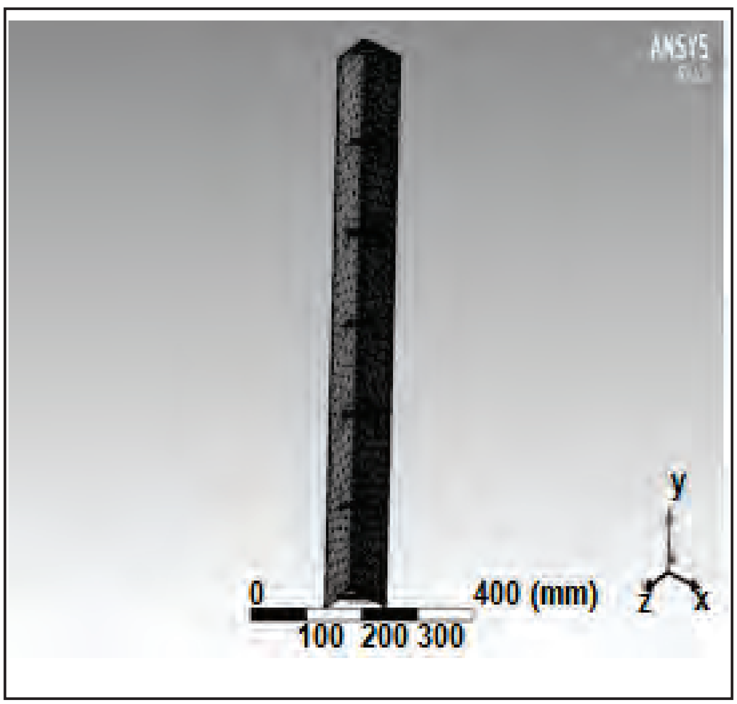

Fig. 8. Meshing the Model

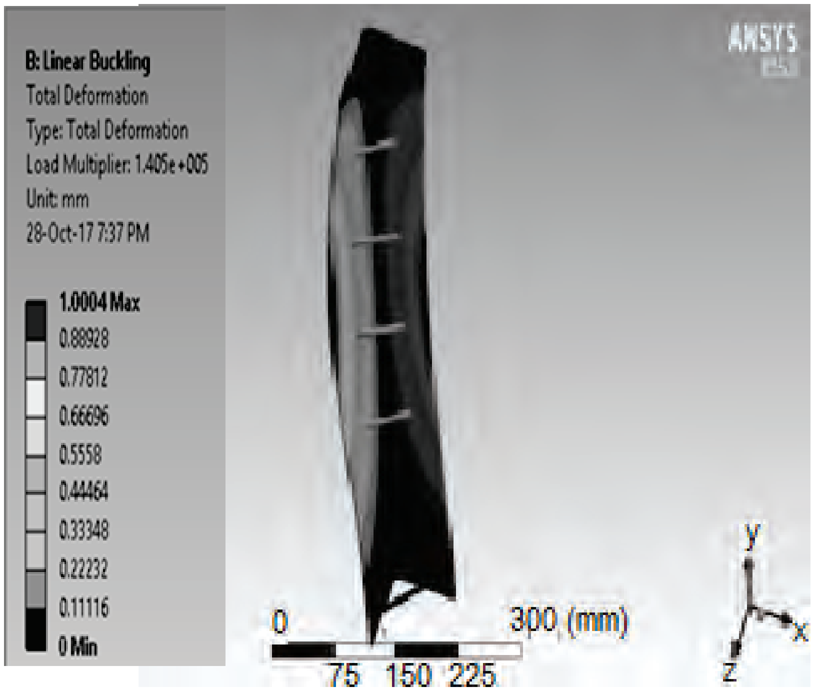

Fig. 9. Mode Shape 1

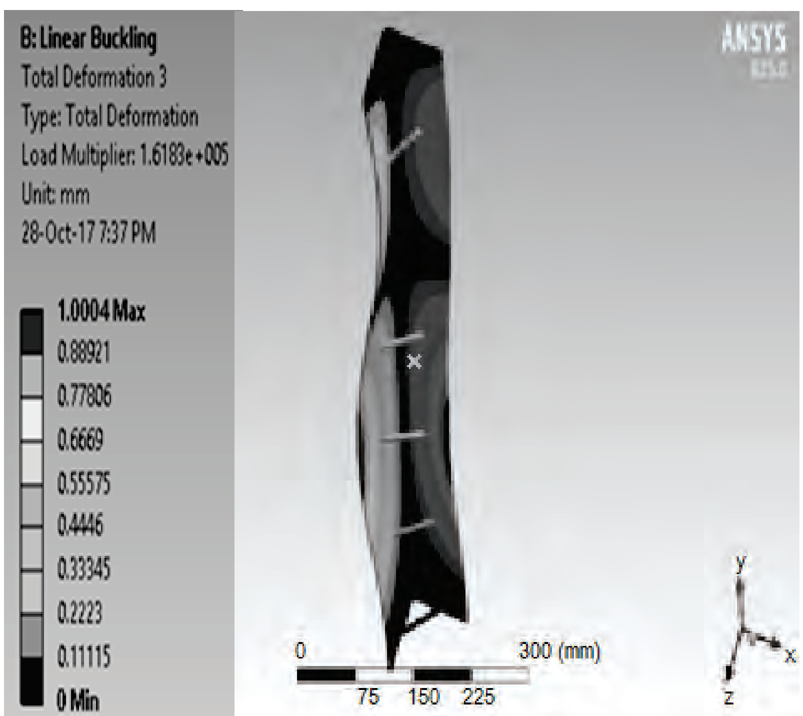

Fig. 10. Mode Shape 2

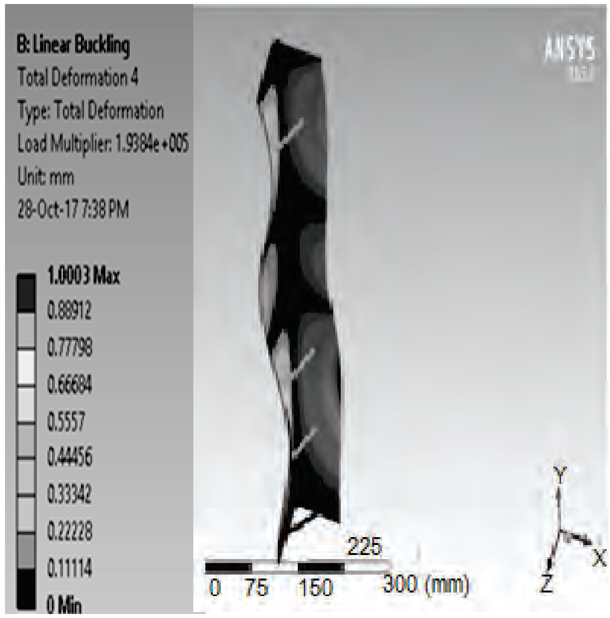

Fig. 11. Mode Shape 3

IV. RESULTS AND DISCUSSION

Table I shows buckling loads of column members with a length of 600 mm, table II presented buckling loads of column members with a length of 900 mm and Table III presented buckling loads of column members with a length of 1200 mm. Fig. 12 to Fig. 26 showed a graphical representations of the results.

From these results, the stiffener placed on full cross section with 100 mm stiffener spacing increases the buckling load from 30% to 100%. The stiffener placed on full cross section with 150 mm stiffener spacing increases the buckling load from 19% to 66%. The stiffener placed on full cross section with 200mm stiffener spacing increases the buckling load from 14% to 44%.

TABLE I.
BUCKLING LOADS OF THE ANGLE SECTION WITH A LENGTH OF 600mm

Length 600mm							
Specimen	Stiffener Spacing	Buckling load (kN)					
		i	ii	iii	iv	v	Conventional
50x50x4	100	211.11	227.92	236.40	215.78	266.87	190.87
	150	207.72	220.87	225.62	209.48	233.10	
	200	206.07	216.62	218.21	206.43	220.48	
60x60x4	100	179.48	199.88	205.78	184.31	245.18	162.31
	150	176.71	193.82	197.00	177.73	208.21	
	200	175.30	182.14	190.04	174.45	193.82	
70x70x4	100	156.97	179.36	184.03	161.87	232.12	141.81
	150	154.44	174.82	176.89	155.42	193.97	
	200	153.35	171.51	171.66	152.26	176.97	
80x80x4	100	140.50	165.81	168.29	146.77	225.02	126.58
	150	138.90	162.48	162.65	139.34	184.14	
	200	137.86	159.32	158.13	136.09	165.92	
100x100x4	100	119.02	149.06	146.21	124.93	213.97	105.89
	150	117.65	146.13	142.06	118.39	175.02	
	200	116.06	144.23	139.15	114.60	152.13	

TABLE II.
BUCKLING LOADS OF THE ANGLE SECTION WITH A LENGTH OF 900mm

Length 900mm							
Specimen	Stiffener Spacing	Buckling load (kN)					
		i	ii	iii	iv	v	Conventional
50x50x4	100	203.66	213.97	222.55	210.33	246.98	185.57
	150	200.33	209.55	218.76	204.43	233.69	
	200	197.72	198.86	202.00	200.71	211.29	
60x60x4	100	174.91	187.16	194.74	185.14	244.28	158.37
	150	172.02	182.77	187.67	178.46	211.29	
	200	169.33	170.91	173.61	173.68	187.93	
70x70x4	100	152.27	166.41	172.18	163.30	224.91	137.67
	150	150.34	162.83	166.09	156.50	192.91	
	200	146.37	147.87	150.49	152.50	166.91	
80x80x4	100	134.33	148.87	153.30	145.25	210.47	121.12
	150	132.46	145.67	148.47	138.49	179.21	
	200	128.46	129.66	131.99	134.20	149.12	
100x100x4	100	111.12	129.12	130.12	124.18	203.58	99.85
	150	110.30	127.66	127.20	117.51	165.78	
	200	105.57	107.46	108.81	113.79	133.22	

TABLE III.
BUCKLING LOADS OF THE ANGLE SECTION WITH A LENGTH OF 1200mm

Length 1200mm							
Specimen	Stiffener Spacing	Buckling load (kN)					
		i	ii	iii	iv	v	Conventional
50x50x4	100	190.52	196.57	203.33	194.88	230.32	177.15
	150	187.49	192.43	196.22	189.79	210.43	
	200	186.00	190.46	192.87	187.56	201.33	
60x60x4	100	167.43	172.40	180.97	175.15	219.02	155.87
	150	164.84	168.63	174.27	169.02	193.34	
	200	163.60	166.06	170.71	166.11	180.27	
70x70x4	100	146.74	152.07	160.03	156.65	205.56	135.94
	150	144.46	148.42	154.10	149.88	176.91	
	200	143.34	146.53	150.89	146.61	161.36	
80x80x4	100	129.95	136.39	143.06	139.52	191.08	120.25
	150	128.07	133.40	138.20	132.79	163.20	
	200	127.13	131.94	135.50	129.63	147.83	
100x100x4	100	106.31	115.16	119.64	117.40	174.46	97.83
	150	104.93	112.77	115.68	110.38	146.19	
	200	104.22	111.63	113.73	107.27	130.13	

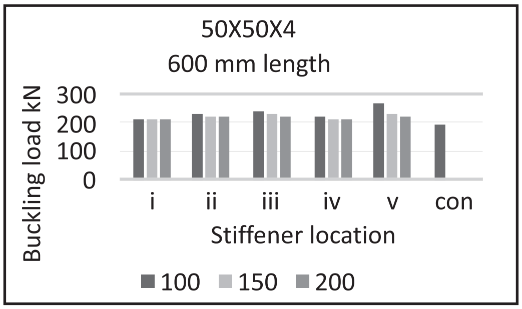

Fig. 12. BucklingLoads of 50X50X4 mm Sized Angles With 600mm Length

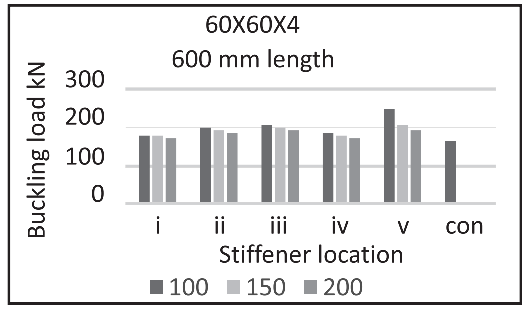

Fig. 13. Buckling Loads of 60X60X4 mm Sized Angles With 600mm Length

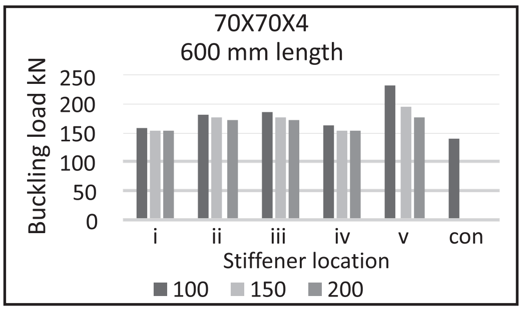

Fig. 14. Buckling Loads of 70X70X4 mm Sized Angles With 600mm Length

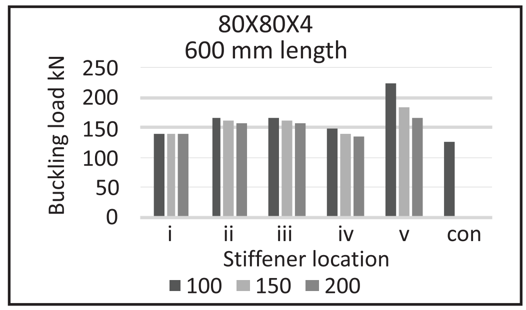

Fig. 15. Buckling Loads of 80X80X4 mm Sized Angles With 600mm Length

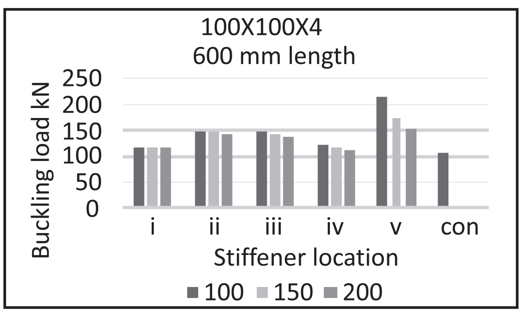

Fig. 16. Buckling Loads of 100X100X4 mm Sized Angles With 600mm Length

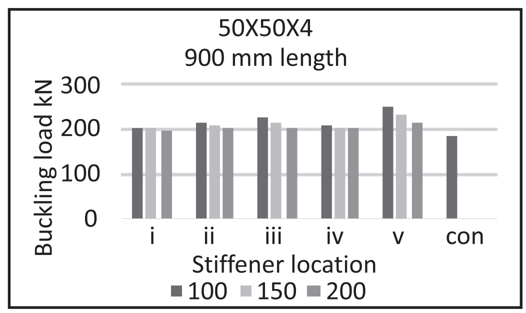

Fig. 17. Buckling Loads of 50X50X4 mm Sized Angles With 900mm Length

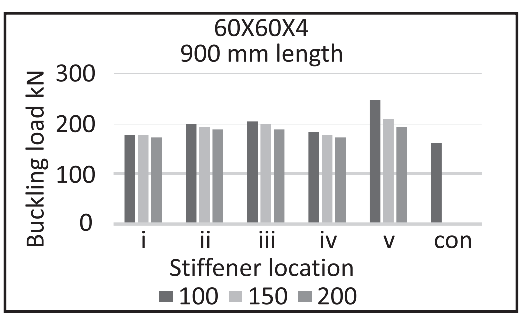

Fig. 18. Buckling Loads of 60X60X4 mm Sized Angles With 900mm Length

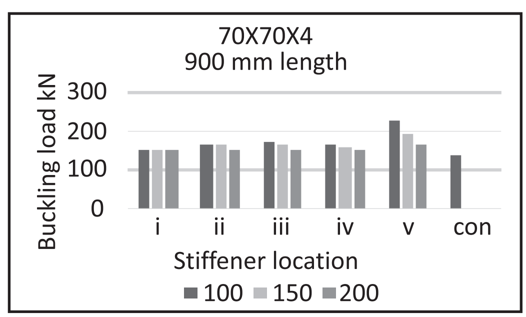

Fig. 19. Buckling Loads of 70X70X4 mm Sized Angles With 900mm Length

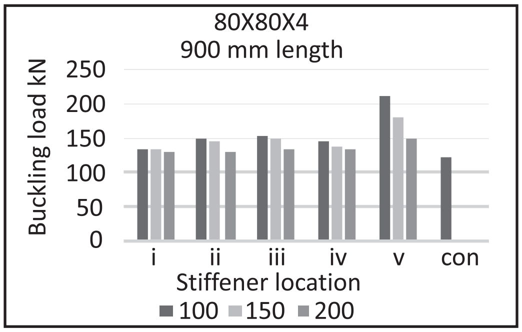

Fig. 20. Buckling loads of 80X80X4 mm sized angles with 900mm length

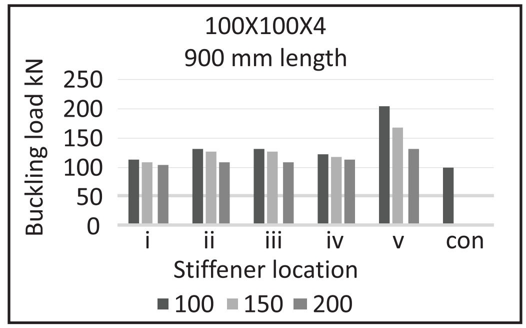

Fig. 21. Buckling loads of 100X100X4 mm sized angles with 900mm length

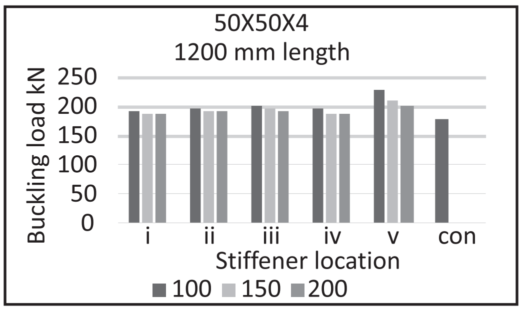

Fig. 22. Buckling Loads of 50X50X4 mm Sized Angles With 1200mm Length

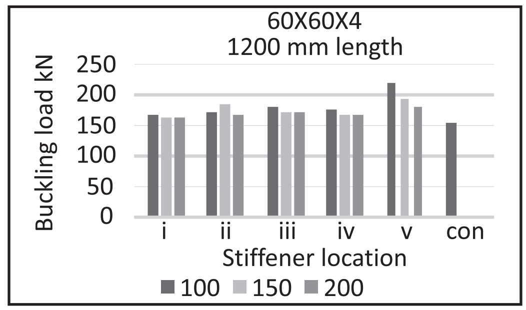

Fig. 23. Buckling Loads of 60X60X4 mm Sized Angles With 1200mm Length

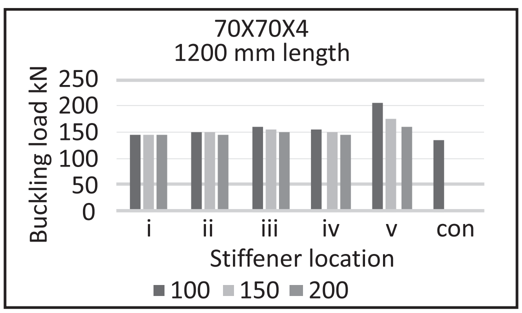

Fig. 24. Buckling Loads of 70X70X4 mm Sized Angles With 1200mm Length

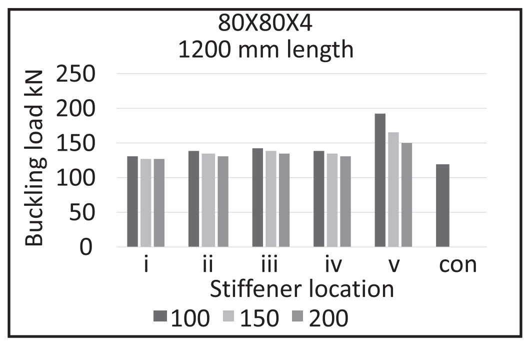

Fig. 25. Buckling Loads of 80X80X4 mm Sized Angles With 1200mm Length

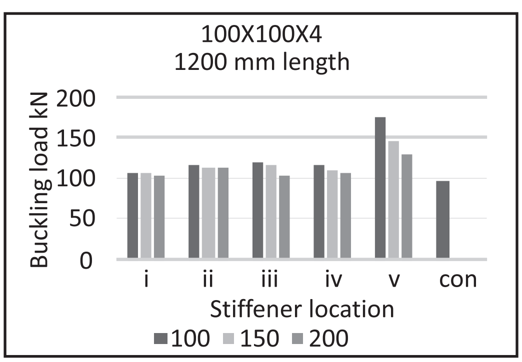

Fig. 26. Buckling Loads of 100X100X4 mm Sized Angles With 1200mm Length

The stiffener placed at both buckling axis and line joining the outer legs with 100 mm stiffener spacing increases the buckling load from 14% to 38%. The stiffener placed at both buckling axis and line joining the outer legs with 150 mm stiffener spacing increases the buckling load from 11% to 34% .The stiffener placed at both buckling axis and line joining the outer legs with 200 mm stiffener spacing increases the buckling load from 8% to 31%.

V. CONCLUSION

This project reveals the buckling load capacity of cold formed steel angles with stiffeners at various locations. Five different sized angles are selected for the investigation.

The results depend on the length, size, stiffener location, and stiffener spacing of angle.

- ❖ Length of angle increases load decreases and vice versa.
- ❖ Size of the angle increases load increases (with same length) and vice versa.
- ❖ Stiffener spacing increases load decreases (with same length) and vice versa.
- ❖ Also the stiffener location decides the buckling load.

The triangular stiffener plate on the full cross section with a spacing of 100 mm gives the 100% increased buckling load carrying capacity compared to unstiffened column. On the other side, the cost for welding and material makes it uneconomical even though the spacing of stiffener is higher.

The stiffener placed at both buckling axis and line joining the outer legs of the angle with 100mm stiffener spacing gives nearly the same amount of buckling load as taken by triangular stiffener plate on the full cross section with stiffener spacing of 200 mm.

On the whole, the stiffener placed at both buckling axis and line joining the outer legs of the angle section is found to be economic as compared to triangular stiffener plate on full cross section. At the same time it has better buckling load carrying capacity.

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