A FINITE ELEMENT STUDY ON THE PERFORMANCE OF CORRUGATED STEEL SECTIONS UNDER COMPRESSION

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Abstract*—Corrugated steel sections are having a wide variety of applications in engineering fields like civil, mechanical, aviation, etc. The unique properties of corrugated steel sections make them a better option compared to the conventional thin steel sections. In the current study behaviour of thin steel shells with corrugations made of mild steel plates under compression is investigated using finite element software ABAQUS. The corrugated sections and the conventional sections under study are having the same area of cross section. For the corrugated sections, trapezoidal profile was used with corrugation angle ranging from 30^o to 90^o. Influence of corrugation height on the characteristics of corrugated section is also studied. In axial compression, corrugated steel section exhibited 1.5 to 2 times the load carrying capacity of conventional steel section. The load carrying capacity was found to be increasing with increasing corrugation angle as well as with increasing corrugation height. It has been also observed that slender members are more sensitive to changes in corrugation profile.

***Index Terms*—Corrugated steel section, compression, corrugation angle, corrugation height, ABAQUS**

I. INTRODUCTION

Steel sections are having many applications in engineering. Conventional steel sections are used as compression members, tension members, etc. The extensive use of steel sections in the engineering fields necessitate studies to improve the structural performance of them. Corrugated steel sections have many advantages over plain steel sections. These include higher load carrying capacity, better performance in flexure and torsion, etc. The corrugations give continuous stiffening which facilitate the utilization of more slender sections. A corrugated section might effortlessly bend in one direction, while it resists bending in the other direction. Some of the applications of corrugated shells include use in web of I- sections, longitudinally or transversely corrugated compression members, etc. Different corrugation profiles commonly used are trapezoidal, triangular, wavy, etc.

Mohammad Nassirnia, Amin Heidarpour, Xiao-Ling Zhao and Jussi Minkkinen [1] studied the behaviour of hollow steel corrugated sections with axial loading. A limited number of parameters have been studied. Stub columns with three different type of corrugation profiles having same area of cross section with corrugation angles 45° and 75° were tested. Benefit-cost analysis was done, which showed that corrugated sections are more beneficial compared to the conventional sections. In the present study, a more elaborate parametric study has been conducted considering different corrugation angles, corrugation heights and slenderness ratios.

II. MATERIAL PROPERTIES

Mild steel is the material used for finite element modelling. Material property values which are used for modelling are as follows: Young's modulus (E) = $2*10^5$ N/mm^2, Poisons' ratio (μ) = 0.3, Density (ρ) = 7860 kg/m^3. Material non-linearity is incorporated by giving plastic properties. i.e. true stress and plastic strain which are obtained after performing tensile coupon test.

III. GEOMETRIC PROPERTIES

For the conventional steel section, square profile is used with side length of 247.5 mm and thickness 3 mm. Various corrugated profiles with their respective abbreviations and corrugation dimension parameters are given in Table 1. All the corrugated profiles and conventional section are having the same cross sectional area. Figure 1 depicts a single side of the corrugation profile. Four such profiles are joined at the corners to form a symmetric corrugated section. The abbreviation 'CA' indicates corrugation angle and 'H' indicates corrugation height. Slenderness ratios (abbreviated as S.R) 10, 25, 40 and 55 are used for calculating length for models.

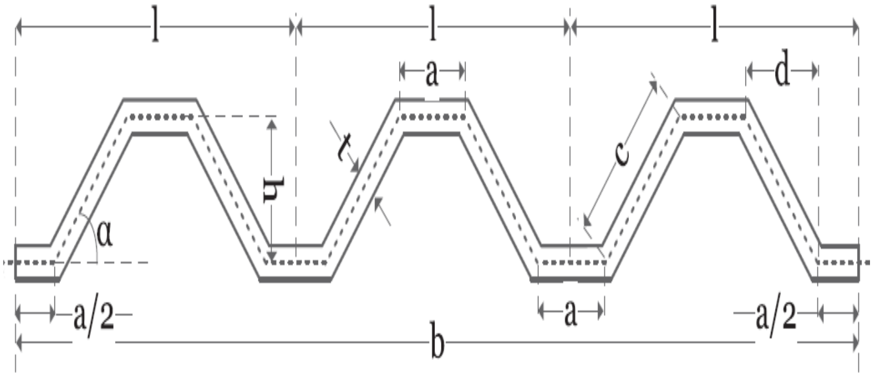

Figure 1 Corrugation profile

Table 1 Corrugation dimensions in mm

	α (degrees)	a	h	t	l	d	c	b
CA30H15	30	11.25	15	3	74.46	25.98	30	223.38
CA45H15	45	20	15	3	70	15	21.21	210
CA60H15	60	23.93	15	3	65.18	8.66	17.32	195.54
CA75H15	75	25.7	15	3	59.42	4.01	15.53	178.26
CA90H15	90	26.25	15	3	52.5	0	15	157.5
CA30H20	30	1.25	20	3	71.78	34.64	40	215.34
CA45H20	45	12.96	20	3	65.92	20	28.28	197.76
CA60H20	60	18.16	20	3	59.41	11.55	23.09	178.23
CA75H20	75	20.54	20	3	51.79	5.36	20.70	155.37
CA90H20	90	21.25	20	3	42.5	0	20	127.5

IV. FINITE ELEMENT MODELLING

The models are created using the finite element software ABAQUS. The models are validated with available experimental results. Material properties are given using property module. Analysis step used for the present study is Statik-Riks which is used for nonlinear analysis of models. Two node sets are created by selecting lower edge nodes and upper edge nodes. Two reference points are created at mid-point of top and bottom of the shell. Rigid body constraint was used to tie the edge nodes to the respective reference points. For applying boundary conditions, bottom of the model is fixed and top is restrained in all degrees of freedom except in axial direction. Compressive load is applied on top of the model. Structured meshing was adopted. S8R elements are used while meshing. S8R elements are 8 noded elements with reduced integration. A mesh size of 10mm x 10mm is adopted after performing mesh convergence study. Geometrical imperfection is also incorporated in the models. After analysis load-deflection graphs are extracted which gives the ultimate load carrying capacity. Figure 2 shows the conventional and corrugated models.

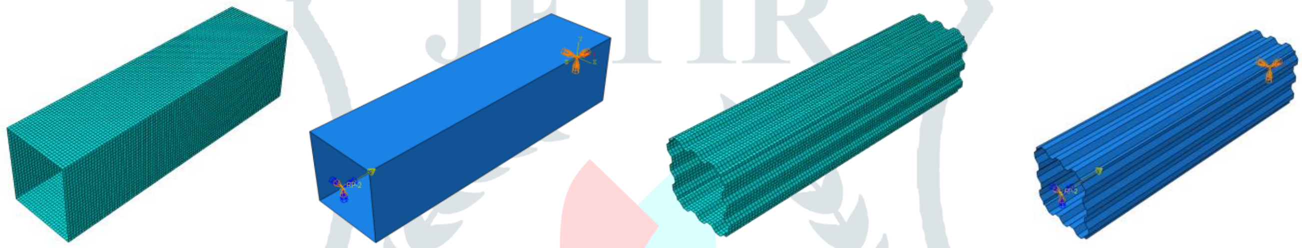

Figure 2 Conventional and corrugated steel models: meshing, boundary conditions and loading

Figure 3 shows the first three mode shapes for conventional and corrugated sections in compression

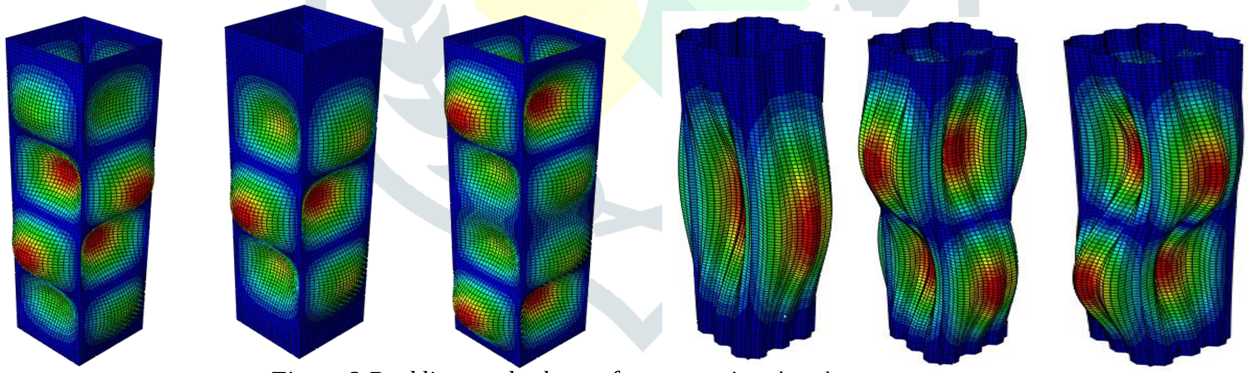

Figure 3 Buckling mode shapes for conventional and corrugated sections

V. RESULTS

The results of the finite element analysis are summarized in Fig.3 to Fig.6. The variation of % increase in load capacity of corrugated shell (compared to the corresponding conventional steel section) vs corrugation angle is plotted for a particular slenderness ratio and two corrugation heights (15 and 20 mm respectively)

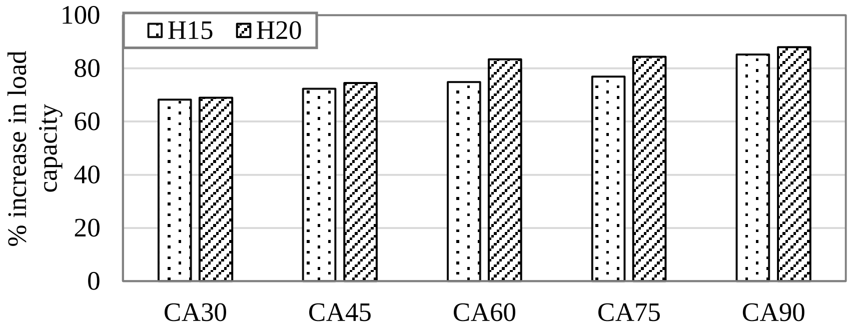

Figure 3 Percentage increase in load capacity vs corrugation angle for slenderness ratio 10

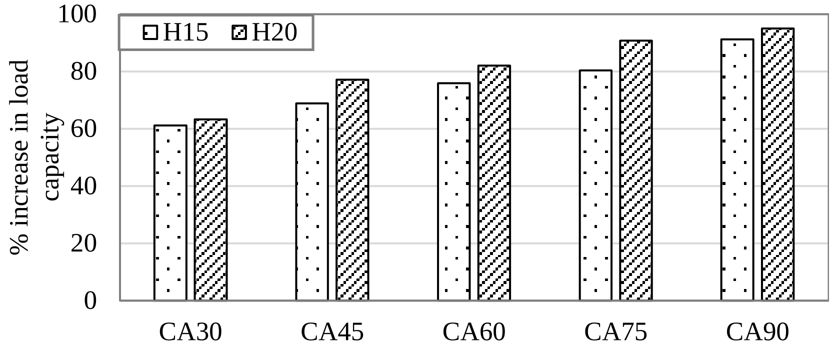

Figure 4 Percentage increase in load capacity vs corrugation angle for slenderness ratio 25

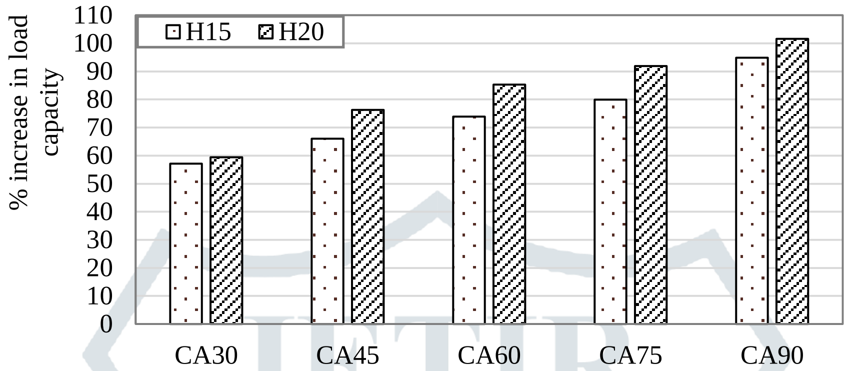

Figure 5 Percentage increase in load capacity vs corrugation angle for slenderness ratio 40

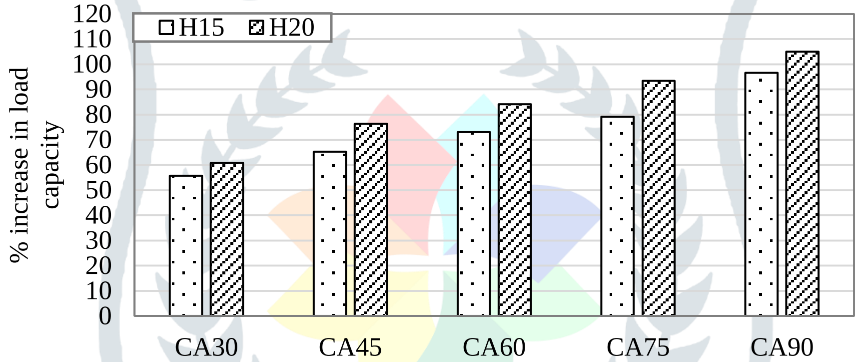

Figure 6 Percentage increase in load capacity vs corrugation angle for slenderness ratio 55

VI. CONCLUSION

The following conclusions are made based on the current study. For corrugated sections in compression as the corrugation angle increases the load carrying capacity increases for a given slenderness ratio. That means 90^o angle is the best option for the optimum corrugated section to carry maximum load. The load carrying capacity of corrugated sections is found to be twice the capacity of corresponding conventional steel section in some cases. The rate of increase in load carrying capacity is more in the case of shells having higher slenderness ratio. i.e. slender members are more sensitive to changes in corrugation profile. It is also obvious from the results that corrugated sections with higher corrugation height can carry higher load. So, for optimum results maximum corrugation height should be adopted. The results clearly indicate that corrugated sections are far superior to conventional sections in resisting compressive loads and can be used in practice for better structural performance.

REFERENCES

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