Performance Analysis of Columns Comprising of Corrugated Plates and Ultra High Strength Steel Tubes

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***Abstract*— In many situations, lighter steel structures are used to the heavier alternatives such as reinforced concrete or prestressed 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 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. In the present work, the behavior of the hollow corrugated stub column with ultra high strength steel tube is studied. Finite element (FE) method is used to analyze the stub columns. The influence of shape of column is being analysed by using ANSYS software. The square, rectangular and triangular shapes of columns are considered. The Load deflection characteristics of corrugated column are studied and compared with columns comprising of flat steel plate. From analysis, it can be seen that corrugated column have high load carrying capacity than flat steel plate columns. Among which rectangular column carries maximum load. The optimization of angle and thickness of corrugated plate were carried out. Concrete filling were done on tubes and core portion and compared with hollow corrugated 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.

A. Corrugation Process

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 press braking cold forming process. 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 of flat region of plate remains unchanged.

B.Ultra High Strength (UHS) Steel Tubes

UHS steel tube is produced from durable high-strength structural steel material. Utilizing individual UHS tube as structural elements is discouraged due to its low ductility and performance under Compression; however, with regard to the high hardness and Tensile strength properties of UHS tubes, an outstanding improvement in conventional sections once used in the proposed Configuration is expected. Despite their high hardness and strength, the weld ability of UHS tube is good. To briefly highlight main production stages of this particular tube, it should be noted that the decoiled strip is fed to forming section. Strip forming applies in small steps, ensuring smooth operation and uniform pipe geometry. Afterward, longitudinal welding takes place using an electric resistance welding technique called HFI (High Frequency Induction) welding process .In this process, the strip edges are heated to welding temperature and pressed together by rollers without any filler metals to give a homogeneous longitudinal weld. Finally, after cooling and sizing, a cut-off machine cuts the pipe to the specified lengths

II. LITERATURE REVIEW

Zakeer M. Mulani et.al (2018)[15] presented a paper on "Comparison of Innovative Corrugated Hollow Steel Columns With Conventional Hollow Steel Column: Experimental And Numerical Study'' In their study, three types of innovative corrugated hollow steel section (HSS) column are developed; fabricated and tested. The current work is separated in to two parts. first part is experimental work, the study of the behavior of the innovative corrugated hollow steel columns under axial loading using UTM was conducted, In the second part, the results of the experimental work are checked with numerical results which are obtained by analytical method by using computer software ANSYS. Results obtained from experimental testing and computer analysis are compared and validated. The comparison of innovative corrugated hollow steel columns with conventional hollow steel column is done to know the advantages of innovative corrugated HSS columns over conventional HSS column

MojtabaFarahi et.al (2017)[10] presented a paper on "Effect of ultra-high strength steel on mitigation of non-ductile yielding of concrete-filled double-skin columns''.In their study, an innovative fabrication strategy is proposed to prohibit the non-ductile yielding of CFDST sections by applying ultra-high strength steel corner steel tubes. Hence, the static compressive behaviour of CFDST columns containing ultra-high strength steel tubes is experimentally investigated. The results are then compared with those for the same experiment conducted on a CFDST specimen with corner mild steel tubes. In addition, a numerical investigation is conducted to examine the effect of different parameters on promoting the ductility and compressive strength.

MojtabaFarahi et.al (2017)[11] presented a paper on "Compressive behavior of concrete filled double skin sections consisting of corrugated plates and ultra-high strength steel corner tubes''. In this study, the mechanical performance of a new type of CFDSTs consisting of corrugated steel skins and ultra-high strength steel (UHSS) or mild-steel (MS) corner tubes is investigated. The efficiency of corrugated skins and UHSS or MS corner tubes is experimentally examined through conducting monotonic compressive tests. It is shown that employing steel skins with corrugated geometry may significantly increase the post-peak compressive strength of CFDST sections. In addition, the experimental results are revealed that the non-ductile compressive behaviour of ordinary CFDST sections can be effectively improved by employing UHSS corner tubes in fabrication of thesesections.The numerical modelling is first validated against the experimental results. The outcome of the paper indicates the potential of corrugated CFDSTs with UHSS or MS corner tubes to be used in various civil engineering construction

Siddharth R Pawar et.al (2017)[13] presented a paper on "Comparative study of innovative corrugated hollow columns and conventional column''. In their study, 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 behaviour 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.

Mohammad Nassirnia et.al (2016)[12] presents an advanced innovative hollow corrugated column by incorporating ultra-high strength (UHS) steel tubes. The superior performance of the proposed column under compressive loading is investigated in the present work. UHS tubes used at the corners have yield stress of 1250 MPa. Three different corrugated plates are introduced and fabricated so that the effect of corrugation geometry parameters such as angle of inclination and height of corrugation get experimentally investigated. Along with experiments, an advanced finite element model is developed for predicting the behaviour of proposed columns and validated by experimental results. The results prove the high capacity and ductility of the proposed innovative columns under compression compared to the accumulated capacity of the individual components. Finally, the proposed high-strength columns are compared with the conventional columns in terms of weight and manufacturing costs.

III.OBJECTIVE

The objectives of the present work, arrived at based on an extensive study of literature are as listed below:

- To study the behaviour of hollow stub columns comprising corrugated plates and ultra-high strength steel tubes by changing the shape of column
- To compare the structural behaviour of hollow corrugated steel stub column with normal steel plate stub column.
- To investigate the performance of stub column after filling concrete in hollow portion.

IV.ANALYSIS OFCORRUGATED AND FLAT STEEL PLATE COLUMNS

A.Modelling and Analysis: In order to determine the effective shape for the column three commonly used shapes of columns were selected for the analysis. The three different shapes chosen for the comparison are square, rectangle and triangle. The areas of cross section of these different shapes were kept equal. The end supporting condition was provided as on end fixed. Dimensional details of the columns were given in the Table 1. The material properties were given in the Table 2.

TABLE I

DIMENSIONAL DETAILS OF COLUMNS

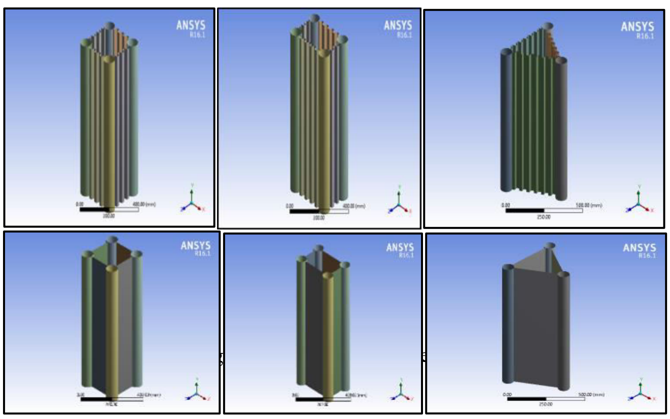
Shape of Specimen	**Size of Specimen(mm)**
Square	298.2 mm × 298.2 mm
Rectangle	346.87 mm × 256.359 mm
Triangle	Width , b = 453.17 mm Height ,h = 392.45 mm

TABLE II

MATERIAL PROPERTIES

Corrugated steel plate	Young's modulus = 2 × 10^5N/mm^2
	Poisons ratio = 0.3
	Yield stress = 262 MPa
UHS Tubes	Young's modulus = 2 × 10^5N/mm^2
	Poisons ratio = 0.3
	Yield stress = 1250 MPa

The modelling of the three different shaped corrugated as well as flat plate steel is done by using SHELL 186 element type to determine the effective shape. The models of the different shapes are shown in Fig 1



It is very important to select the mesh size and layout in finite element analysis. A proper mesh means accurate results with better convergence but also has time consideration. A very fine mesh model will always provide accurate results but will require excessive computer time. Here four nodded rectangular mesh with size 15mm is selected. Load is applied as displacement according to displacement convergence method. Displacement of 15 mm is given as load for all models.

Static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads. Static structural analysis is carried out in ANSYS software. Deformation and load carrying capacity is studied. The deformation diagram is shown below;

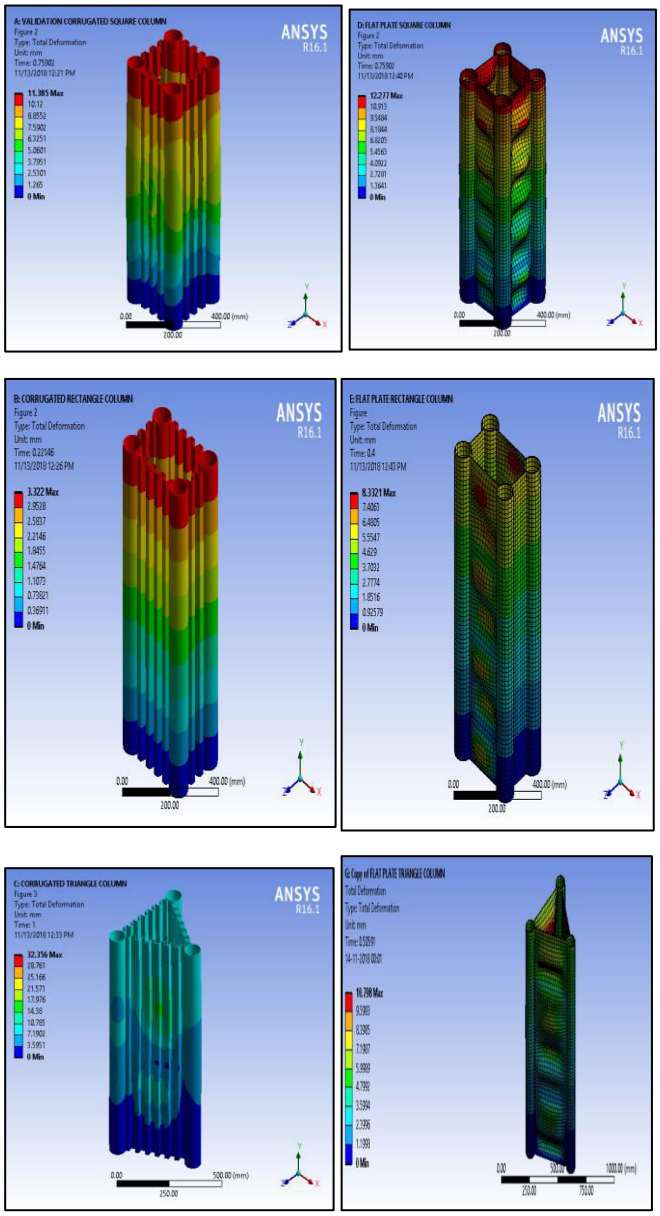


Fig. 2Deformation Diagram of Corrugated Steel Column

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B.Results and Discussions

The maximum load carried by the different shaped corrugated and flat steel plate column is taken into account to determine the effective shape of column. The load-deflection curves of different shaped corrugated and flat steel plate columns are shown in Fig 3 & 4.

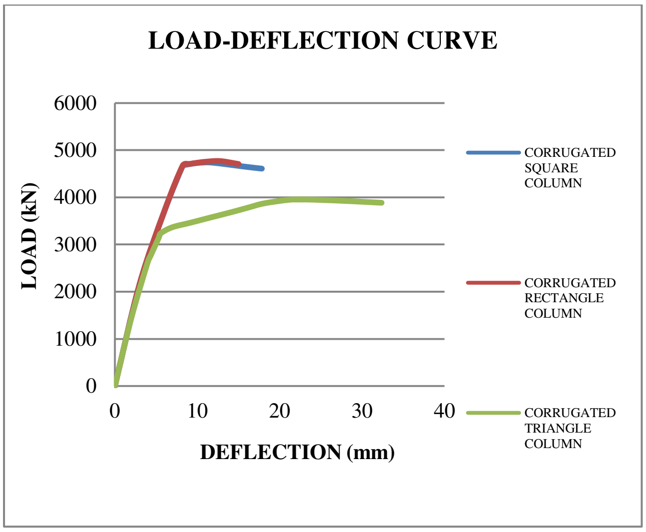

Fig. 3 Load-Deflection Curves of Corrugated Columns

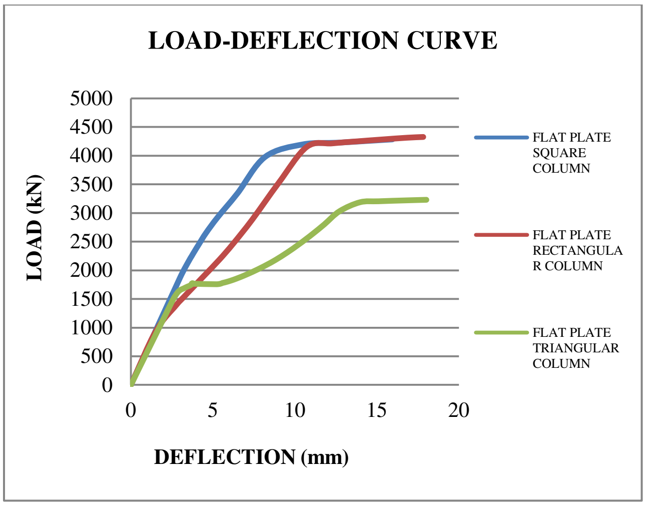

Fig. 4Load-Deflection Curves of Flat Steel Plate Columns

The corrugated Rectangular column carries maximum load. Also corrugated steel columns carry more load compared to flat plate steel columns.The percentage increase in load carrying capacity of corrugated column as compared to flat steel plate column are as follows :

- Square column – 9.63 %
- Rectangular column – 9.29 %
- Triangular column – 18.25 %

V.Analysis of Concrete Filled Corrugated Stub Column

A.Modelling and Analysis

After optimizing the angle and thickness of corrugated plate (3mm & 75°), further studies where carried on modelling and analysis corrugated column with concrete filling in hollow portions. Concrete filling is given by two ways:

- Concrete Filling in Tubes
- Concrete Filling in Core Portion

The material properties of steel tube, corrugated plate and concrete used are shown in Table 3

TABLE III

Material Properties

Corrugated steel plate	Young's modulus = $2 \times 10^5 N/mm^2$
	Poisons ratio = 0.3
	Yield stress = 262 MPa
UHS Tubes	Young's modulus = $2 \times 10^5 N/mm^2$
	Poisons ratio = 0.3
	Yield stress = 1250 MPa
Concrete	Grade = M30
	Young's Modulus = 27386MPa
	Density = 2400 Kg/m³
	Poisson ratio = 0.15

Static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads. Static structural analysis is carried out in ANSYS software. Deformation and load carrying capacity is studied.

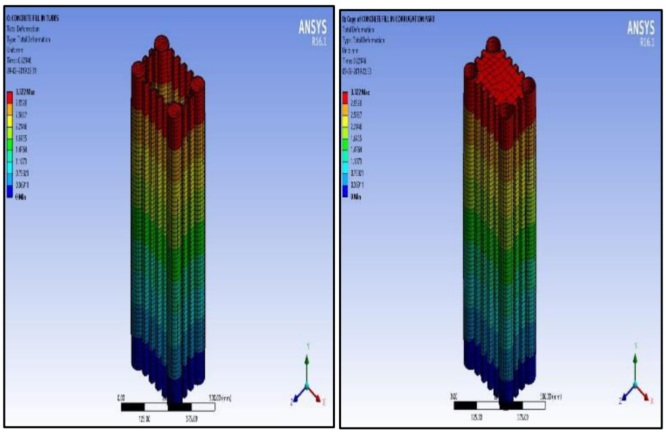

Fig. 5Deformation Diagram of Columns

B. Results and Discussions

The load, deflection & Stiffness of concrete filled columns are compared with hollow corrugated column. The table 4 shows the comparison of these three types of columns.

TABLE IV
LOAD-DEFLECTION AND STIFFNESS COMPARISON OF COLUMNS

MODEL	DEFLECTION (mm)	LOAD (kN)	Stiffness (kN / mm)
H-C-C	12.778	4769	373.21
C-C-CFT	9.9375	5263.56	529.66
C-C-CFC	14.202	6344.2	446.71

The Fig 6 shows the load deflection comparison of hollow column with concrete filled columns.

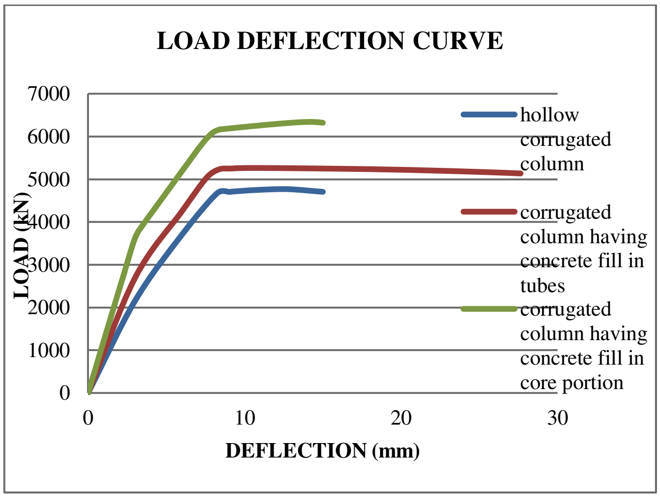

Fig 6 :Load Deflection Comparison of Hollow Column with Concrete Filled Columns

Table 5 shows the comparison of total weight of hollow column, column with concrete fill in tubes and column with concrete fill in hollow portion.

TABLE 5

WEIGHT COMPARISON OF COLUMNS

MODEL	WEIGHT OF STEEL (kg)	WEIGHT OF CONCRETE (kg)	TOTAL WEIGHT OF COLUMN (kg)
H-C-C	47.37	-	47.37
C-C-CFT	47.37	43.66	91.04
C-C-CFC	47.37	117.21	164.58

As concrete is introduced into the column, it shows better load carrying capacity than that of hollow column. The stiffness of columns also increased as compared to hollow column when concrete filling is provided. The column having concrete fill in core portion have greater load carrying capacity but the section is too heavy due to more amount of concrete in it. Comparing the above three columns, the column with concrete fill in tube shows better overall performance and is light weight.

VI. CONLUSIONS

Columns with corrugated plate and flat steel plate of different shapes were modelled and analysed .The result was analysed and optimized to find the better column section. Comparison of corrugated column with flat steel plate column was also done. After that hollow column were compared with concrete filled columns. The following conclusions obtained from the analysis are as follows;

- Effect of shape of column :
  - Hollow corrugated stub columns have better load carrying capacity compared to that of flat steel plate columns.
  - Rectangular corrugated stub column carry more load as compared to all other columns and also shows better load deflection characteristics.
  - Rectangular corrugated stub column carries 9.295 % more load as compared to rectangular flat plate column
  - Square and rectangular columns show almost same load deflection characteristics.
  - Rectangular columns have higher moment of inertia about one axis and it also exhibiting better load deflection characteristics, so rectangular section was adopted for further studies
- Effect of concrete filling:
  - As concrete is introduced into the column, it shows better load carrying capacity than that of hollow column.
  - The stiffness of columns also increased as compared to hollow column when concrete filling is provided.

- The column having concrete fill in core portion have greater load carrying capacity but the section is too heavy due to more amount of concrete in it.
- Comparing the above three columns , the column with concrete fill in tube shows better overall performance and is light weight

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REFERENCES

1] A.Heidarpour, S.Cevro, Q.Y.Song, X.L.Zhao, (2013) "*Behaviour of innovative stub columns utilising mild steel plates and stainless steel tubes at ambient and elevated temperatures"*, Eng.Struct.57 416–427

[2] D.VanBinh, R. Al Mahaidi, X.L.Zhao, (2004)"*Finite element analysis (FEA) of fabricated square and triangular section stub columns utilizing very high strength steel tubes*", Adv.Struct.Eng.7 447–460

[3] E. Hosseinpour,S.Baharom,Y.Yadollahi,(2015) "*Evaluation of steel shear walls behaviour with sinusoidal and trapezoidal corrugated plates"*,Adv.Civ.Eng.

[4] F.Javidan, A.Heidarpour, X.L.Zhao, J.Minkkinen, (2015)"*Performance of innovative fabricated long hollow columns under axial compression"*, J.Constr.Steel Res.106 99–109.

[5] F.R.Mashiri,B.Uy,Z.Tao,Z.B.Wang,(2014) "*Concrete-filled VHS-to-steel fabricated section stub columns subjected to axial compress[]ion*",J.Constr.SteelRes.95 141–161

[6] J.Rhodes, X.L.Zhao,R.Al-Mahaidi, (2005) "*Rational design analysis of stub columns fabricated using very high strength circular steel tubes"*, Thin-walled Struct.43 445–460.

[7] J.H. Ye,X.L.Zhao,R.AlMahaidi, (2007) "*Plastic mechanism analysis of fabricated Square and triangular sections under axial compression"*,Thin-walledStruct.45 135–148

[8] J. Chen,W.lJin, (2010)"*Experimental investigation of thin-walled complex section concrete-filled steel stub columns"*, Thin-Walled Struct.48 718–724

[9] M.Nassirnia, A.Heidarpour, X.L.Zhao, J.Minkkinen, (2015)"*Innovative hollow corrugated columns : a fundamental study"*, Eng.Struct.94 43–53

[10] MojtabaFarahi , Amin Heidarpour , Xiao-Ling Zhao , Riadh Al-Mahaidi , (2017) "*Effect of ultra-high strength steel on mitigation of non-ductile yielding of concrete filled double skin columns*", Construction and Building Materials 147 736–749

[11] MojtabaFarahi , Amin Heidarpour , Xiao-Ling Zhao , (2017) "*Compressive behaviour of concrete filled double skin sections consisting of corrugated plates and ultra-high strength steel corner tubes"* , IJERT 13-15

[12] Mohammad Nassirnia , Amin Heidarpour , Xiao-Ling Zhao , JussiMinkkinen , (2016) "*Innovative hollow columns comprising corrugated plates and ultra-high strength steel tubes"* , Thin-Walled Structures 101 14–25

[13] Siddharth R Pawar, M MMagdum , (2017) "*Comparative Study of Innovative Corrugated Hollow Columns And Conventional Column"*, IJCESR Volume-4, Issue-7,

[14] X.L. Zhao, D.VanBinh, R.Al-Mahaidi, Z.Tao, (2004) "*Stub column tests of fabricated Square and triangular sections utilizing very high strength steel tubes"*, J. Constr.SteelRes.60 1637–1661.

[15] Zakeer M. Mulani, Y. M. Ghugal , (2018) "*Comparison of Innovative Corrugated Hollow Steel Columns With Conventional Hollow Steel Column: Experimental And Numerical Study*",ISBN