COMPARATIVE STUDY OF INNOVATIVE CORRUGATED HOLLOW COLUMNS AND CONVENTIONAL COLUMN

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Abstract

In many situations, lighter steel structures are used to the heavier alternatives such as reinforce concrete or prestress concrete. With the development of steel as a construction material, the varieties of steel sections were also increased. Among these sections, the Hollow structural sections (HSS) or Structural hollow sections were the most reliable one. Extensive research has been carried of corrugated web beam and girders, but fewer amounts of research for corrugated column and its utilization and advantages is available. In current project, five types of innovative hollow steel section (HSS) column are designed; fabricated and tested. The present work is divided in two broad parts such that in the first part, the study of the behavior of the innovative corrugated steel column under axial loading using UTM was conducted, this part being called experimental work. In the second part, the results of the practical experiments are checked with theoretical results which are obtained by analytical method by using computer software ANSYS. The results obtained from experimental testing and computer analysis are compared and validated. The comparison of corrugated hollow column with conventional hollow column is done to know the advantages of innovative column over conventional column. Keywords: Corrugated hollow column, computer software, thin walled structures, innovative column, and conventional column.

I. Introduction

Nowadays, lighter steel structures are extensively used in building and construction industry. The main advantages of steel structure over reinforced concrete are 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 hollow structural section (HSS) is a type of metal profile with a hollow tubular cross section. HSS members can be circular, square, or rectangular sections. The extensive use of thin-walled steel structural systems in the building and construction industry is mostly indebted for their high strength to weight ratio attributes and remarkable fabrication versatility. 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 and have attracted research interest since they were introduced. The corrugation shape provides continuous stiffening which permits the use of thinner plates. A corrugated plate can easily be bent in one direction, whereas it retains its rigidity in the other direction. 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 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 steel is lightweight and easily transported. It was and still is widely used especially in rural and military buildings such as sheds and water tanks. Fabrication costs for elements with corrugated panels are normally lower than those with stiffened plates. It is also worth noting that limited research has been conducted on the structures consisting of corrugated shells. From the other side, although corrugated plates have been studied either individually or implemented in girders web, they have never been used in fabricating of hollow columns. Therefore, for better understanding of the performance of the proposed innovative corrugated columns, column specimen are designed, fabricated and tested. Thus, numerical and experimental models are required to be developed and compared.

II. Formulation of Problem

In current project, five types of innovative hollow steel section (HSS) column are designed; fabricated and tested experimentally and analytically. In the experimental study, a total of five innovative HSS steel column specimens are tested. These specimens are fabricated using steel plates having respective thicknesses. The complete load−deflection behavior and strength of column specimens were obtained and the results are discussed in the study. In second part, 3-D solid model of innovative HSS steel column is generated by using modeling software ANSYS. Thus, we will be analyzing the various parameters of innovative hollow corrugated columns such as loading capacity, buckling of column, stress, strain and deformations analytically. The results obtained from experimental testing and computer analysis are compared and validated.

III. Innovative hollow steel section (HSS) columns

In current study five different types of column are designed, fabricated and tested. In some of the columns corrugated steel plates are used while in some columns there are hexagonal openings in flat steel plates. Using these different steel plates HSS columns are prepared by welding four steel plated at corners. This paper aims at numerical and experimental study on these five different types of columns under compressive loads.

A. Corrugated steel plates

Corrugated steel plated are produced by cold forming of initially flat or plane steel plates. There are many types of corrugation shapes available such as sinusoidal, triangular, trapezoidal, rectangular, etc. from which trapezoidal corrugation is used in current study. The thickness of plates is taken as 3mm,

Inclination angle equals to 45˚ is considered and corrugation height of 15mm is taken into consideration for corrugated steel plates. Three modules of corrugation are used for corrugation steel plates. Figure1. Shows a typical corrugated steel plate used in innovative steel columns. Corresponding geometric parameters for each corrugated steel plate is given in Table 1.

B. Corrugation procedure

Steel structural members formed by using cold forming are widely used nowadays in steel construction industry. This is because cold forming is cheaper than hot rolled sections and they allow weight reduction.

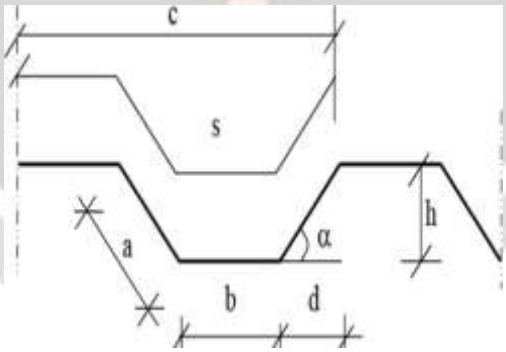
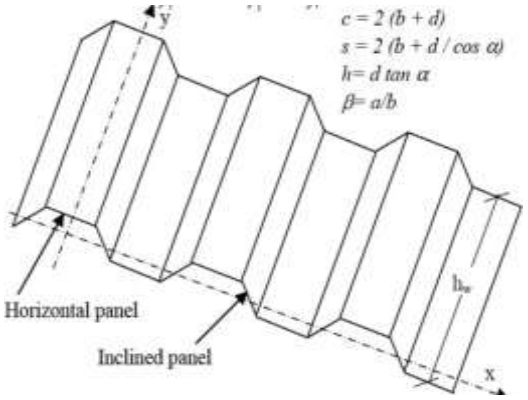


Fig 1. Trapezoidal corrugated steel plate cross section and dimension notations.

α	h	a	b	d	c	h_w
45˚	15 mm	20 mm	20 mm	15 mm	70 mm	700 mm

Table1. Corrugation dimension parameter (in mm)



The initially flat plate is turned into corrugated steel plate by cold forming process. There are many methods of cold forming but here we use press braking of flat plates to form corrugated plates. A 250 ton press braking machine is used and individual fold are formed in between 16mm V block die. Generally, the cold forming procedures changes some properties of original material, but it depends upon the chemical composition of material here steel. In press braking method, the strength gain happens in corner region and the properties flat region of plate remains unchanged.

A. Fabrications of the columns

Hollow steel section (HSS) column consists of four steel plates. These plates are welded at corner by using butt weld. The height of column is kept constant i.e. L = 700mm. cross sectional size of all columns is taken as 210mm x 210mm. In some of steel plates hexagonal openings are made of similar dimensions for reduction of weight and better performance of column. Length of side of hexagon equals 45mm for hexagonal opening. In total five different types of columns are designed and fabricated According to dimensions of conventional HSS column, innovative corrugated steel column is designed by considering equal volume and corrugated steel plates using press brake machine.

Fig 2. Cold forming of initially flat plates into Length of the beam. In innovative corrugated steel column, dimensions are same, only thickness is varie

(A) (B) (C) (D) (E)

Fig 3. Different types of fabricated innovative HSS columns, 3(A) Column type 1, 3(B) Column type 2

In column type 1, all four steel plates are flat plates.

For column type 2, all steel plates are corrugated plates. In column type 3, two plates are flat and two plates are corrugated and are welded on opposite side such that they face each other.

For column type 4, is similar to type 1 but consists of four hexagonal openings on two opposite sides.

In column type 5, it is similar to type 3 but consists of four hexagonal opening on flat plates on opposite sides. Fabricated columns and their specifications and type are given in table 2 below.

Figure 2 shows different fabricated innovative HSS columns.

Fig 3(C) Column type 3, 3(D) Column type 4, 3(E) Column type 5

Table 2.Fabricated Column and their Specifications

Sr. no.	Column name	Type of column
1	Column Type 1	Conventional HSS column
2	Column Type 2	Corrugated HSS column
3	Column Type 3	Two side corrugated 2 side plane column
4	Column Type 4	Conventional HSS column with hexagonal openings
5	Column Type 5	Two side corrugated 2 side plane column with hexagonal openings

IV. Experimental Works

All the five innovative HSS columns are tested by using 1000KN UTM machine. A data acquisition instrument was used which automatically collected the test data.

A static compression test is carried out on the column specimens for obtaining load displacement. The column specimen is located between two rigid blocks, of which bottom block is fixed while the top block is moving downward during the test. The boundary condition at both ends of column specimen is assumed to be clamped, because the particular shape of column specimens avoids them from translation and rotation.

A steel plate of thickness 15mm is kept on each of the column specimen before giving any load. This is done to equally distribute the machine load on all top faces of the column specimen. During the testing, the corresponding load and displacement for every second of test are recorded using data taker. Figure 4 below shows the innovative HSS column setup and equipments.

All five specimens fail due to local buckling. Local buckling occurs first and it increases as the load increases. Buckling is maximum at the ultimate load by which overall displacement increases.

I. Numerical Modeling

The computation of loads acting on body and deformation caused due to that body gives us the collapse analysis of that body. In current project along with experimental work, a finite element model is also developed to know the behavior of innovative HSS column under compressive loads. The results obtained from finite element model are compared with experimental tests. The FE model was generated using software ANSYS. FE models are based on measured geometries of the column specimens. SHELL 181 is used in this study to mesh the innovative HSS steel column. SHELL 181 is a 4 node shell element each node consisting of 6 degree of freedom. As shown in figure, a plate is fixed on top of column specimen where load is applied at middle of plate so that load is distributed equally along top face of column specimen and result obtained is accurate. The grade of steel is kept same all column specimens. Modulus of elasticity of steel equals to 200GPa. Figure 6 shows FE model of Column type 2 which is a corrugated steel HSS column.

All the FE models of column specimen are generated. Strength analysis is carried out to find out the load carrying capacity of beams and Stress induced at critical location in ANSYS software. Following steps are performed on the ANSYS:

Fig 4. Innovative HSS column setup and equipments

1. Preference- A static structural analysis gives the deflection, stresses, strains, and forces in structures or elements caused due to loads.

2. Pre-processor- A. Element type- SHELL181 is used for 3-D modeling of solid structures.

II. Results and Discussion

The behavior of innovative HSS steel column under compressive load is discussed in following section below. The comparison of experimental results with that of numerical FE models is also done.

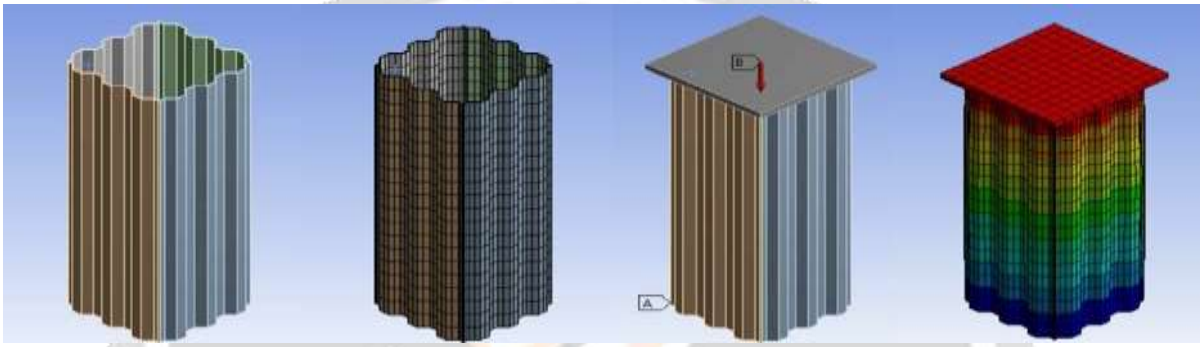
A. Numerical Model Verification

The load versus deformation curve obtained from FE model is compared with the result from experimental work in figure 7. From the comparison it is found out that the FE model has excellently predicted the experimental behavior of the innovative HSS steel columns. The results show FE model give satisfactory results for different parameters such as strength, deformation and stress very much accurately.

B. Failure mechanism

For the compressive test on column specimens the load was increased from zero to peak load. All the column specimens failed due to local buckling failure

B. Material Properties- Material properties are entered for structural steel.



(A) (B) (C) (D)

Fig 6. FE model of column type 2 (corrugated steel HSS column), Fig 6(A) Solid Model of Column Fig 6(B) Mesh Model of Column,

Fig 6(C) Boundary Conditions of Column, Fig 6(D) Total Deformation

Initially buckling occurred in plates by which horizontal displacement increased and overall buckling occurred at ultimate load.

C. Hexagonal Opening Advantages

The provision of hexagonal opening in column decreases the weight and volume of column thus decreasing its cost. Hexagonal opening made at equal intervals bear the load effectively. The buckling occurred by these is slightly more than steel column specimen having no opening but the deformation caused is not much as compared to them. Also these opening can be used to gain access to services and reduce the use of costly steel. It can be used for light weight constructions.

D. Performance of Innovative Columns

By observing the graphs in Figure 7 and figure 8 it can be clearly seen that 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. For the column consisting of hexagonal opening, the corrugated columns have much more energy absorption than conventional or plane column consisting of hexagonal openings. Thus, corrugated column and other innovative HSS columns can be used instead of conventional HSS column as they have more energy absorption and are light weight due to their smaller thickness than conventional column

I. Conclusions

The current study has presented the behavior of Innovative HSS steel column under Compressive loading and its comparison. With experimental testing of column, a finite element model has also prepared and compared with the results of experimental work. The comparison of both experimental and numerical analysis gives satisfactory results.

- The experimental tests carried out on the column specimen show that the corrugated HSS column and column having corrugation and hexagonal opening carry double the axial load than conventional HSS column. Hence the load carrying capacity is increased by corrugation shape.

- The provision of hexagonal opening in column decreases the weight and volume of column thus decreasing its cost. Hexagonal opening made at equal intervals bear the load effectively. The buckling occurred by these is slightly more than steel column specimen having no opening but the deformation caused is not much as compared to them. Also these opening can be used to gain access to services and reduce the use of costly steel. It can be used for light weight constructions.

- Due to corrugation and hexagonal opening 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.

- From the experimental and numerical analysis, it can be seen that innovative HSS column have high energy absorption. Therefore they can be used in conditions such as cyclic loading, earthquake load, blast load and other high energy loading.

- 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

Fig 7A Comparison of Load V/S Deflection for numerical and experimental results for column 1

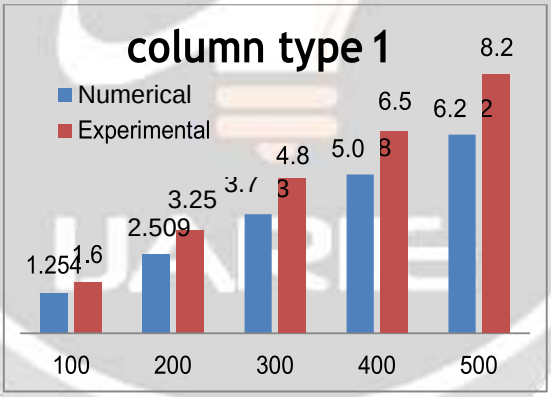


Fig 7B Comparison of Load V/S Deflection for numerical and experimental results for column 2

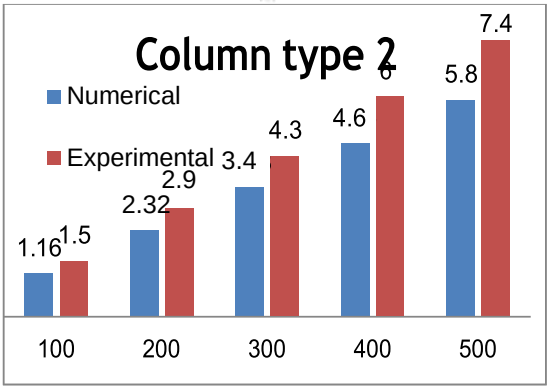


Fig 7C Comparison of Load V/S Deflection for numerical and experimental results for column 3

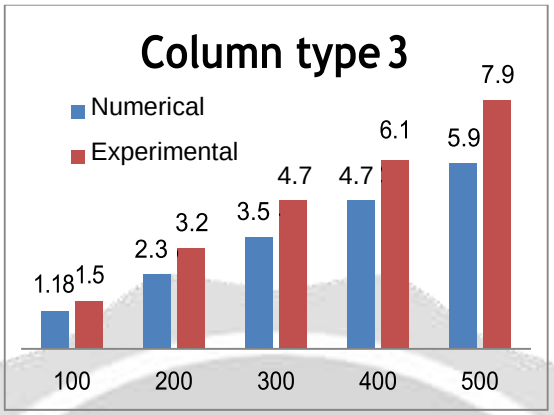


Fig 7D Comparison of Load V/S Deflection for numerical and experimental results for column 4

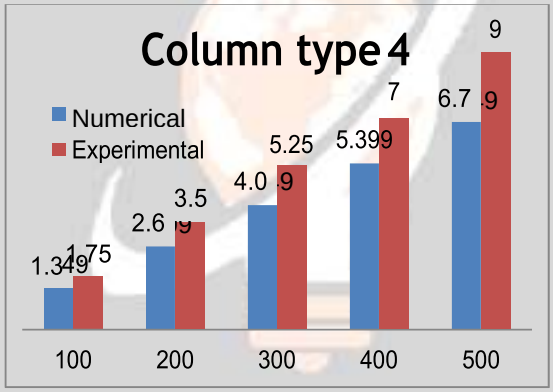
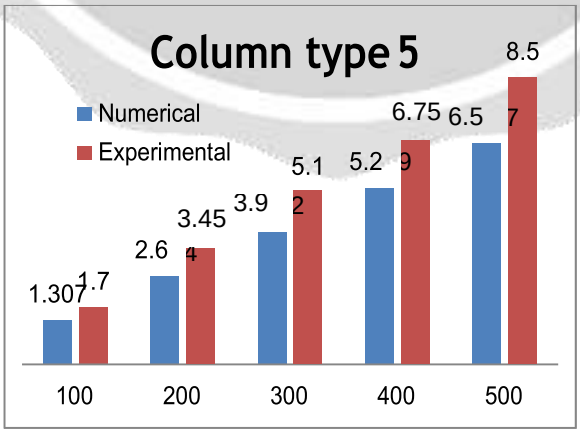


Fig 7E Comparison of Load V/S Deflection for numerical and experimental results for column 5



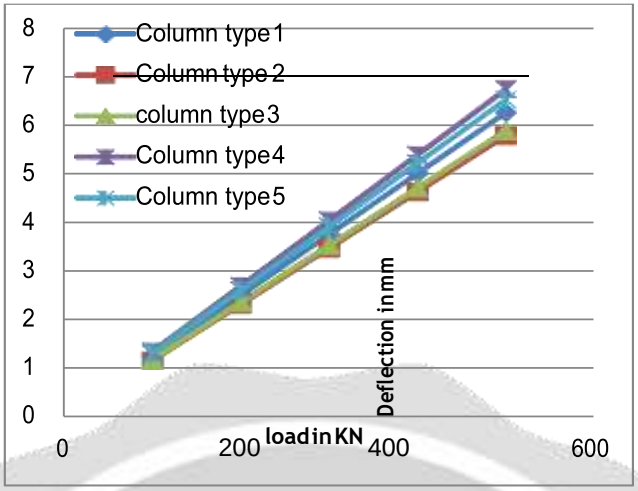


Fig 8 Load V/S Deflection by Using ANSYS Results

- Thus, corrugated column and other innovative HSS columns can be used instead of conventional HSS column as they have more energy absorption and are light weight due to their smaller thickness than conventional column.

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