"COMPARATIVE STUDYOF INNOVATIVE CORRUGATED HSS COLUMNS AND CONVENTIONAL HSS COLUMNS "

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Abstract

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 fallen in this category, 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. It has been demonstrated that high performance sections are required to be developed for extreme action. Many researchers have studied capacity of various types of novel cross sections. Aoki et al studied the local buckling behavior of short length regular polygonal steel columns fabricated from two half section pieces made of folded plates. The empirical design formula based on the test data were presented for five different section profiles. Heidarpour et al. have recently studied the mechanical behavior of a new-style innovative stub columns utilizing mild-steel flat plates and stainless steel tubes or very high strength steel tubes at the corners. Narayanan and Mahendran investigated the buckling behaviour of a series of innovative cold-formed steel columns all of which failed by distortional buckling with very little post-buckling strength. Sixteen innovative column sections made of G550 and G250 steel with variety of cross-sections and dimensions were investigated. Taoetal presented the improvement of ductile behavior of stiffened composite stub columns with various methods

Introduction

In many situations, lighter steel structures are invariably preferred to the heavier alternatives such as reinforced concrete or prestressed concrete. The main advantages of steel structures are its intrinsic strength, prefabrication and quicker transportability to the work site and faster erection. Steel structures can easily dismantle without loss to the integrity of the original structure. Most structural steel units were prefabricated in a workshop with a superior quality control compared to In-situ construction. Tolerances specified in the Indian Standard codes for structural steel components during the fabrication erection are small compared to similar reinforced concrete structures. Steel also plays an important role in composite construction in conjunction with reinforced and prestressed concrete structure. 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. Due to their outstanding features, the application of these sections in present commercial market has been tremendously increased. In the recent past, HSS was commonly available in mild steel, such as A500 grade B. Today, HSS is commonly available in mild steel, A500 grade C. Other steel grades available for HSS are A847 (weathering steel), A1065 (large sections up to 50 inch sq made with SAW process), and recently approved A1085 (higher strength, tighter tolerances than A500). Square HSS is made the same way as pipe.

During the manufacturing process flat steel plate is gradually changed in shape to become round where the edges are presented ready to weld. The edges are then welded together to form the mother tube. During the manufacturing process the mother tube goes through a series of shaping stands which form the round HSS (mother tube) into the final square or rectangular shape. Most American manufacturers adhere to the ASTM A500 or newly adopted ASTM A1085 standards, while Canadian manufacturers follow both ASTM A500 and CSA G40.21. European hollow sections are generally in accordance with the EN 10210 standard. HSS is often filled with concrete to improve fire rating, as well as robustness this is done, the product is referred to as a "Lally column" after its inventor John Lally of Waltham, Massachusetts. However, the pronunciation is often corrupted to "lolly column". For example, barriers around parking areas, bollards, made of HSS are often filled, to at least bumper height, with concrete. This is an inexpensive (when replacement costs are factored in) way of adding compressive strength to the bollard, which can help prevent unsightly local denting, though does not generally significantly increase the overall structural properties of the bollard.

Typically, these designations will also relate to metric sizes, thus the dimensions and tolerances differ slightly from HSS. The history of hollow structural section was very old and interesting because of their shape. The origin of Hollow structural section was connected with the origin and development of steel only. Basically, the concept of hollow structural section was developed by day to day lifestyle, first the concept of steel and then after the use of steel for different purposes. The concept of circle was firstly originated and then after square, rectangle etc. Initially, they were used for different purposes such as wheels of bullock carts, for different shapes of pot etc. First the conventional steels were used for different structures and then after, on identifying the benefits of different shapes such as circular, square, rectangular etc. The hollow sections were developed, experimented and used for construction purpose. The excellent properties of the tubular shape have been recognized for a long time i.e. from ancient time. In 18th century, the first production methods for seamless and welded circular hollow sections were developed. In 1886, the “Mannesmann Brothers” developed the skew roll piercing process.

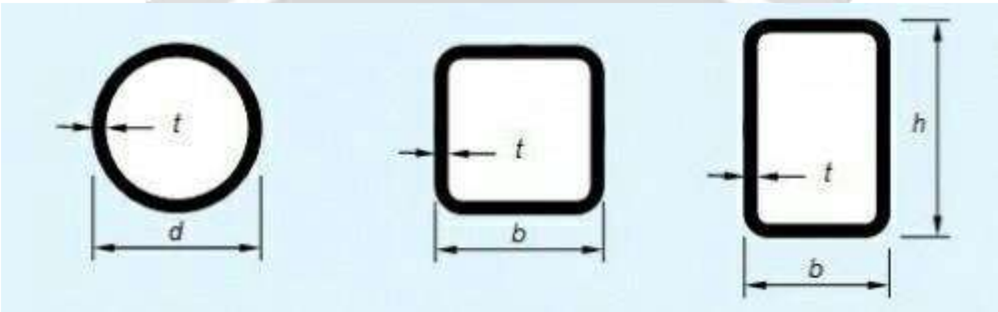


Fig 1.1 Different types of hollow structural section

1. Fundamental Details:

A column in structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member. For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest. In architecture, "column" refers to such a structural element that also has certain proportional and decorative features.

Stress: The stress in the column cross-section can be calculated as

Where, f is assumed to be uniform over the entire cross-section.

This ideal state is never reached. The stress-state will be non-uniform due to:

- Accidental eccentricity of loading with respect to the centroid
- Member out of straightness (crookedness), or
- Residual stresses in the member cross-section due to fabrication processes.

Accidental eccentricity and member out-of-straightness can cause bending moments in the member. However, these are secondary and are usually ignored. Bending moments cannot be neglected if they are acting on the member. Members with axial compression and bending moment are called beam-columns.
Consider a long slender compression member. If an axial load P is applied and increased slowly, it will ultimately reach a value Pcr that will cause buckling of the column. Pcr is called the critical buckling load of the column.

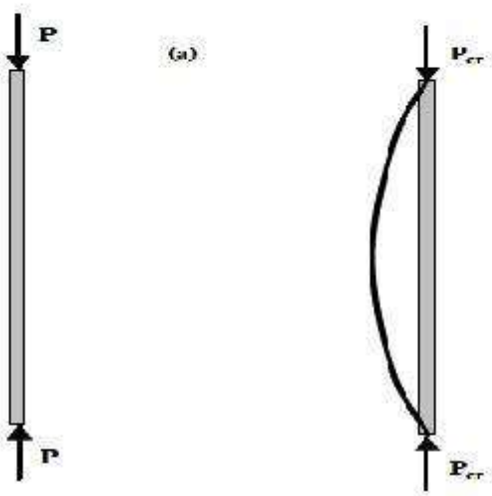


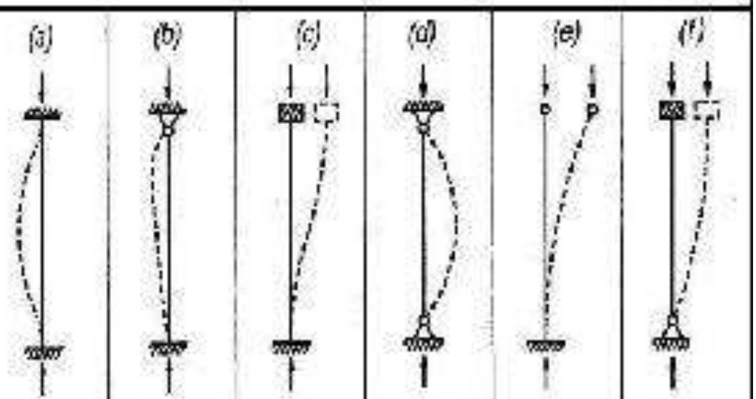
Figure 1.7 Buckling of axially loaded compression members

The critical buckling load Pcr for columns is theoretically given by Equation below,

Pcr $=\pi^2$EI / KL

Where, I = moment of inertia about axis of buckling
K = effective length factor based on end boundary conditions
Effective length factors are given below

Table 1.1 Effective length factors for different end conditions

Buckled shape of column is shown by dashed line	(a)	(b)	(c)	(d)	(e)	(f)
						
Theoretical K Value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design value when ideal condition are approximated	0.65	0.80	1.2	1.0	2.10	2.0
End Condition code	Rotation fixed and translation fixed; Rotation free and translation fixed; Rotation fixed and translation free; Rotation free and translation free					

.1 Problem Definition:

The study of the behavior of the innovative corrugated steel column under axial loading using UTM was conducted, being called experimental work. In the experimental part of the study, five innovative HSS steel column are tested to determine the ultimate strength capacity and load-deflection behavior. Finally, the theoretical results obtained using the proposed procedures are also compared with the test results available in the literature for HSS columns.

This project presents experimental behavior of innovative HSS steel column. 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.. 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 validated. The comparison of corrugated hollow column with conventional hollow column is done to know the advantages of innovative column over conventional column.

3.2 Methodology:

1. To design of innovative corrugated columns and selection of conventional HSS column
2. Redesign and fabrication of innovative corrugated columns and standard conventional HSS column to get deformation/stress induced in critical location will be carried out.
3. By using suitable Experimental set up Stress analysis of innovative corrugated columns and conventional HSS column will be carried out.
4. To compare and validate the result obtained by using results obtained by experimental Analysis for both strength and buckling for innovative corrugated columns and conventional HSS column.

3.3 Design and Development Calculation

The objective of present dissertation is to carry out finite element analysis of 4 innovative Corrugated columns and Conventional HSS column and experimental validation of it. Firstly columns are designed; their dimensions such as length, width, height, and thicknesses are fixed. 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.

3.3.1 Trapezoidal corrugated plates

The corrugated plates, known as self-strengthened plates, are regularly produced from flat plates. The corrugations increase the bending strength of the plate in the direction perpendicular to the corrugations. The profile of a corrugated plate may have several shapes: sinusoidal, trapezoidal, triangular, or rectangular as shown in Fig 1.3. The most common profiles used are trapezoidal and sinusoidal. In this research, trapezoidal profile is chosen to be studied as it exhibits more ductility and higher bearing capacity compared to sinusoidal profile. It is assumed that all corrugated plates have three modules of corrugation.

3.3.2 Hexagonal opening

In following research hexagonal openings are made in the columns. Two of the columns i.e column type 4 and column type 5 have these hexagonal openings on the flat plates of the column. Hexagonal openings show more load carrying capacity and lesser deflection as compared to solid columns with circular opening, rectangular opening and diamond shaped openings. Hexagonal openings are not provided on corrugated plates as the stiffness of plates is decreased and corrugated plates fails quickly with very high deflection. Hexagonal opening have length of each side equal to 45mm and a total height of 90mm. Total of four openings are provided on two opposite sides of the flat steel plates facing each other.

3.3.3. Theoretical Design Calculation

For research dissertation purpose, five columns such that 4 innovative steel HSS columns and Conventional HSS column are to be designed. These five columns and there specifications is given in the table below,

Table 3.1 Types of columns designed and their specifications

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

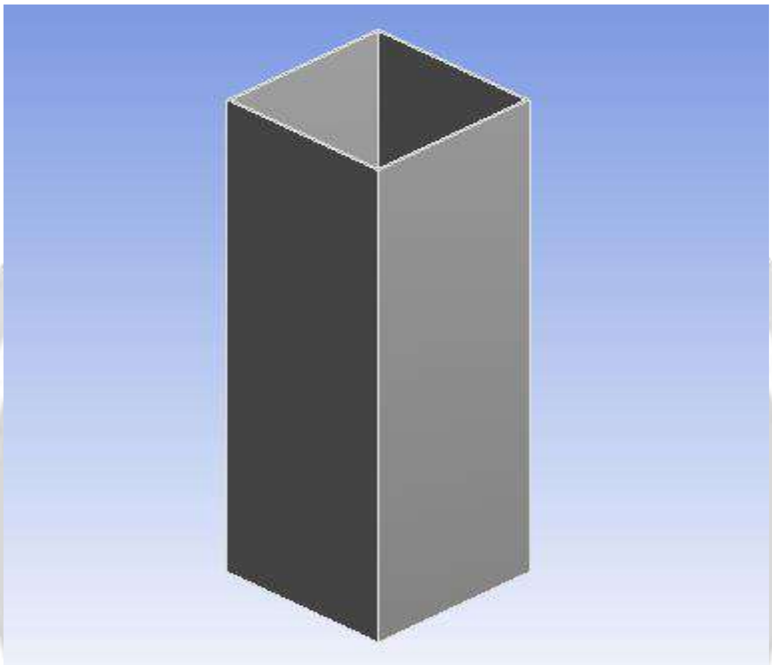


Fig 3.1 Conventional HSS column

A) For CC, a Hollow steel section (HSS) is selected whose dimensions are 210mm x 210mm x 3mm. Then various parameters like mass and volume are calculated, these are as follows.

Volume and Mass are calculated by Following Equations,

Volume = 4(D X T X L)

Mass= (D X B) X ((D – 2T) X (B-27)) ×Density

Table 3.2 Details of Conventional HSS (CC) Column

SYMBOL	DESCRIPTION	QUANTITY	UNIT
D	Depth of the column	210	mm
B	Width of column	210	mm
T	Thickness of column	3	mm
P	Density of Structural Steel	0.0078	kg/mm3
U	Poisons ratio	0.26	unit
Y	Young's modulus of structural steel	200	GPa
G	Modulus of Rigidity	75	GPa

L	Modulus of Rigidity	700	mm
M	Mass of the column	12.92	kg/m
V	Volume of column	176400	mm3

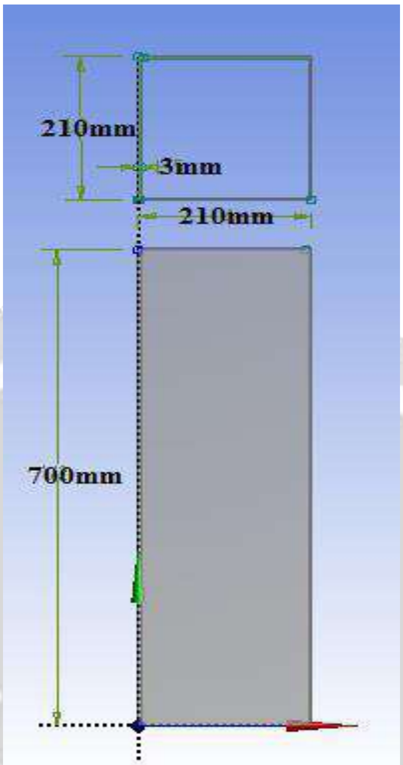


Fig 3.2 Conventional HSS Column (CC) dimensions

According to above dimensions of conventional HSS column, innovative corrugated steel
Column is designed by considering equal volume and length of the beam. In innovative corrugated steel column, dimensions are same, only thickness is varied. So, only volume of column is compared and thickness is calculated which is 2.6 mm.
B) For CHSS, an innovative corrugated steel column is designed; whose dimensions are 210mm x 210mm x 2.5mm. Then various parameters like mass and volume are calculated, which are as follows.

Volume and Mass are calculated by Following Equations,
Volume = 4(D X T X L)
Mass= (D X B) X ((D – 2T) X (B-27)) ×Density
Calculation of thickness,
Length of one corrugated sheet = 280mm
Volume of column type 1 = volume of column type 4
4(210 x 3 x 700) = 4((280 x 700 x T)
Solving above equation,
T = 2.7 mm

Table 3.3 Details of Corrugated HSS column (CHSS)

SYMBOL	DESCRIPTION	QUANTITY	UNIT
D	Depth of the column	210	Mm
B	Width of column	210	Mm
T	Thickness of column	2.7	Mm
P	Density of Structural Steel	0.0078	kg/mm3

U	Poisons ratio	0.26	Unit
Y	Young's modulus of structural steel	200	GPa
G	Modulus of Rigidity	75	GPa
L	Height of the column	100	Mm
M	Mass of the column	12.92	kg/m
V	Volume of column	176400	mm3

For ∝= 45 degree corrugation,

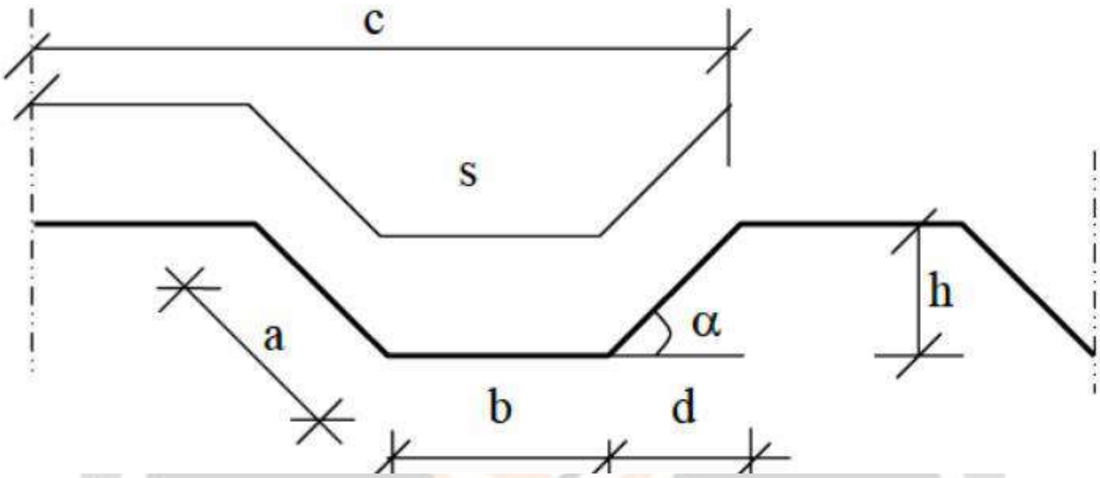


Fig 3.3 a) Trapezoidal Corrugated plates Design Consideration

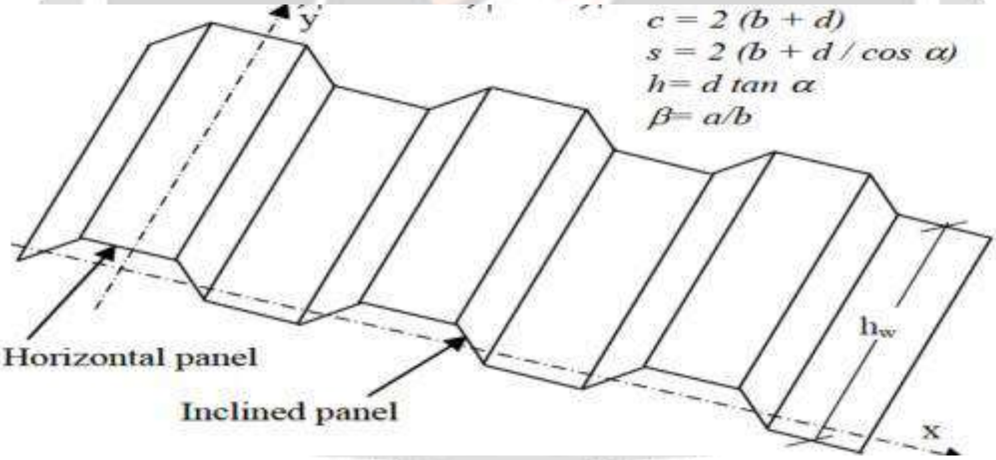
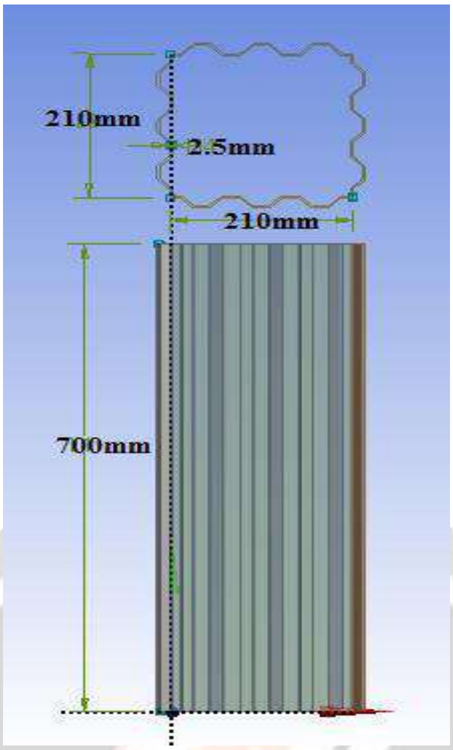


Fig 3.3 b) Trapezoidal Corrugated plates Design Consideration

d = 15mm.
b= 20mm.
h= d×tan∝ = 15mm.
C= 2(b+d) = 2(15 + 20) = 70 mm.
S= 2(b+d)/cos∝ = 99mm.
a= 20mm.



C) For TCC, an innovative two side corrugated 2 side plane HSS column is designed. In this column, corrugated sheets are on two opposite sides and on remaining two opposite sides there are plane sheets. Here, thickness obtained is 2.8mm.

Length of one corrugated sheet = 280mm
Length of plane sheet = 210mm
Total length = 210+210+280+280= 980
Volume of column type 1 = volume of column type 3
(840 x 3 x 700) = (980 x 700 x T)
Solving above equation,
T = 2.8 mm

Table 3.4 Details of Two side corrugated 2 side plane column (TCC)

SYMBOL	DESCRIPTION	QUANTITY	UNIT
D	Depth of the column	210	Mm
B	Width of column	210	Mm
T	Thickness of column	2.8	Mm
P	Density of Structural Steel	0.0078	kg/mm3
U	Poisons ratio	0.26	Unit
Y	Young's modulus of structural steel	200	GPa
G	Modulus of Rigidity	75	GPa
L	Height of the column	700	Mm
M	Mass of the column	12.92	kg/m
V	Volume of column	176400	mm3

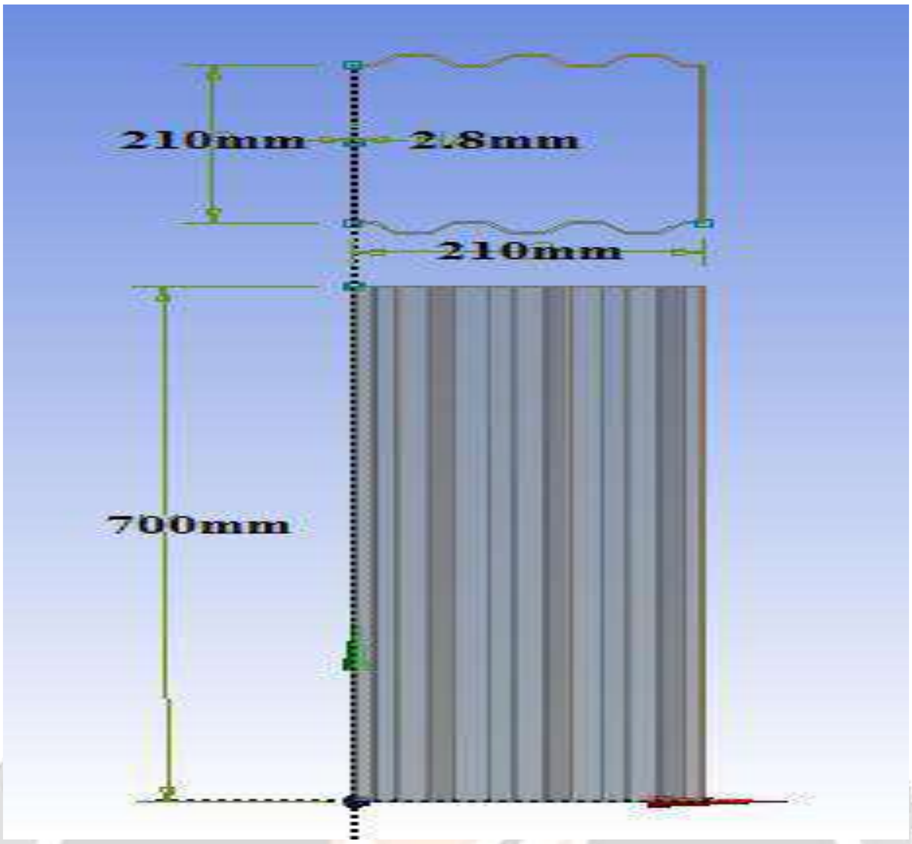


Fig 3.5 Two sides corrugated 2 side plane column (TCC) dimensions

D) For CCH, Conventional HSS column with hexagonal openings on opposite side is designed. It is atypical conventional HSS steel column but having 4 hexagonal openings on any 2 opposite side. Calculation of thickness for this column is given below,

Length of one hexagonal side = 45mm

Area of hexagon = 5261.1 sq.mm

Area of 4 hexagons = 21044.4

Volume of column type 1 = volume of column type 4

4(210 x 3 x 700) = 4((210 x 700 – 21044.4) x T)

Solving above equation,

T = 3.5 mm

Table 3.5 Details of Conventional HSS column with hexagonal openings (CCH)

SYMBOL	DESCRIPTION	QUANTITY	UNIT
D	Depth of the column	210	Mm
B	Width of column	210	Mm
T	Thickness of column	3.5	Mm
P	Density of Structural Steel	0.0075	kg/mm3
U	Poisons ratio	0.26	Unit
Y	Young's modulus of structural	200	GPa

	steel		
G	Modulus of Rigidity	75	GPa
L	Height of the column	700	Mm
M	Mass of the column	12.92	kg/m
V	Volume of column	176400	mm3

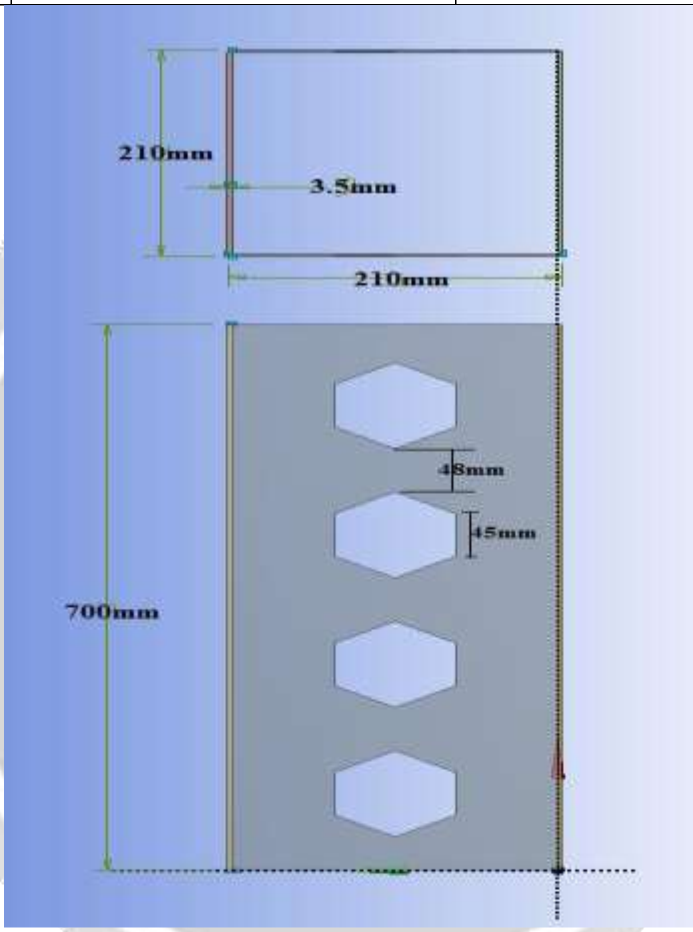


Fig 3.6 Conventional HSS column with hexagonal openings (CCH) dimensions

E) For TCH, two side corrugated 2 side plane column with hexagonal openings is designed. It is a typical Column type 3 but having 4 hexagonal openings on any 2 opposite side. Calculation of thickness for this column is given below,

Length of one hexagonal side = 45mm
Area of hexagon = 5261.1 sq.mm
Area of 4 hexagons = 21044.4
Volume of column type 1 = volume of column type 4
(4 x 210 x 3 x 700) = 4(980 x 700 – 21044.4) x T)
Solving above equation,
T = 2.65 mm

Table 3.6 Details of Two side corrugated 2 side plane column with hexagonal openings (TCH)

SYMBOL	DESCRIPTION	QUANTITY	UNIT
D	Depth of the column	210	Mm
B	Width of column	210	Mm
T	Thickness of column	2.6	Mm
P	Density of Structural Steel	0.0078	kg/mm3
U	Poisons ratio	0.26	Unit
Y	Young's modulus of structural steel	200	GPa
G	Modulus of Rigidity	75	GPa
L	Height of the column	700	Mm
M	Mass of the column	12.92	kg/m
V	Volume of column	176400	mm3

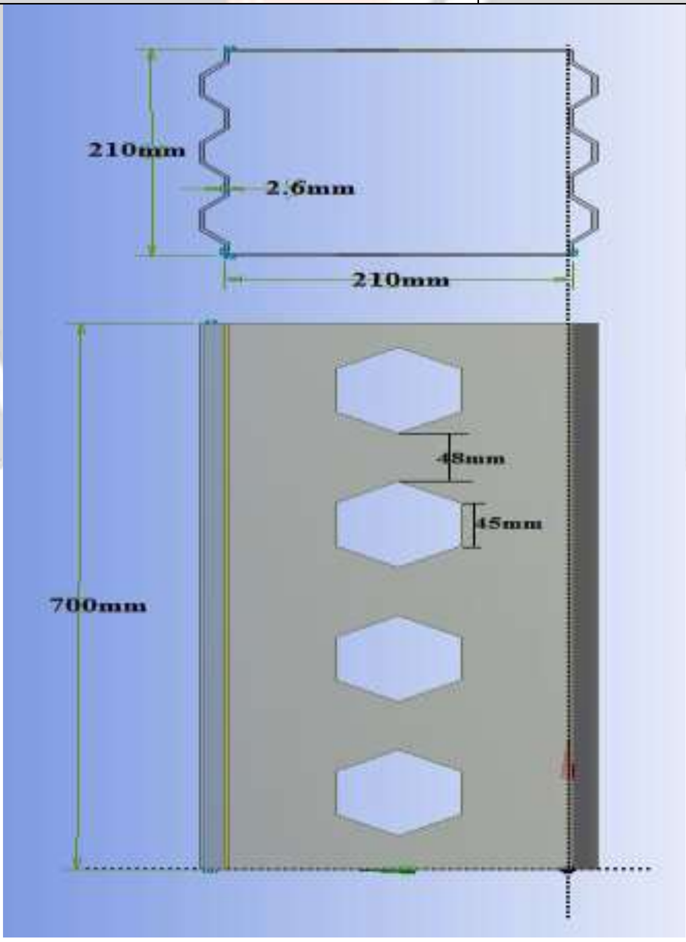


Fig 3.7 Two sides corrugated 2 side plane column with hexagonal openings(TCH) dimensions

3.4 Experimental Investigation

In current project along with finite element model, a experimental work is also done to know the behavior of innovative HSS column under compressive loads. The results obtained from finite element model are compared with experimental tests.

3.4.1 Objective of the Work:

The objective of present dissertation is to carry out finite element analysis and experimental validation of the five innovative HSS columns. Following steps are followed to meet the objective of present dissertation work.

3.4.2 Experimental Validation:

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.

3.4.3 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. Figure 3.14 shows a typical corrugated steel plate used in innovative steel columns. Corresponding geometric parameters for each corrugated steel plate is given in Table 3.7.

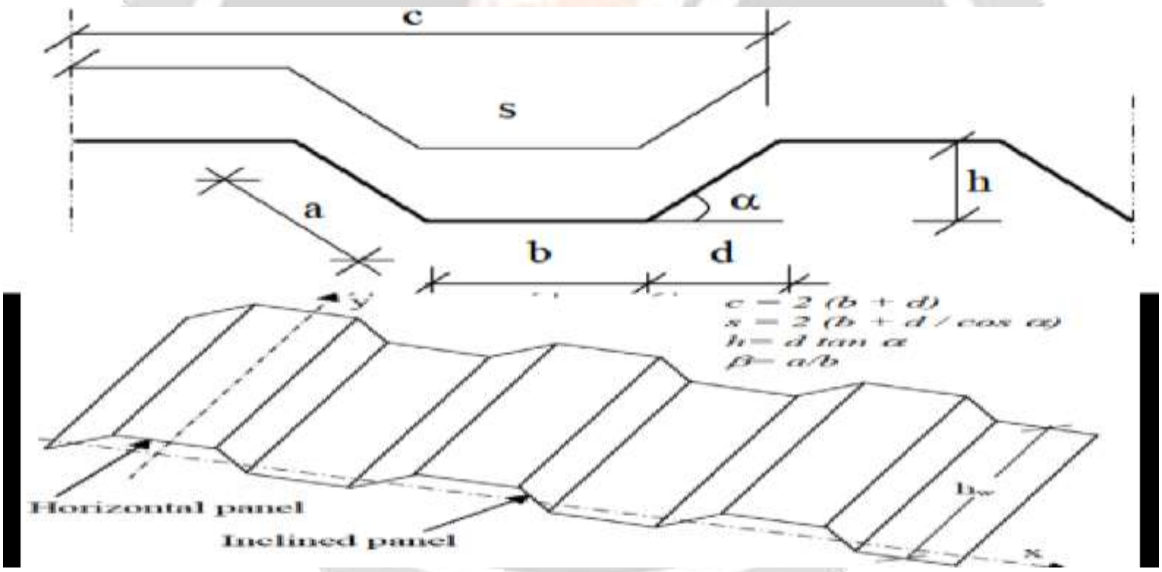


Fig 3.14 Trapezoidal corrugated steel plate cross section and dimension notations. Table 3.7 Corrugation dimension parameter (in mm)

α	h	a	b	c	D	Hw
45˚	15mm	20mm	20mm	15mm	70mm	700mm

3.4.4 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.

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. Fig 3.15 shows the Schematic view of press-brake forming machine and Fig 3.16 shows cold forming of initially flat plates into corrugated steel plates using press brake machine.

Fig 3.15 Schematic view of press-brake forming machine.

3.4.5 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.

In CC, all four steel plates are flat plates. For CHSS, all steel plates are corrugated plates. In TCC, two plates are flat and two plates are corrugated and are welded on opposite side such that they face each other. For CCH, is similar to type 1 but consists of four hexagonal openings on two opposite sides. In TCH, it is similar to TCC but consists of four hexagonal opening on flat plates on opposite sides.

Figure 3.17 shows different fabricated innovative HSS columns. According to dimensions of conventional HSS column, innovative corrugated steel column is designed by considering equal volume and length of the beam. In innovative corrugated steel column, dimensions are same, only thickness is varied.

3.4.6 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. The axial compressive load was applied incrementally using a load increment of 5kN until the column exhibits failure. Figure 3.18 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.

Fig 3.17 Different types of fabricated innovative HSS columns, (A) CC (B) CHSS (C) TCC (D) CCH (E) TCC

Fig 3.18 HSS column setup and equipment

EXPERMENTAL ANALYSIS

The behavior of innovative HSS steel column under compressive load is discussed in following section below. The comparison of experimental results done.

4.1 Experimental Analysis

For experimental work purpose five columns were designed and fabricated. These columns were tested using 1000KN UTM machine under compressive loads for deflection.

Following are the results obtained from experimental results.

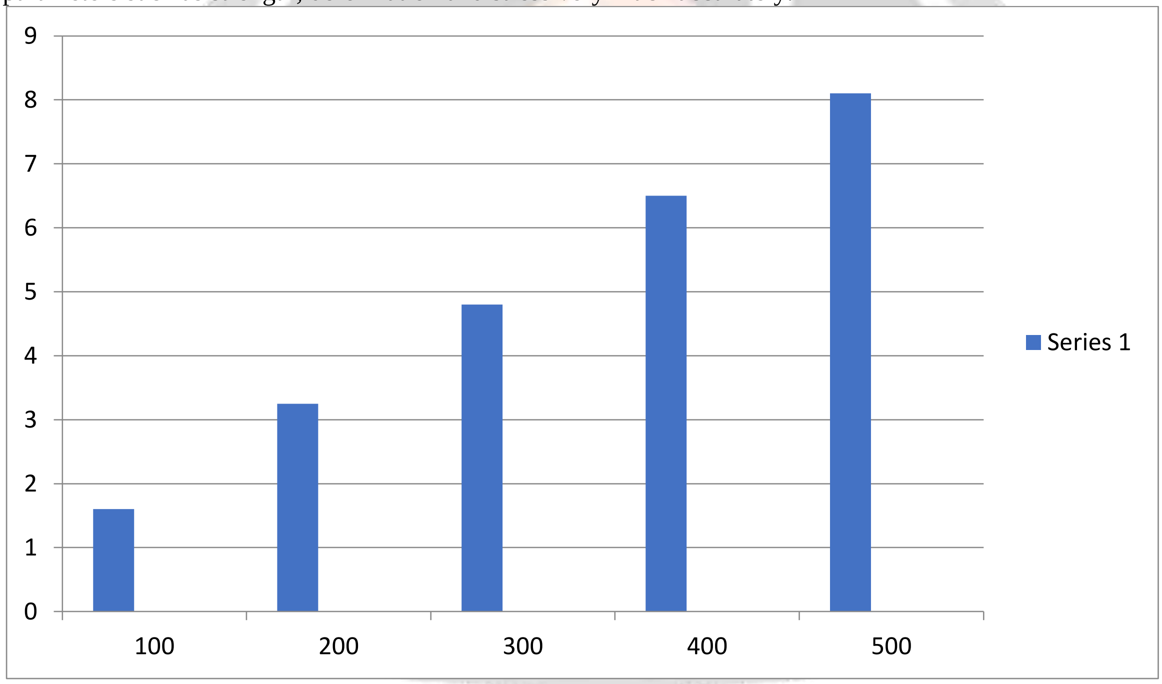
Table 4.9 Load and deflection of all column specimens by UTM experimental testing

Sr no	Load in KN	CC	CHSS	TCC	CCH	TCH
		Maximum deformation in mm				
1	100	1.6	1.5	1.5	1.75	1.7
2	200	3.25	2.9	3.2	3.5	3.45
3	300	4.8	4.6	4.7	5.25	5.1
4	400	6.5	6	6.1	7	6.75
5	500	8.1	7.4	7.9	9	8.5

From above experimental results it is clear that innovative HSS steel columns have less deflection than that of conventional column.

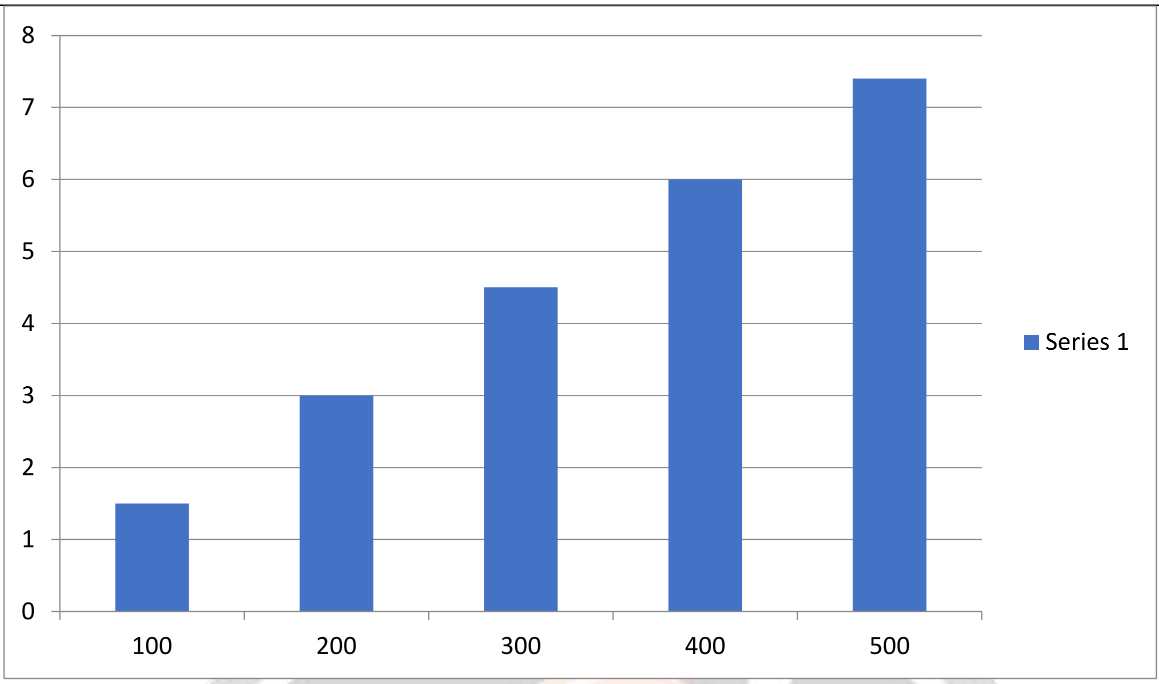
4.2 Validation

The load versus deformation curve obtained from FE model is compared with the result from experimental work in figure 4.1. 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.



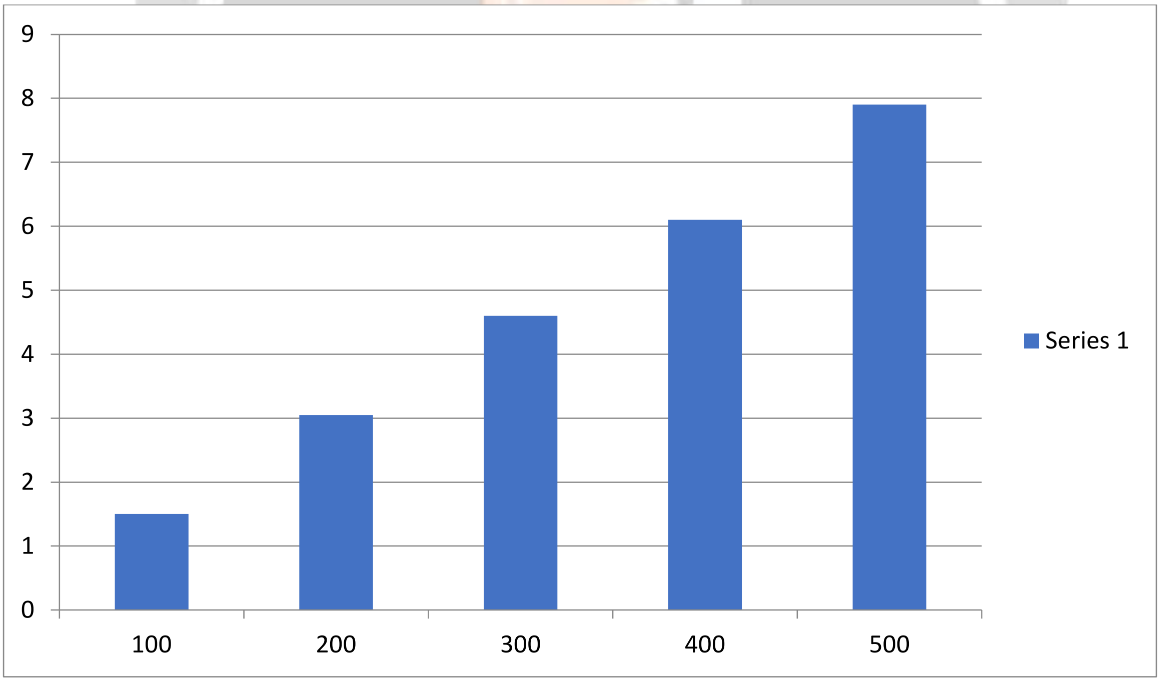
experimental	1.6	3.25	4.8	6.5	8.1

Fig 4.1 a) Comparison of Load V/S Deflection for numerical results for Cc



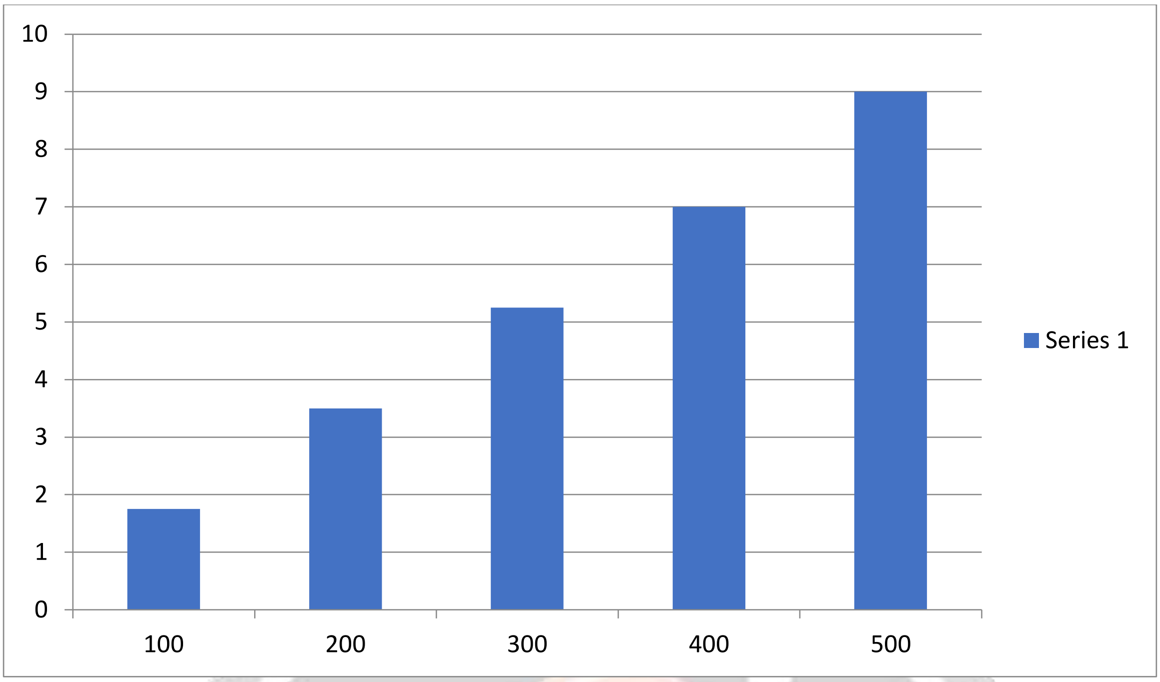
experimental	1.5	3	45	6	7.4

Fig 4.1 b) Comparison of Load V/S Deflection experimental results for CHSS



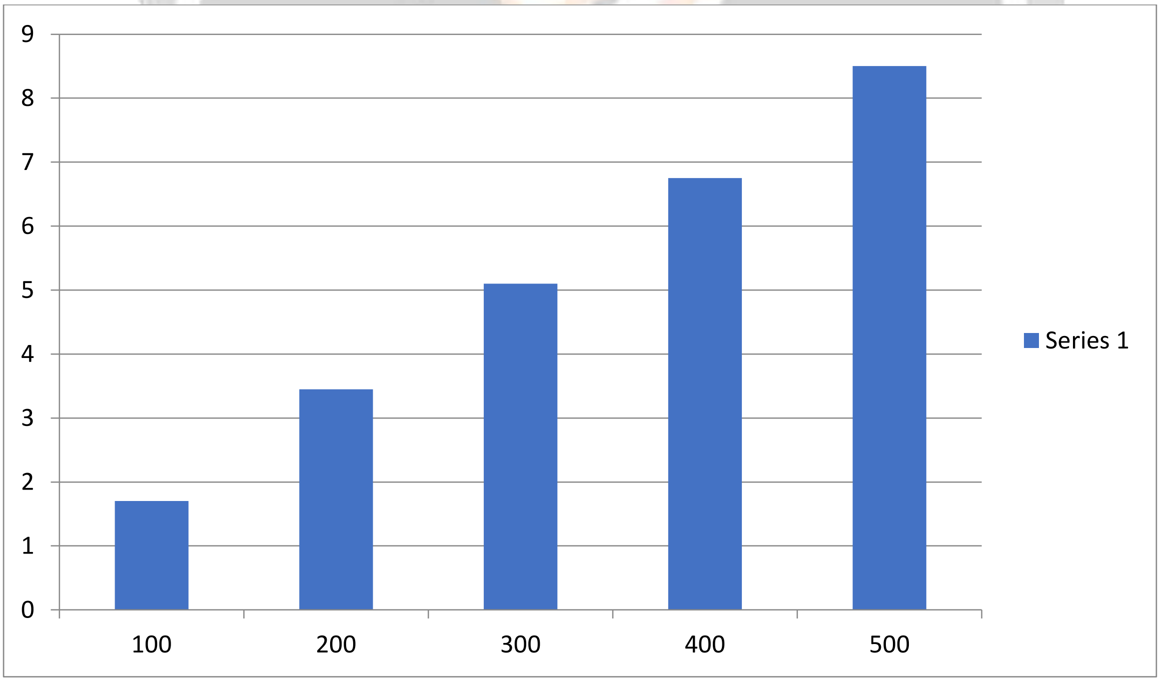
experimental	1.5	3.05	4.6	6.1	7.9

Fig 4.1 c) Comparison of Load V/S Deflection for experimental results for TCC



experimental	1.75	3.5	5.25	7	9

Fig 4.1 d) Comparison of Load V/S Deflection experimental results for CCH



experimental	1.7	3.45	5.1	6.75	8.5

Fig 4.1 e) Comparison of Load V/S Deflection experimental results for TCH

Experimental maximum deflection of Innovative column specimens and a conventional column specimen matches difference which is in, acceptable range. Difference in reading is present due to may sliding is present in the lead screw of UTM

Table 4.11 Comparison of Deflection by Using Experimental Results

Sr No.	Load in KN	CC	CHSS	TCC	CCH	TCH
		Maximum deformation in mm				
1	100	1.6	1.5	1.5	1.75	1.7
2	200	3.25	2.9	3.2	3.5	3.45
3	300	4.8	4.3	4.7	5.25	5.1
4	400	6.5	6	6.1	7	7.75
5	500	8.1	7.4	7.9	9	8.5

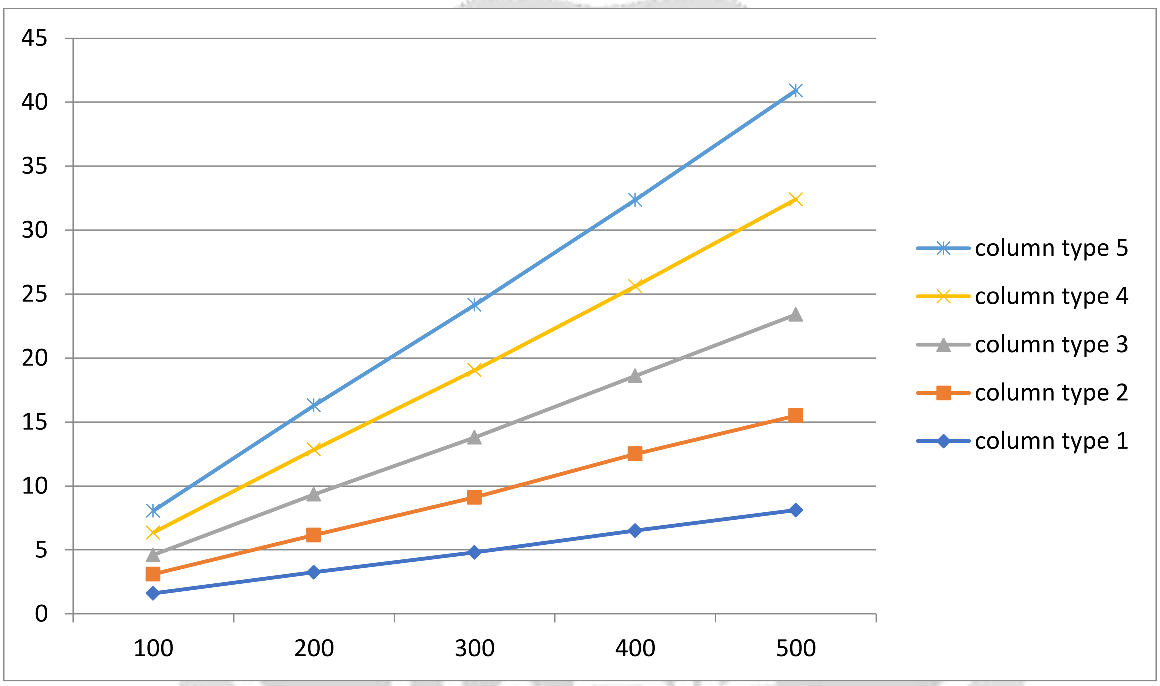


Fig 4.3 Load V/S Deflections by Using Experimental Results

From above graph and values from experimental results it is clear that innovative HSS steel columns have less deflection than that of conventional column. The corrugated steel HSS column has least deflection among all the columns and than that of conventional column (CC). The combination of corrugated plates and flat plate that is TCC also has minimum deflection. The combined action of corrugation and flat plate bear the load effectively and also resist compressive stresses acting on them excellently. Thus it is seen that corrugation shape bears more load than flat plates. Typical trapezoidal shape provides more strength to the column.

The innovative columns having hexagonal opening also perform very well. The column having combination of corrugated plates and flat plate with hexagonal opening (TCH) performs very well and has deflection slightly more than conventional column. Here too combined action of corrugation and flat plates work very well CCH that is conventional column having hexagonal openings has maximum deflection among all columns. Hexagonal opening reduces weight and also resists loads coming upon them due to their excellent shape. Hexagonal openings work same as castellation in castellated beams.

RESULT AND DISCUSSIONS

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. Initially buckling occurred in plates by which horizontal displacement increased and overall buckling occurred at ultimate load. All tested columns experience local buckling of columns sections but at different locations along column length depending on corrugation and hexagonal openings. It can be seen from Fig. 4.5 that for the HSS steel columns with four hexagonal opening considered in the experimental tests, the location of the local buckling has moved toward the end of the column. When hexagonal opening is present, the column axial stiffness will be considerably reduced and the column will exhibit less axial strength. This behavior may be attributed to the effect of the column axial stiffened which is affected by the presence of the opening in the column section.

Fig 4.5 Failure mechanism for various column specimens

5.1 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. By observing the stresses developed for steel columns with hexagonal opening it is seen that the stress concentration is more near the opening leading to shear failure. 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.

5.2 Performance of Innovative Columns

By observing the graphs in Figure 4.2, 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 columns.

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.

1. 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.
2. 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.
3. 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.

4. 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.
5. 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.
6. 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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