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Analysis of Concrete-filled Lean Duplex Stainless Steel Columns Using ANSYS

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Abstract: The Lean Duplex Stainless Steel (LDSS) which is a category of stainless steel is becoming popular as a structural member because of its increased corrosion resistance and durability compared with that of steel. LDSS offers relatively cheaper cost (as compared to austenitic stainless steel), higher strength, acceptable weld ability, and fracture toughness properties, etc. When concrete is filled inside the stainless steel hollow section the load-carrying capacity of this section increases. The aim of this study is to understand the buckling behaviour of concrete-filled stainless steel columns of L, T, and + shaped cross-sections using ANSYS. The LDSS columns having equal material cross-sectional areas with varying thickness are analysed in the current study. This paper gains an understanding of different cross-sectional shape effects under varying thickness.

Keywords: Lean duplex stainless steel, Concrete filled sections, Buckling, Finite element analysis.

I. INTRODUCTION

The Lean Duplex Stainless Steel (LDSS), which is a category of stainless steel is becoming popular as a structural member that has more corrosion resistance and durability compared with that of steel. Austenitic stainless steels are the most widely used types with about 17-18% chromium and 8- 11% nickel additions [1], [2], [3].

It is the most weldable of the stainless steel and is used for various industrial and consumer applications such as in chemical plants, power plants, food processing and dairy equipment [4]. However, with increasing nickel prices (nickel content of 8%–11% in austenitic stainless steel) there is an escalation in the demand for lean duplexes stainless steel (LDSS) with low nickel content of 1.5%, such as grade EN 1.4162 [4–6].

Concrete-filled steel tubular (CFST) columns with circular, square, and rectangular cross-sections have been widely used in civil engineering applications owing to their good structural performance. In addition, the special-shaped (L-, T- and +-shaped) CFLDSS columns have been increasingly favored by many researchers and designers owing to their advantages of avoiding column protrusions from walls and increasing room space. promising and innovative way to reduce the cost is a composite construction, where concrete is filled inside the stainless steel hollow sections (also known as concrete-filled steel tubular (CFST) structures), which combines the advantages of both steel and concrete, and thus provide not only an increase in the load-carrying capacity but also rapid construction.

In this paper an attempt has been made to investigate the behaviour and strength of LDSS columns by employing finite element approach. The main objective of this study is to explore and compare the ststic behaviour of LDSS L-shaped column (L-CFLDSS), T-shaped column (T-CFLDSS), and +-shaped column (þ-CFLDSS) but noting that all these column types have equal material cross-sectional areas.

The particular grade used in this study is EN 1.4162, which is generally less expensive than the austenitic counterpart but offers higher strength, while maintaining a reasonable corrosion resistance.

II. LITERATURE REVIEW

Huang and Young [6] conducted finite element analysis (FEA) on cold-formed lean duplex stainless steel with square and rectangular hollow sections. An accurate finite element model has been created to simulate the pin-ended cold-formed lean duplex stainless steel short columns.

Lam and Giakoumelis [7] evaluated CFST columns under a variety of loading conditions with load applied: 1) on the steel and concrete simultaneously, 2) on the concrete alone and 3) on the concrete and steel with greased interface. The steel grades of S275 and S355 were used and the concrete strength varied from 30 to 100 MPa. Results have shown that when the concrete and steel were loaded concurrently, the tube provided less confinement by comparison to the specimens that were only loaded to the concrete core, similar findings are also reported by Sakino et al. [9].

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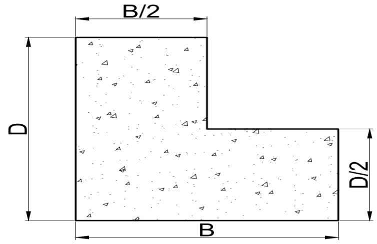
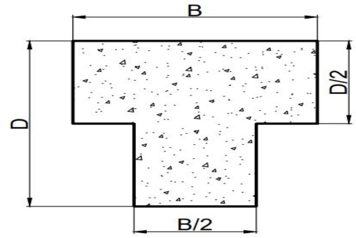
III. STATIC ANALYSIS

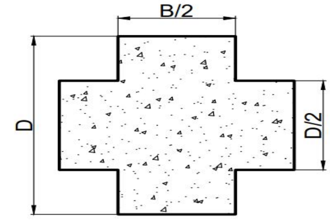
Static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads. Static structural analysis is carried out in ANSYS software. Deformation and load carrying capacity is studied.



(a) L- shape



(b) T- shape



(c) +- shape.

Fig. 1 Section models (a) L- shape (b) T- shape (c) +- shape.

IV. FINITE ELEMENT ANALYSIS

The finite element package ANSYS was used to simulate the concrete filled lean duplex stainless steel column tests. Details of the FE modelling are discussed in the following sections.

A. Geometry

Lean duplex stainless steel of grade EN 1.4162 was used for the modelling. Three different cross-sectional shapes, viz. L-shaped Concrete-filled lean duplex stainless steel column (L-CFLDSS), T-shaped Concrete-filled lean duplex stainless steel column (T-CFLDSS), +-shaped Concrete-filled lean duplex stainless steel column (+-CFLDSS) were studied and the influence of parameters like length, breadth and thickness on behaviour on sections were investigated. The thickness of specimen ranges from 4mm to 6mm were modelled in ANSYS workbench. Geometric details of columns are given in Table I.

TABLE I
MEASURED DIMENSIONS OF CONCRETE FILLED COLUMN

Label	Sections	Dimensions (mm)	L/D (mm)
S1	TL+	100X100X4	30
S2	TL+	100x100x5	30
S3	TL+	100x100x6	30

B. Meshing, Boundary conditions and Loading

Uniform quadrilateral mesh of same size is provided for all the specimens. The FE models considered herein are fixed at one end and allowed to displace only at the loaded end, which is in the direction of the applied load. The other nodes are free to translate and rotate in any direction. Figure 1 shows the typical geometry of a CFLDSS column.

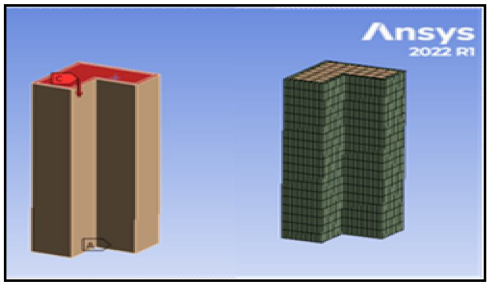


Fig. 2 Model developed in FEA with meshing, loading and boundary condition

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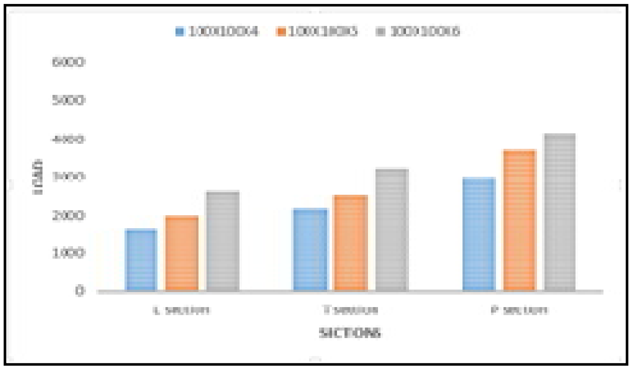
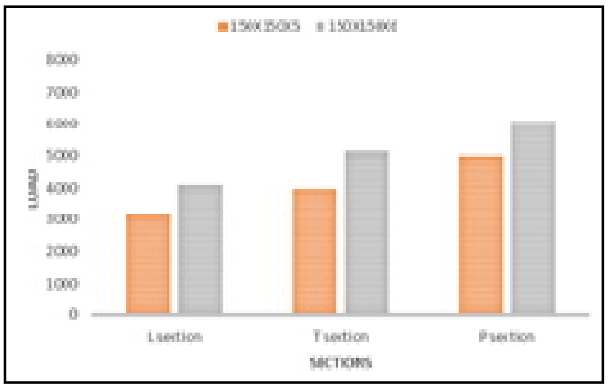
V. RESULTS AND DISCUSSIONS

The results of the FE analysis for the fixed-ended CFLDSS columns were presented in terms of variation in the thickness with a change in the cross-sectional shapes.



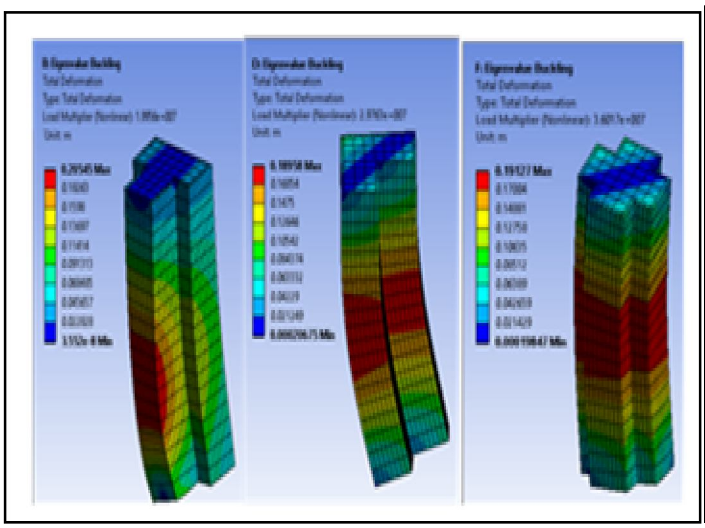
Section S1, S2, S3

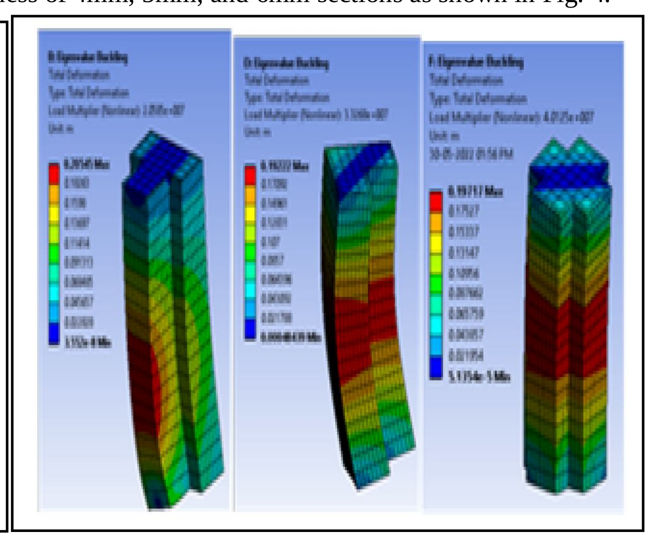


Section S4,S5

Fig. 2.Ultimate load chart of each section

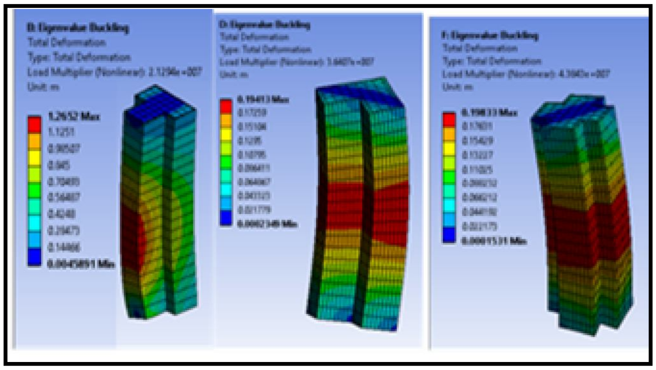
It can be observed from the graph that the ultimate strength of column increases as it goes from L-, T-, to + shaped sections. As the number of corners are increased the ultimate load also increases. From fig. 3, it can be seen that + section has highest ultimate load than T and L section. Also the same behavior is shown for thickness of 4mm, 5mm, and 6mm sections as shown in Fig. 4.





(a) Models of 100x100x4 mm sections.

(b) Models of 100x100x5 mm sections



(c) Models of 100x100x6 mm sections.

However, it can be seen that 6mm thick sections can take more load as compared to other thickness.

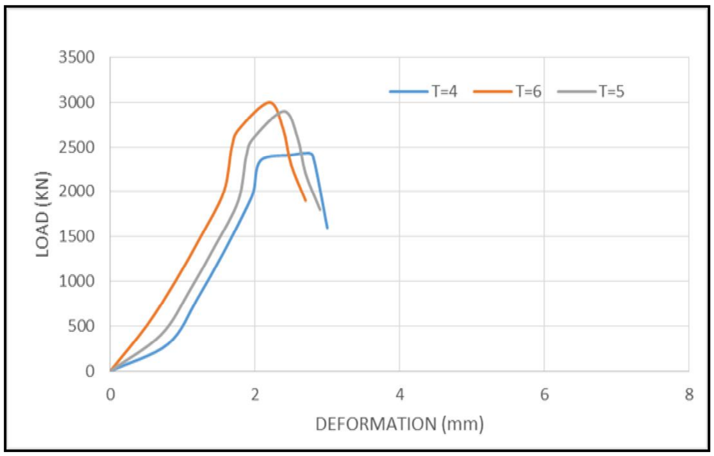
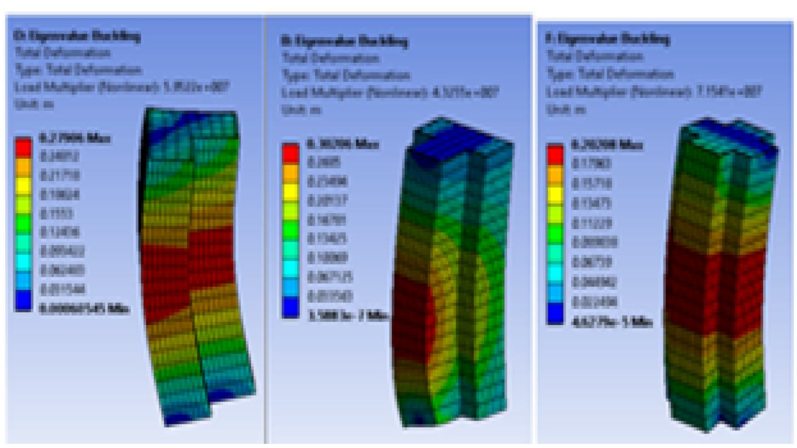


Fig.5 Load- Deformation graph of + section.

Figure 6 shows the analysis of S4, S5 sections. As the section breadth parameter changes, the load capacity also increases. Therefore as B/T ratio changes the there is a significant change in load factor. Thus it can be seen that by switching over to + sections, significant gain in load capacity can be obtained for all thickness considered. Thus it can be possible to achieve higher buckling load with increasing number of corners/ sides than increasing thickness, so can obtain much lighter structures and hence economizing the cost.



(a) Models of 150x150x5 mm sections.

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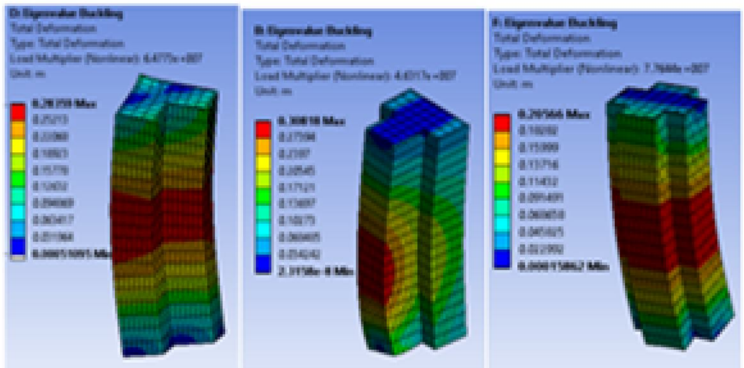

(b) Models of 150x150x6 mm sections.

Fig.6 Models in FEA with varying thickness S4, S5 sections.

VI. CONCLUSIONS

In this paper the FE analyses of CFLDSS columns with Non-rectangular Sections (NRSs) are presented to understand cross-sectional shape effect on the ultimate load and deformation characteristics. For comparing the result, the cross- sectional area for all the specimens are kept equal.

As the thickness, depth and length of the section increases, the load value increases i.e as L/T and B/T ratio increases the load value also increases.

As the section changes from L – T - + shape (i.e number of sides in a section increases) the section becomes more effective in controlling the buckling.

The load value also increases with changes in cross-sectional shape and thickness from L-, T-, + shape sections. So + section with small thickness ratio can gain good resultant value than other sections. From these results it is evident that + section is more economical and efficient.

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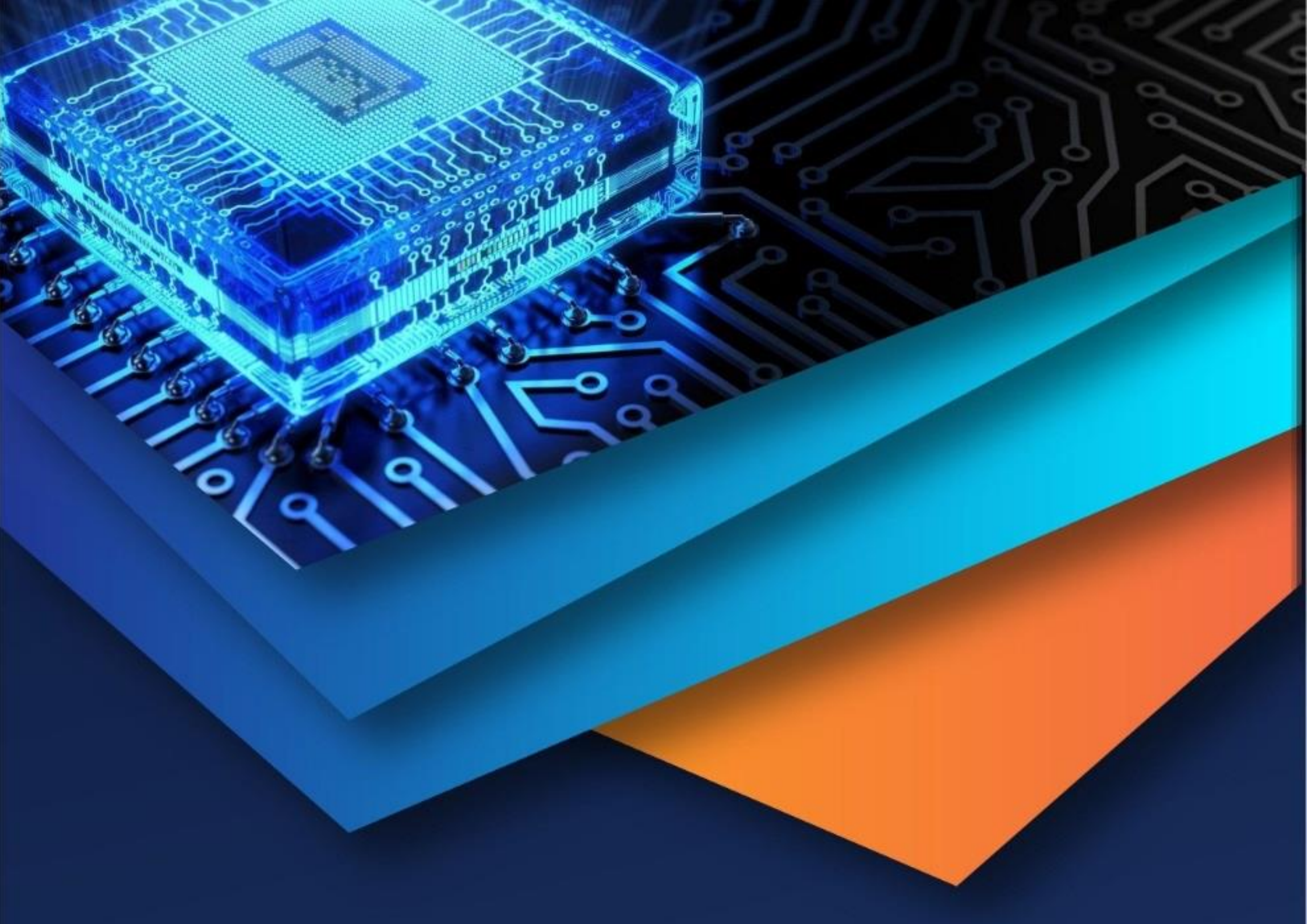

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