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A STUDY ON COMPRESSIVE BEHAVIOUR OF DOUBLE SKIN CORRUGATED COLUMNS

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Abstract: This paper comprises an analytical study of double skinned corrugated columns (DSCC) of square sections filled with concrete. This analysis reveals the compressive nature of the Concrete Filled Double Skin Tube (CFDS) columns, in which their inner and outer skins were replaced with corrugated plates. A finite component modeling framework has been developed to obtain the response of CFDST columns with corrugated plates. Analyses on the specimens were done by applying axial and lateral loads. The parameters varied for columns were, slenderness ratio and grade of concrete. The specimens used to investigate the compressive and ductile behaviour of the columns. Various characteristics such as stiffness and failure mode are also discussed with the help of load- deflection curves obtained from ANSYS 16.1. The end stiffeners are provided at both ends of columns. The analyses of DSCC with and without end stiffeners were done. As DSCC with end stiffeners are performs better, another two models were developed. One is aligning corrugated plates in parallel and another one is in perpendicular to inner tubes with end stiffeners. From the analysis corrugated plates with parallel is chosen as the best model. Remaining parameter studies has been done by using this model throughout the project.

Keywords: **Double Skin Columns, Corrugated Plates, Stiffeners, Compressive Behaviour.**

1. INTRODUCTION

With the development of urban construction, the height and span of buildings are increasing, and the loads on beams and columns are also increasing. The structure and components need to have higher bearing capacity, smaller cross section size, better ductility, stronger fire resistance, and good construction convenience to meet the requirements. The CFDST column composes of an empty steel tube which is infilled with concrete, and both materials sustain together the applied load. In recent years, CFST column has widely been used in various building structures and bridges due to their good mechanical properties and construction performance. Conventional CFDST sections consist of two hollow corrugated steel skins, and the gap between these two skins is filled with concrete. Since CFDST sections use the merits of the high compression strength of the concrete core as well as the ductility of the steel material in the surrounding skins, these sections are choice in structural design. Similar to other steel- concrete composite sections, here the steel skins provide the confinement for the concrete core. In actual the concrete core prevents them from inward buckling. The section of the whole composite column is divided into several parts. They are the steel tube and corrugated steel plate. The surface to surface contact was usually used for the interaction of the steel tube and concrete. Consequently, this interaction enhances the overall strength of the section. However, the efficiency of the confining action has been shown to be dependent on the shape. Previous experiments showed that trapezoidal sections are best out of all types. Investigations were done to conduct the behaviour of innovative corrugated hollow steel column under axial loading and buckling using ANSYS 16.1 WORKBENCH. It has been also observed that slender members are more sensitive to changes in corrugation profile. 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.

1.1 Objective of the Project

- To study the axial and lateral behavior of DSCC with and without end stiffeners
- To study the axial and lateral behavior of DSCC with corrugation plates in parallel and perpendicular directions
- To study the axial and lateral behaviour of best model from above analysis by changing the slenderness ratio
- To study the axial and lateral behaviour of the best model by changing the grade of concrete
- To study the ductile behaviour of best model having light weight and suitable slenderness ratio’s

2. CORRUGATED PLATES

The term ‘‘corrugated’’ in general describes a series of parallel ridges and furrows. In engineering any structure which has a surface with the shape of corrugation either made by folding, moulding, or any other manufacturing methods is called a corrugated structure. Three typical corrugated structures may be classified as: a corrugated pipe, a corrugated sheet and a corrugated panel. The main common feature of all corrugated structures is their exceedingly anisotropic behavior and high stiffness transverse to the corrugation direction in contrast to the compliance along the corrugation direction. Because of this important feature, these structures have been widely used in industrial applications and academic research. By adding two face sheets as upper and lower surfaces to the corrugated sheet a new geometry would be obtained known, as a corrugated panel. By selecting the appropriate shape, dimensions and materials of the face sheets and corrugated core, a variety of stiffness and strength at low weight of the corrugated panel will be achieved. The structural characteristics of this corrugated structure depend mainly on the lightweight corrugated core which separates the face sheets and provides the necessary stiffness for the panel. However, by considering different material stiffness for the face sheets and the corrugated core, different mechanical behaviour of the identical geometry would be expected.

Fig-1: Trapezoidal Corrugated Plates [17]

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. Today the corrugation process is carried out using the process of roll forming. This modern process is highly automated to achieve high productivity and low costs associated with labour. In the corrugation process sheet metal is pulled off huge rolls and through rolling dies that form the corrugation. After the sheet metal passes through the rollers it is automatically sheared off at a desired length

3. MODELLING AND ANALYSIS

3.1 Details of Model

The columns are modeled in ANSYS Workbench 16.1. The column has dimensions of 210mm x 210mm outer tube and 70mm x 70mm inner tube. Height of the column is 1000 mm. The column is infilled with concrete of grade M40. The end stiffeners provided at both ends are of size 2 mm x 10 mm. The ANSYS 16.1 software was used to model all the specimens for nonlinear analysis. SOLID 186 from ANSYS library was used for 3-D finite element modeling of the column model. Two models were studied using ANSYS 16.1 (DSCC with and without end stiffeners). Firstly, the axial load is only provided at an eccentricity of 20 mm (as per IS 456: 2000). In the next step lateral is applied to the structure.

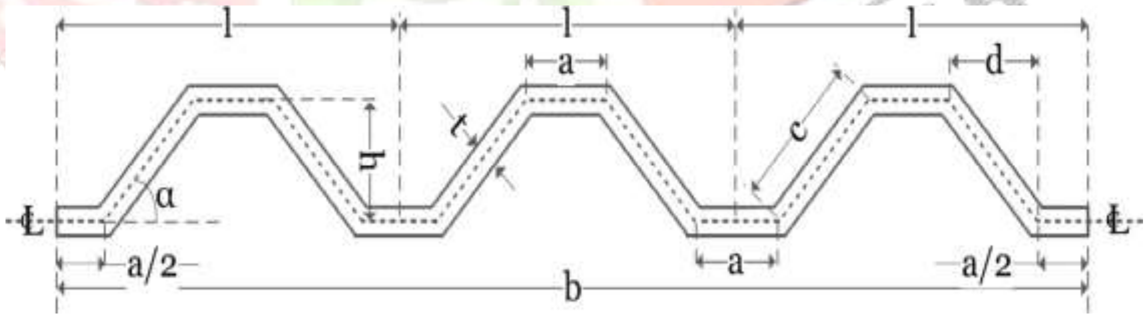

Fig-2: Details of Corrugated Plates [9]

The dimensions are; a- 20 mm, b- 210 mm, c- 25 mm, d- 20 mm, h- 15 mm, t- 3 mm, l- 70 mm, α- 45º. The eccentricity of column was load is acting were calculated. In the column concrete was infilled in between two corrugated tubes. For the analysis both axial and lateral loads were applied to study the compressive and ductile behaviour of corrugated columns. The aim is to determine the behaviour of column under lateral and axial loadings.

3.2 Material Properties

The properties of concrete and steel taken for the analysis is tabulated and shown below.

Table-1: Properties of Concrete and Steel

Concrete
Grade - M40
Poisson's Ratio - 0.3
Compressive Strength - 40 MPa
Density - 2400 kg/m³
Young's Modulus - 31622.77 MPa
Steel
Young's Modulus - 209 GPa
Yield Strength - 556 MPa

3.3 Preparation of Model

The eccentricity of column and the load acting were calculated. In the column concrete was infilled in between two corrugated tubes. For the analysis both axial and lateral loads were applied to study the compressive behaviour of corrugated columns. The aim is to determine the behaviour of column under lateral and axial loadings. The first sets of models are DSCC with and without end stiffeners (Figure.2). Both lateral and axial behaviour is noted. From the results the best model will be selected and it was DSCC with end stiffeners, since the stiffeners provide an extra confinement for the column. The selected model will change its configuration into corrugations in parallel and perpendicular (Figure.3). After their analysis one will be selected for the parametric studies that are by changing its slenderness ratio and grade of concrete.

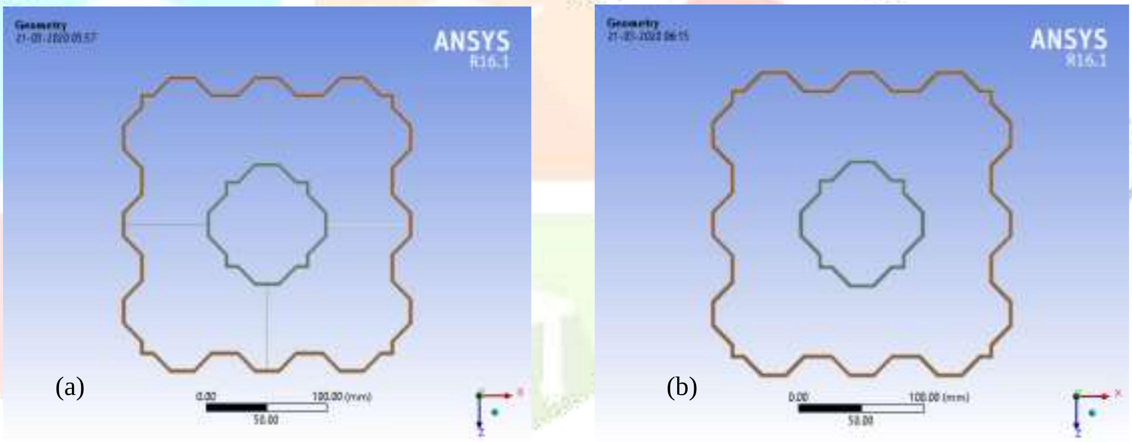

Fig-3: Column Model; (a) DSCC with End Stiffeners, (b) DSCC without End Stiffeners

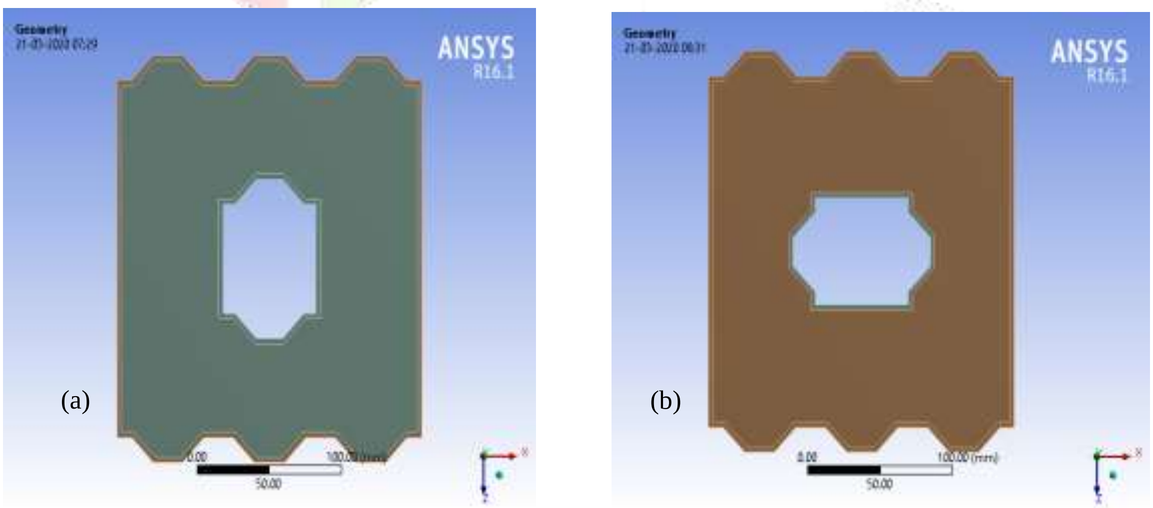

Fig-4: DSCC with End Stiffeners; (a) In Parallel (b) In Perpendicular

3.4 Details of Parametric Study

From the analysis, DSCC with end stiffeners having corrugated plates in parallel is performs better than corrugated plates in perpendicular in both axial and lateral loading conditions. Therefore, this model is used for parametric studies. The parametric studies include, DSCC with different slenderness ratio and different grades of concrete.

3.4.1 Analytical Models with Different Slenderness Ratio's

In this parametric study three different slenderness ratios were studied. For that here columns with three different heights is modeled. They are of heights 500 mm, 1000 mm, and 1500 mm. The loads were provided at top of the columns with an eccentricity of 20 mm.

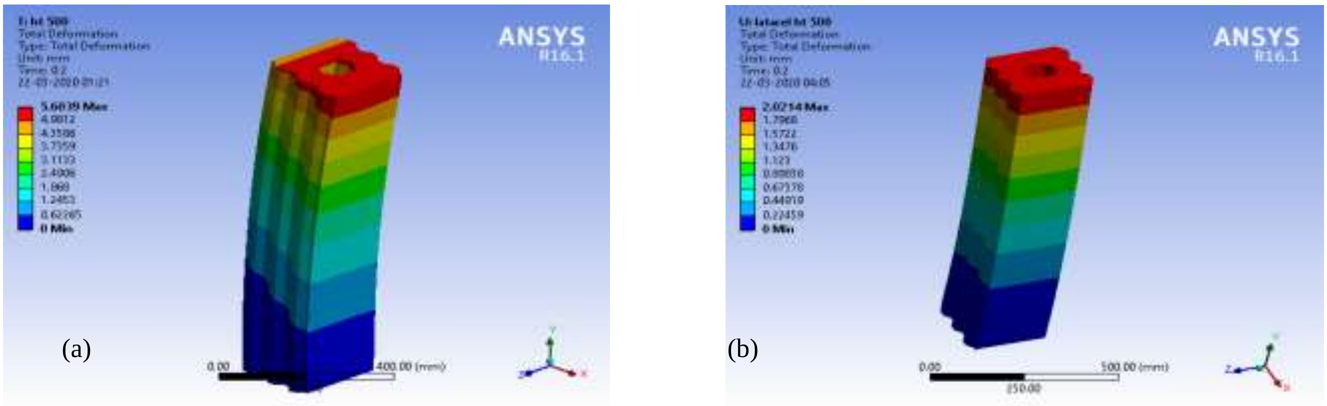

Fig-5: Total Deformation- Height 500 mm (a) Axial Loading (b) Lateral Loading

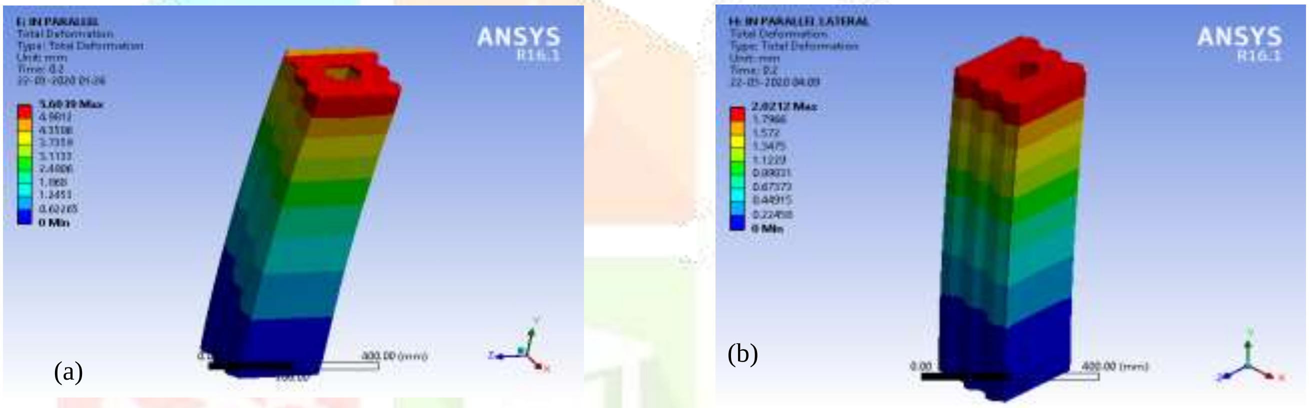

Fig-6: Total Deformation - Height 1000 mm; (a) Axial Loading (b) Lateral Loading

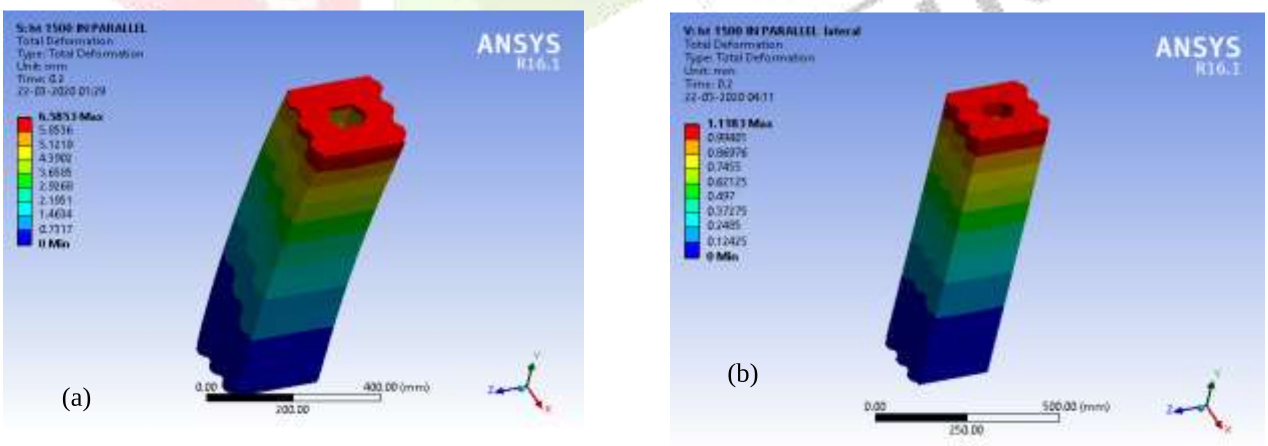

Fig-7: Total Deformation - Height 1500 mm; (a) Axial Loading (b) Lateral Loading

3.4.1 Analytical Models with Different Grades of Concrete

In the next level of analysis, the compressive behavior of DSCC columns when changing their grades of concrete will be studied. This study aims to find that how much lighter column can be made by using corrugated plates. For all models M40 grade is selected as per one previous study which is already detailed in data collection. So that, here adopted concrete grades are less than M40. They are, M35, M30, M25, M20, and M15. The results obtained in axial and lateral loadings are shown below.

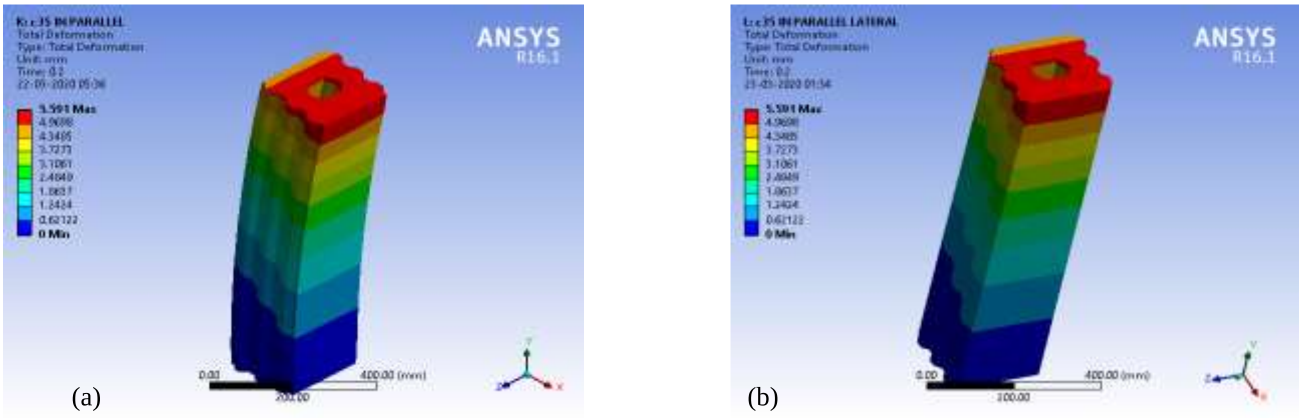

Fig-8: Total Deformation- M35; (a) Axial Loading (b) Lateral Loading

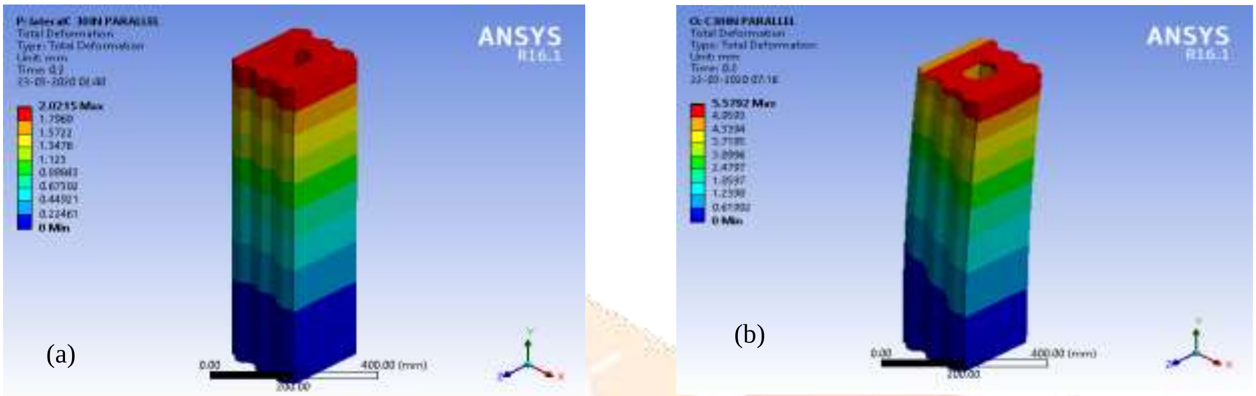

Fig-9: Total Deformation- M30; (a) Axial Loading (b) Lateral Loading

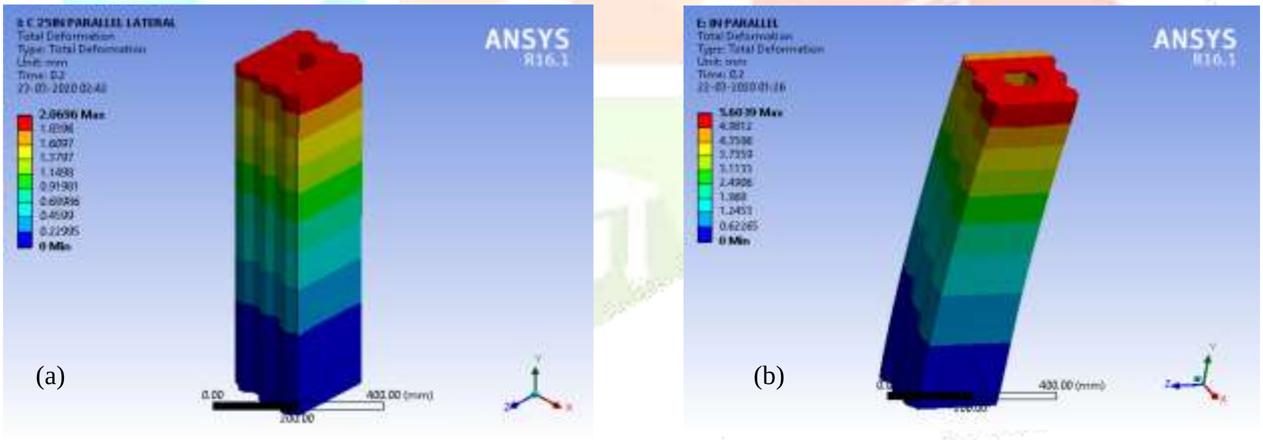

Fig-10: Total Deformation- M25; (a) Axial Loading (b) Lateral Loading

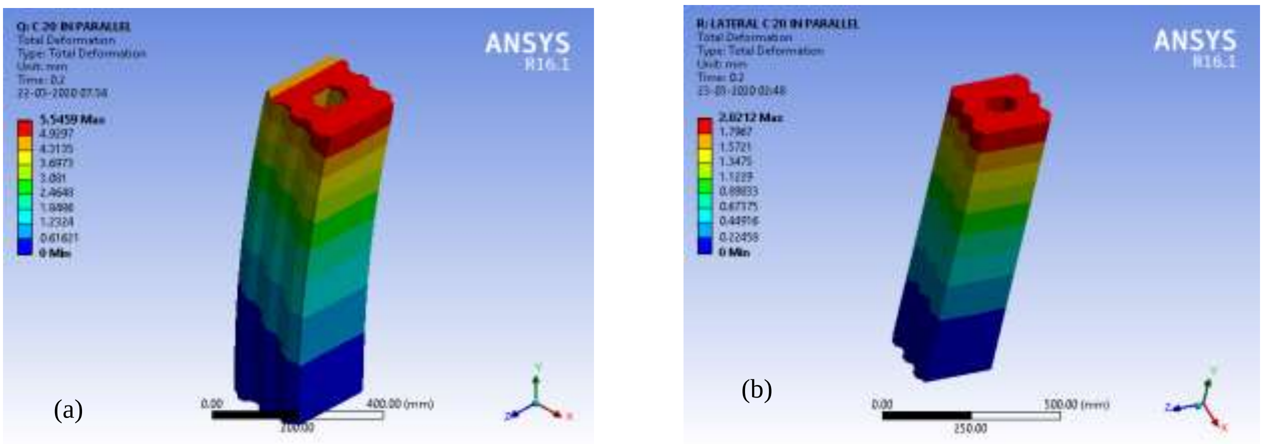

Fig-11: Total Deformation- M20; (a) Axial Loading (b) Lateral Loading

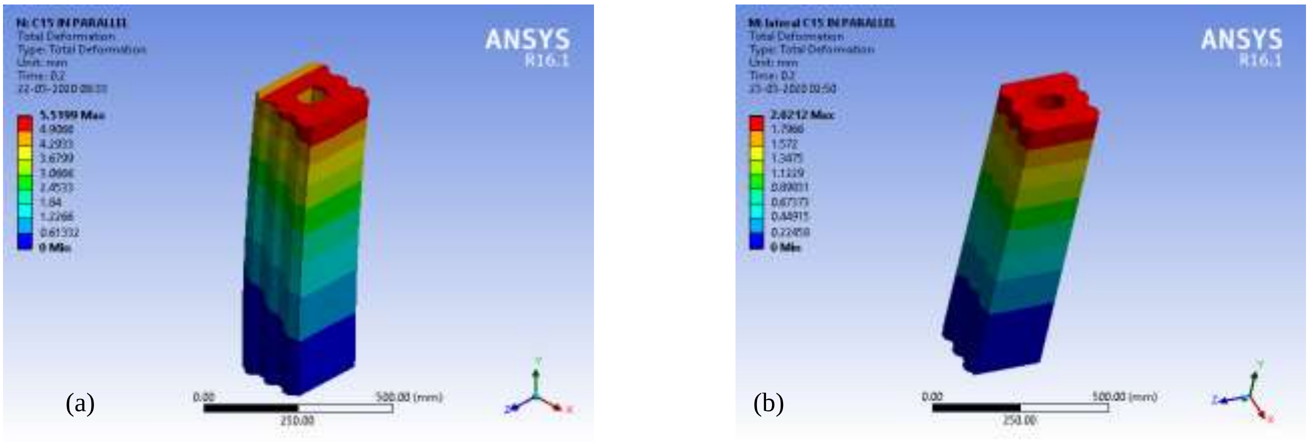

Fig-12: Total Deformation- M15; (a) Axial Loading (b) Lateral Loading

3.4.2 Results and Discussions

The load acting on the columns and their corresponding displacements are noted. The results obtained from analysis using ANSYS 16.1 are shown below;

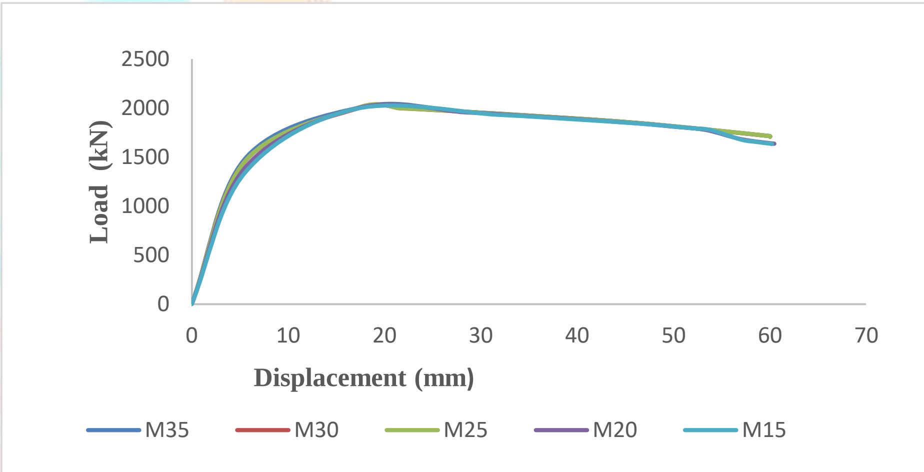

Chart-1: Load- Displacement Curve of Various Slenderness Ratio's

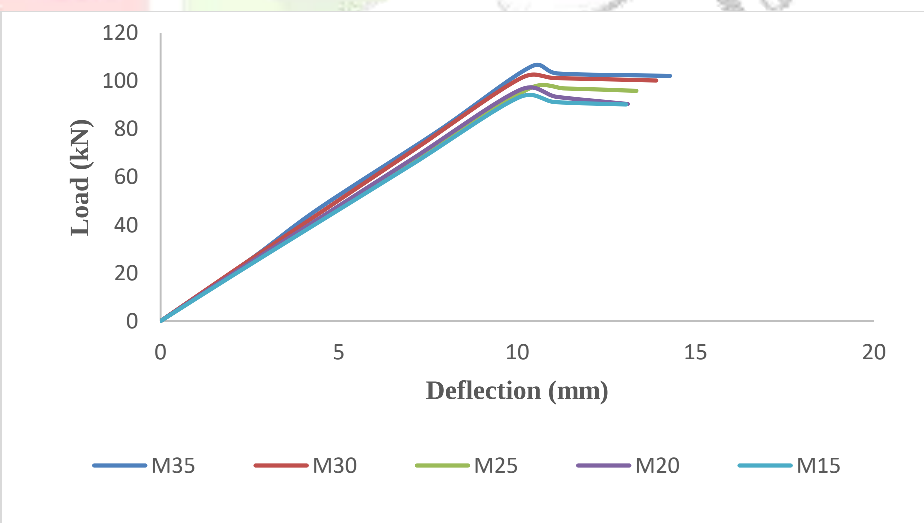

Chart-2: Load- Displacement Curve of Various Grades of Concrete

This analytical study shows that, in both axial and lateral loading, as slenderness ratio increases deformation of column decreases (Chart-1). From the analysis of models, the deflection of the columns increasing with increase of grade of concrete. But the increment is not too large when comparing each other. So, these columns can also construct as light weight structures (Chart-2).

4. CONCLUSIONS

From the analysis of DSCC with and without end stiffeners in axial load case, it is observed that there are only slight variations are present. The column with end stiffeners was performed better than column without end stiffeners. The same column analysis in lateral load case, there is 88.12% of load increment for DSCC with end stiffeners when compared with DSCC without end stiffeners. At the next stage of analysis DSCC with end stiffeners having parallel corrugated plates has an axial load increment of 58.46% than DSCC with end stiffeners having perpendicular corrugated plates. In lateral load case of the above mentioned model has an increment of 51.26% than DSCC with end stiffeners having perpendicular corrugated plates.

As slenderness ratio of the columns increases the deflections decreases in both axial and lateral load cases. From the analysis of columns by changing their concrete grades it is observed that as the grade of concrete increases the deflections of the columns also increases in the case of axial and lateral loads. By using such columns in building structure it can take more lateral and axial load, more deflection without fail, that make civil structures high efficient and safe during earthquake load.

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