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Buckling Analysis of Corrugated Hollow Columns Using Trapezoidal and Sinusoidal Corrugations

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Abstract - *Corrugated steel sections are having variety of applications in engineering fields like civil, mechanical etc. The novel properties of corrugated steel sections make them a better idea compared to the conventional thin sections. The corrugated sections and the conventional sections (Rectangular columns) under study are having the same region of cross sectional area. For the corrugated sections, trapezoidal and sinusoidal profile were used with corrugation angle 45°. The best load carried column were connected with Ultra high strength (UHS) steel tubes. This was done to ensure effective utilization of UHS steel tubes in civil engineering field. It is produced from durable high-strength structural steel material. Numerical Investigation were done to conduct the behaviour of innovative corrugated hollow steel columns under axial loading and buckling using ANSYS 16 WORKBENCH. It has been also observed that slender members are more sensitive to changes in corrugation profile.*

Key Words: **Corrugated plates, Hollow columns, Ultra high strength, Buckling load, Corrugation angle.**

1. INTRODUCTION

Nowadays, lighter steel structures are extensively used in building and construction industry over reinforced concrete due to its intrinsic strength, prefabrication and quicker transportability to the work site and faster erection. With increased use of steel, the varieties of steel sections are used. Among these sections, the Hollow structural sections (HSS) or Structural hollow sections were most reliable one. A HSS is a type of metal profile with a hollow tubular cross section. HSS members can be circular, square, or rectangular sections.

Corrugated steel is a building material composed of sheets of hot-dip galvanized mild steel, cold-rolled to produce a linear corrugated pattern in them. The corrugated plates, known as self-strengthened plates, are regularly produced from flat plates. The corrugations increase the bending strength of the sheet in the direction perpendicular to the corrugations, but not parallel to them. Normally each sheet is manufactured longer in its strong direction. Corrugated plates fall in this category and also have a wide range of application in various engineering fields. They are lightweight, economical, and have much higher load carrying capacities than flat plates, which ensure their popularity.

The profile of a corrugated plate may have several shapes: sinusoidal, trapezoidal, triangular, or rectangular as shown in Table 1. The most common profiles used are trapezoidal and sinusoidal. The shape of profile has little influence on the performance characteristics of a self-strengthened plate; however for a corrugated plate with thickness of (t), the depth of corrugation (h) and corrugation angle (α) are more influential parameters[2,10]

ADVANTAGES OF CORRUGATED PLATES

1. Corrugated plates are lightweight, economical, and have much higher load carrying capacities than flat plates.

2. The corrugation shape provides continuous stiffening which permits the use of thinner plates.

3. A corrugated plate can easily be bent in one direction, whereas it retains its rigidity in the other direction.

4. Fabrication costs for elements with corrugated panels are normally lower than those with stiffened plates.

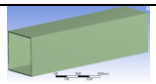
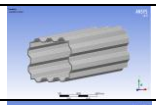
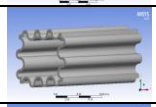
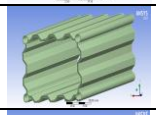
2. NUMERICAL INVESTIGATION USING ANSYS WORKBENCH 16

2.1 BASE MODEL

Numerical modelling of Square Hollow column was done using ANSYS 16 WORKBENCH, a finite element software for mathematical modelling and analysis. The software is capable of solving complex structural engineering problems more effectively and complex models can be completed using this. Material property for the model was selected from engineering data section of the software, where all the available materials are pre-assigned with a default value for various properties. All the steel members were modelled using SOLID 186 element. Geometry of Square hollow corrugated column model was sketched in workbench window as shown in fig 1. A Rectangular hollow corrugated column consists of an inner and outer length as R1 = 252 X 175 mm and R2 = 242 X 165 mm respectively. It was modelled with thickness, 5 mm.

The Rectangular hollow column base model having an area of 44100 mm ^{2}. Similarly the other 4 models also were done maintaining the same area of cross section to make a comparative study. For applying boundary conditions, bottom of the model is fixed and top is restrained in all degrees of freedom except in axial direction. RECT Type 1 UHS is modelled with tube made of having outer diameter as 25mm and inner diameter as 20mm. Table I shows the modelled view of hollow corrugated columns. Columns without UHS Tubes are known as conventional type of column in this study.

Table -1: Modelled View of Hollow Corrugated Columns

SPECIMEN NAME	MODEL	COLUMN HEIGHT (m)
RECT BASE MODEL		1
RECT Type 1		1
RECT Type 2		1
RECT Type 1UHS		1
RECT Type 2 UHS		1

RECT- Rectangular

UHS –Ultra High Strength

Type 1 – Trapezoidal Shaped

Type 2 – Sinusoidal Shaped

2.2 ANALYSIS CONDUCTED FOR PRESENT STUDY

Eigenvalue buckling analysis is a good approximation technique that, although less precise than nonlinear buckling analysis, is a relatively quick and easy way to determine, for example, critical loads that induce buckling and possible buckling modes (that is, the different ways the structural member can deform). This type of analysis was carried in this study. For the analysis all the models are subjected to a displacement of 9 mm on top with initial sub steps as 3.The stepdown load was found out when a displacement of 3mm was given. The buckling load is calculated by multiplying the load multiplier with the stepdown load (Reaction force). Fig 1 shows the calculation of buckling load for RECT Type 1.

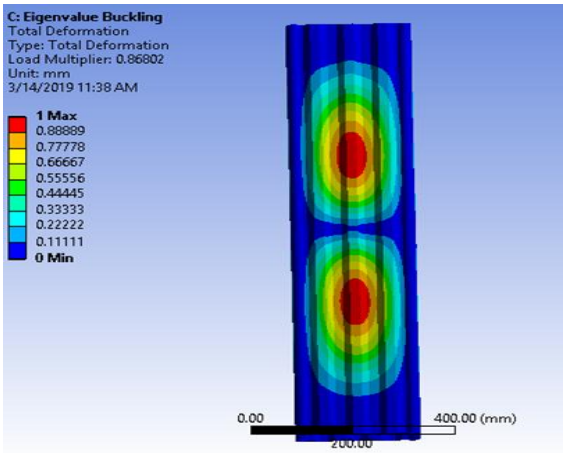


Fig.-1: Deformation of RECT Type 1 UHS

Load Multiplier = 0.8602 and Buckling load = 1269.04kN

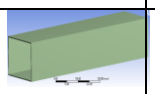
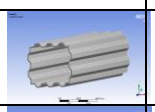
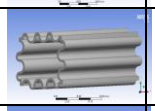
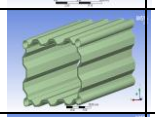
Table-2: Calculation of buckling load

SPECIMEN NAME	FORCE REACTION (kN)	LOAD MULTIPLIER	BUCKLING LOAD (kN)
RECT BASE MODEL	1250	0.272	340
RECT Type 1	901.7	0.86869	783.29
RECT Type 2	362.34	1.473	534.016
RECT Type 1 UHS	1462	0.86802	1269.04
RECT Type 2 UHS	523	2.350	1231.557

3. RESULTS

The results of corrugated hollow columns using different corrugated plates under buckling using finite element analysis have been discussed. The analysis was conducted to obtain best type of corrugated column which could carry the maximum value of buckling load. The analysis was done for obtaining the mode shapes of each type of column and find which is better. Table 3 below shows the values of buckling load and stresses obtained after doing Analysis.

Table -3: Values of buckling load and Stress

SPECIMEN NAME	MODEL	BUCKLING LOAD (kN)	MAXIMUM STRESS (N/mm²)
RECT BASE MODEL		75	300
RECT Type 1		783.29	300
RECT Type 2		534.016	357.79
RECT Type 1UHS		1269.04	363.39
RECT Type 2 UHS		1231.557	344.71

3.1 BUCKLING LOAD

When a structure is subjected to compressive stress, buckling may occur. As an applied load is increased on a member, such as a column, it will ultimately become large enough to cause the member to become unstable and it is said to have buckled.

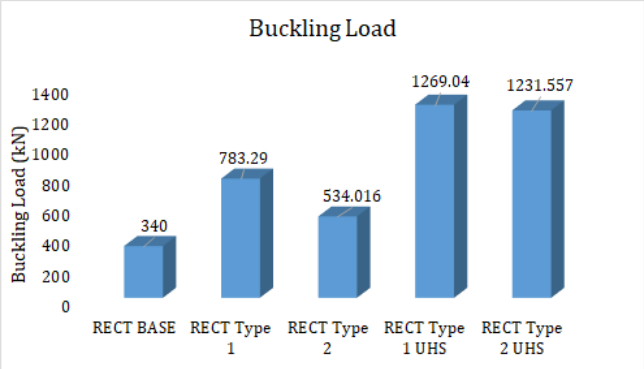


Chart -1: Graph showing the buckling value

From Chart 1, it is seen that the conventional column and column having corrugation carry double the axial load than conventional column. Hence the load carrying capacity is increased by corrugation shape.

3.2 MAXIMUM STRESS

Equivalent stress (also called *von Mises stress*) is often used in design work because it allows any arbitrary three-dimensional stress state to be represented as a single positive stress value. It is part of the maximum equivalent stress failure theory used to predict yielding in a ductile material.

After doing analysis we find that RECT Type 1 UHS have a higher value of stress as 363.39 N/mm² as seen in Chart 2 below. This is due to the trapezoidal shape and the UHS Tube.

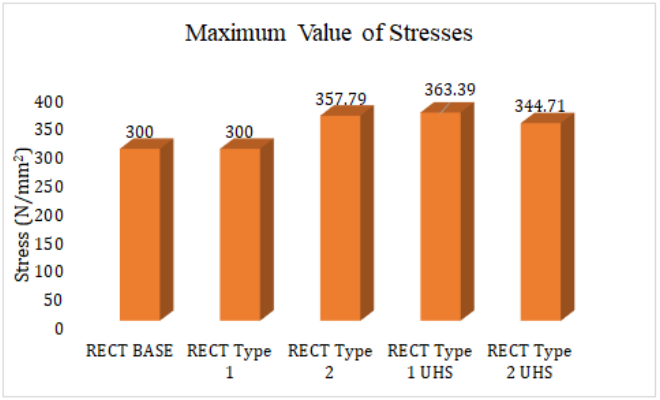


Chart -2: Maximum Value of Stresses

4. CONCLUSIONS

The following major conclusions are drawn based on the studies carried out under this investigation.

- Conventional columns carry less load as the load is transferred through edges while corrugated column's transfer rate is increased due to sufficient corrugations provided.
- Corrugation has not only increased the load carrying capacity but also strength and ductility of column. The conventional column buckle very early before the buckling of corrugated column.
- Due to corrugation and hollow structure in columns, the weight and thickness of the column is decreased without decrease in load carrying capacity. This decreases the cost of the structure and building becomes efficient. These columns can also be used in light weight buildings.
- For a very less thickness, the innovative HSS column carries a high load. By further research more slender column can be made which can carry more loads than conventional welded column having same strength and volume.
- RECT Type 1 UHS is the best column as it can carry a buckling load of 1269.04 kN, which means failure of the column occur only after this load. It is due to sufficient corrugations provided than conventional column.

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BIOGRAPHIES

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