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Analytical Study of Concrete Filled Steel Tube (CFST) Columns of Different shapes under Close-Range Blast Loading

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ABSTRACT: This study investigates the behaviour of Concrete Filled Steel Tube (CFST) columns of various shapes, namely L-shaped, T-shaped, and X-shaped columns, under axial and blast loads. CFST columns are composite structural elements that combine concrete's high compressive strength and steel's high tensile strength, making them useful and long-lasting components for modern construction. Static structural analysis is performed using ANSYS Workbench 18.1 to analyse the behaviour of CFST columns. The models are created for different column shapes and variations in dimensions, thickness, force, pressure, and length. Material properties such as concrete grade, steel grade, density, Young's Modulus of Elasticity, and Poisson's ratio are considered for the analysis. The results indicate that X-shaped CFST columns perform better under both axial and blast loads compared to L and T-shaped CFST columns. The maximum stresses and strains for each column shape under different loading conditions are compared and presented in charts. The study concludes that the behaviour of CFST columns is influenced by their shapes, loading conditions, and material properties. By understanding the performance of different column shapes, engineers can optimize their designs to withstand various loads and improve structural safety.
KEYWORDS:CFST columns, Blast load, Axial load, Equivalent Stress, Equivalent Elastic Strain, Total Deformation.

I. INTRODUCTION

The effective use of space has taken center stage in modern building, especially when it comes to vertical parts like columns. These vertical members are essential for transferring tensile and compressive loads inside of a structure. The design of columns has improved throughout time as a result of architects stressing aesthetics and moreover structural functionality. As a consequence, many column designs, including round, square, rectangular, elliptical, triangular, and T-shaped columns, have been developed.

Columns are divided into long columns and short columns depending on their slenderness ratio, which affects how they behave. Short columns typically fail in compression, whereas long, thin columns are more vulnerable to buckling. Columns need to be constructed with improved strength, ductility, and toughness when they've become more susceptible to lateral and vertical loads, including those from wind and earthquakes. Additionally, columns must be resistant to a variety of dangers, such as bombings and terrorist assaults and also natural calamities like earthquakes.

When constructing a road or railway bridge, the dimensions of the columns is often higher than that of residential or commercial constructions. Concrete-filled steel tubes (CFST) or Concrete-filled Double Skin Steel Tubes (CFDST) have been utilized to decrease the dimensions of the columns while enhancing its performance under compressive stresses. In low-rise industrial structures, multi-story buildings, and high-rise skyscrapers, these materials are employed as columns, beams, and beam-columns. They also have uses in a variety of other buildings, including stores, subway stops, electric poles, bridge piers, arches, and towers for numerous types of bridges, including cable-stayed bridges.

Concrete-Filled Steel Tube (CFST):A concrete - filled steel tube (CFST) is a structural component made of a metal pipe or tube that has been stuffed with concrete of high strength. As seen in Figure 1, it can also known as a concrete-encased steel column or a concrete - filled steel pipe (CFSP). By combining the advantageous qualities of steel & concrete, this method produces a structural element that is both highly effective and long-lasting. The CFST system is makingutilize of the strong compressive-strength of concrete and the high-tensile-strength of steel to withstandseveral kinds of loading conditions. The outside steel tube acts as a covering shield, enhancing the flexibility and toughness of the mortar core. Contrarily, the steel pipe is given more mass, stiffness, and fire resistance by the concrete core.

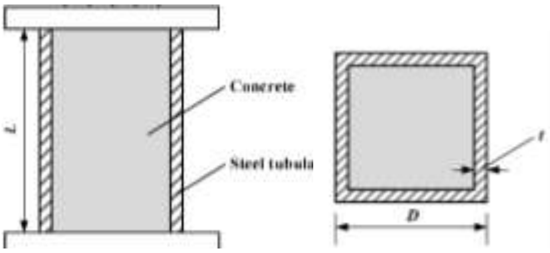

Fig 1: CFTS column

Different Shapes of CFST: The L-shaped CFST consists of a metal pipe that is packed with concrete. The L-shaped configuration is created by the right angle connecting two steel tubes, as showing in Figure 2, to create the cross-section shape. The concrete filling improves the element's ability to carry loads and resist fire, while the steel pipe gives the structure its stiffness and also strength.

The T-shaped concrete-filled-steel-tube (CFST) contains metal pipe that is packed with concrete and connected by steel plates as showed in the Figure 2. Due to its great strength and load-bearing capacity, this form of structural element is frequently utilized in construction.

The X-shaped concrete-filled-steel-tube (CFST) is a structural component that consists of steel pipes in the shape of an "X" that are filled with concrete. These tubes are connected by steel plates showing in the Figure 2. Since the high tensile capacity of steel and the compressive capacity of concrete employed in this system, a sustainable and effective structural solution is produced.

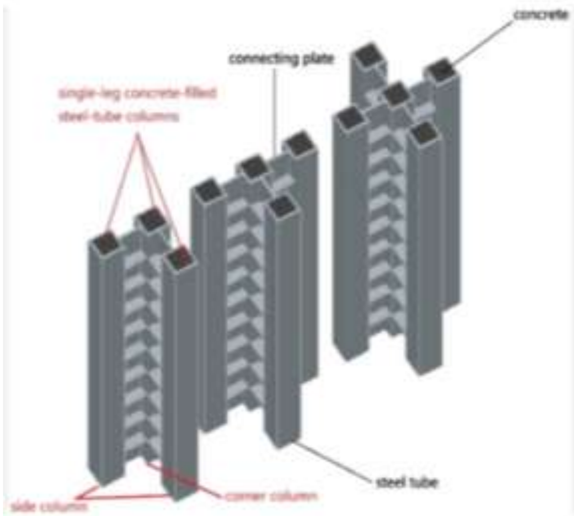

Fig 2: CFST columns: L-shaped, T-shaped, X-shaped

II. METHODOLOGY

- CFST column models are built using ANSYS Workbench 18.1
- By performing a static structural analysis of various column shapes, such as L, T and X-shaped columns for dimension, thickness, force, pressure and length (3m), It is feasible to research how CFST columns behave, including its deformity, stress, strain Characteristics.
- Tabulate the outcomes that are obtained from the deformity, stress, strain and compute the chart

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Tabulation of model, material and load properties.

Table 1:Details of Models

Type of Geometry	Square section
Type of structural element	Column
Concrete grade	M_{40}
Steel grade	Fe_{345}
Mesh size	50mm
Analysis type	Static structural

Table 2: Specification of materials

Material	Concrete	Steel
Density	2400 kg/m^3	7850 kg/m^3
Grade	M40	Fe345
Young's modulus of elasticity	3.1622e+10	2e+11
Poisson's ratio	0.18	0.3

Table 3: Details of CFST column

W (mm)	D (mm)	t (mm)	L (mm)
100	100	8	3000

Table 4: Details of loads

Shape	Length (mm)	Axial load (kN)	Blast load (TNT equipment)	
L-shaped	3000	2400	50kg	1kg
T-shaped	3000	2400	50kg	1kg
X-shaped	3000	2550	50kg	1kg

The table 4contains the details of loads where axial load is gradually increasing from 500kN, here L and T-shaped CFST columns breaks at 2400kN and X-shaped columns breaks at 2550kN of axial loads.

III. RESULT AND DISCUSSIONS

This section contains the results obtained after the model analysis was conducted. The characteristics of the CFST columns in the current study were seen under applied load employing dynamic structural analysis. There were numerous models used in this investigation. The models were created in the form of L, T, and X-shaped column, among other CFST column types. Deformation, stress, and strain are some of the analysis findings that are evaluated and tabulated. The results were compared to the different study parameters.

Variation With Deformation for both Axial and Blast load

This section explored the variations in deformations of CFST columns of L, T and X-shaped column for both axial and blast load. The analysis is done for the same loading by modifying the different shapes, and the force and pressure are applied as uniformly distribute load over the entire surface.

- **For 50kg TNT Equipment**

The variation in deformation of different shaped CFST columns for both axial and blast load. Where L, T and X-shaped column deformed differently under force and pressure. It demonstrates that for a 2400kN force and pressure of 50kg TNT equipment, an L-shaped column deforms by 300.13mm, T-shaped column deforms by 299.06mm and an X-shaped column deforms by 268.13mm for a 2550kN force and pressure 50kg TNT equipment of length 3000mm.

- **For 1kg TNT Equipment**

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The variation in deformation of different shaped CFST columns for both axial and blast load. Where L, T and X-shaped column deformed differently under Force and pressure. It demonstrates that for a 2400kN force and pressure of 1kg TNT equipment, an L-shaped column deforms by 23.02mm, T-shaped column deforms by 22.52mm and an X-shaped column deforms by 20.21mm for a 2550kNforce and pressure 1kg TNT equipment of length 3000mm.

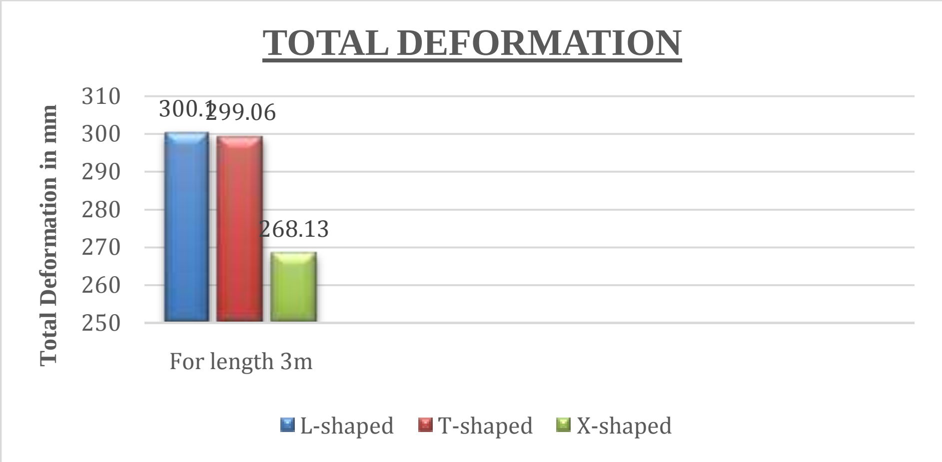

Fig 3: Deformation chart for both Axial and Blast load of 50kg TNT

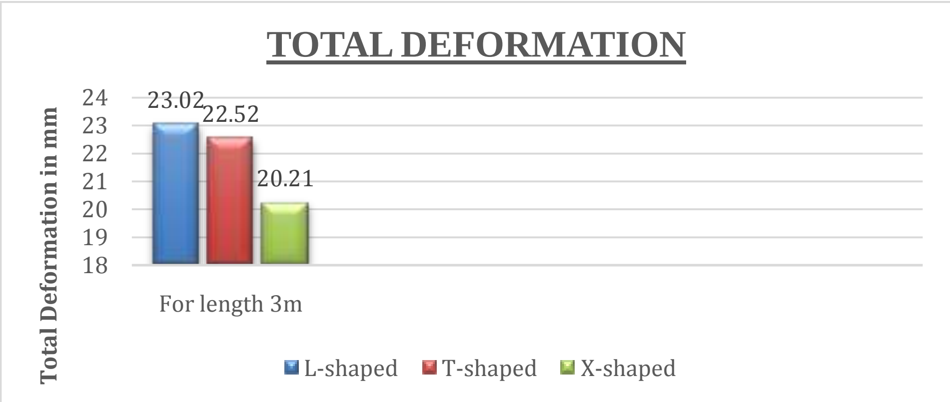

Fig 4: Deformation chart for both Axial and Blast load of 1kg TNT

Variation With Equivalent Stresses for both Axial and Blast load

This section explored the variations in stresses for L, T and X-shaped CFST column. The analysis is done for the same loading by modifying the different shapes, and the force and pressure are applied as uniformly distributed load over the entire surface.

- **For 50kg TNT Equipment**

The equivalent stress variation of L, T and X-shaped CFST columns are plotted in Fig 5. Under both force and Pressure, L, T and X-shaped column have various maximum stresses. It demonstrates that for2400kN force and pressure of 50kg TNT equipment, the L-shaped column's maximum stress is 618.37N/mm^2 for concrete and 4810.6N/mm^2 for steel, T-shaped column's maximum stress is 636.61N/mm^2 for concrete and 4858.5N/mm^2 for steel and for a 2550kN force, an X-shaped column's maximal stress is 1117.7N/mm^2 for concrete and 7579.9N/mm^2 for steel of length 3000mm.

- **For 1kg TNT Equipment**

The Equivalent stress variation of L, T and X-shaped CFST column are plotted in Fig 6. Under both force and Pressure, L, T and X-shaped column have various maximum stresses. It demonstrates that for a 2400kN force and pressure of 1kg TNT equipment, the L-shaped column's maximum stress is 40.75N/mm^2 for concrete and 136.2N/mm^2 for steel, T-shaped column's maximum stress is 40.794N/mm^2 for concrete and 140.19N/mm^2 for steel and for a 2550kN force, an X-shaped column's

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maximum stress is 40.473N/mm^2 for concrete and 233.75N/mm^2 for steel of length 3000mm.

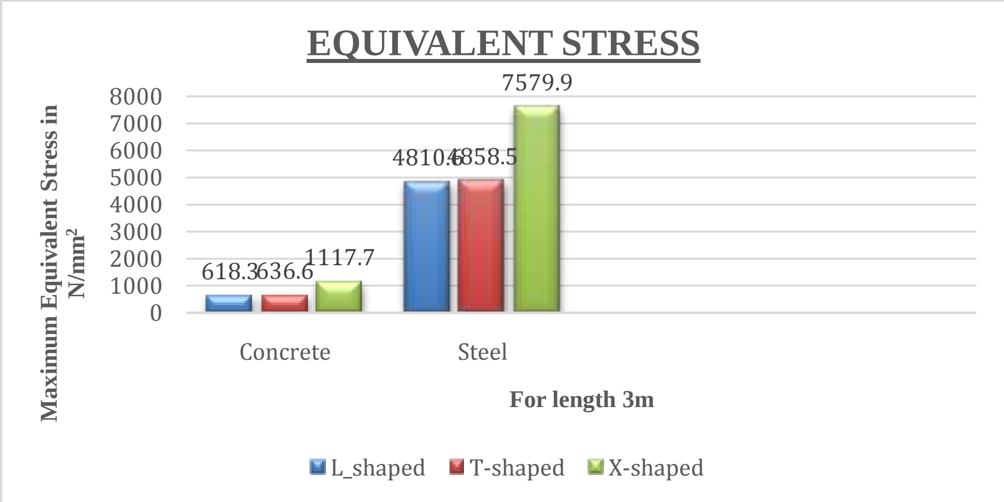

Fig 5: Equivalent Stress chart for both Axial & Blast load of 50kg TNT

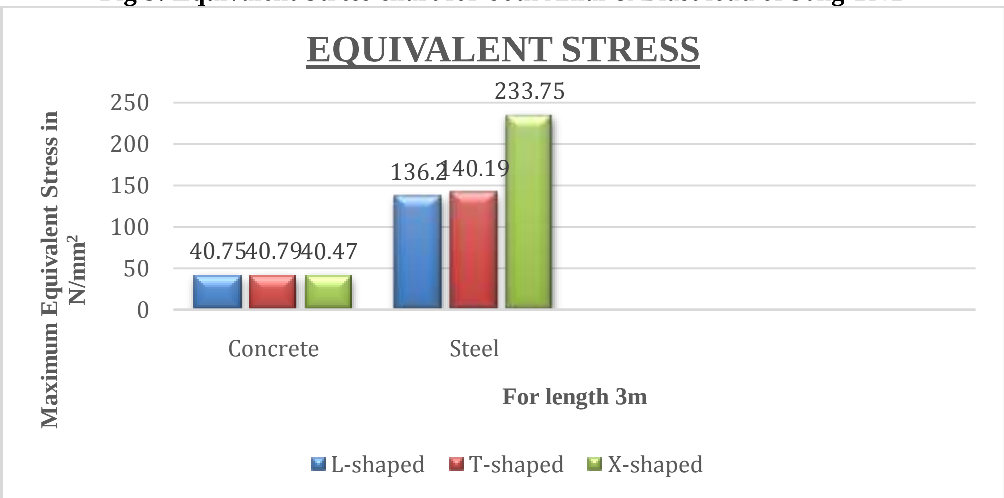

Fig 6: Equivalent Stress chart for both Axial and Blast load of 1kg TNT

Variation With Equivalent Elastic Strain for both Axial & Blast load

This section explored the variations in Elastic Strains for L, T and X-shaped CFST columns. The analysis is done for the same loading by modifying the different shapes, and the force and pressure are applied as uniformly distribute load over the entire surface.

- **For 50kg TNT Equipment**

The Equivalent Elastic Strain variation of L, T and X-shaped CFST compression member are plotted in Fig 7. Under both axial and blast load of 50kg TNT equipment. It demonstrates that for2400kN force and blast load of 50kg TNT equipment, the L-shaped column's maximum elastic strain is 0.020712 for concrete and 0.02455 for steel, T-shaped column's maximum elastic strain is 0.021253 for concrete and 0.02481 for steel and for a 2550kN force, an X-shaped column's maximum elastic strain is 0.037255 for concrete and 0.047359 for steel of length 3000mm.

- **For 1kg TNT Equipment**

The Equivalent Elastic Strain variation of L, T and X-shaped CFST column are plotted in Fig 8. Under both axial and blast load of 1kg TNT equipment. It demonstrates that for2400kN force & blast load of 1kg TNT equipment, the L-shaped column's maximum elastic strain is 0.0021244 for concrete and 0.0024655 for steel, T-shaped column's maximum elastic strain is 0.0021509 for concrete and 0.0023038 for steel and for a 2550kN force, an X-shaped column's maximum elastic strain

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is 0.003733 for concrete and 0.0048563 for steel of length 3000mm.

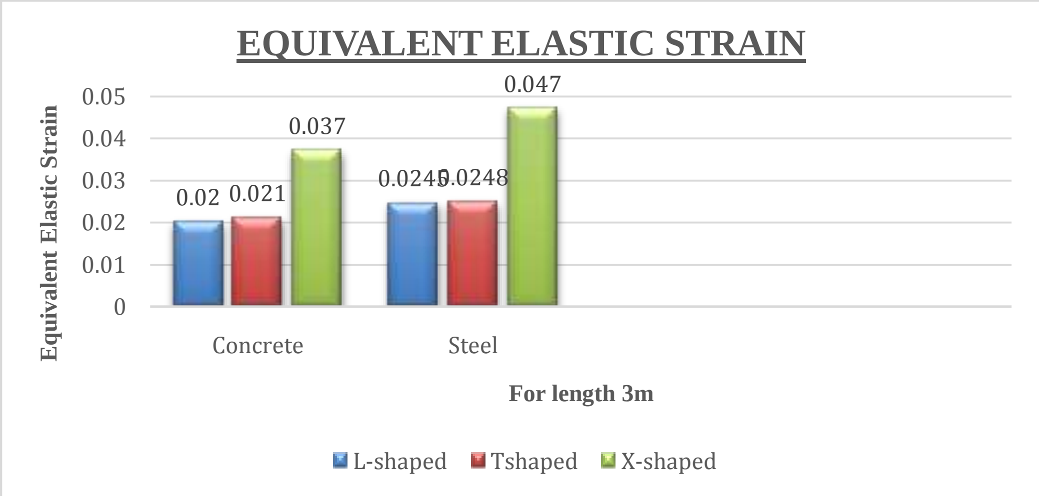

Fig 7: Equivalent Elastic Strain chart for both Axial and Blast load of 50kg TNT

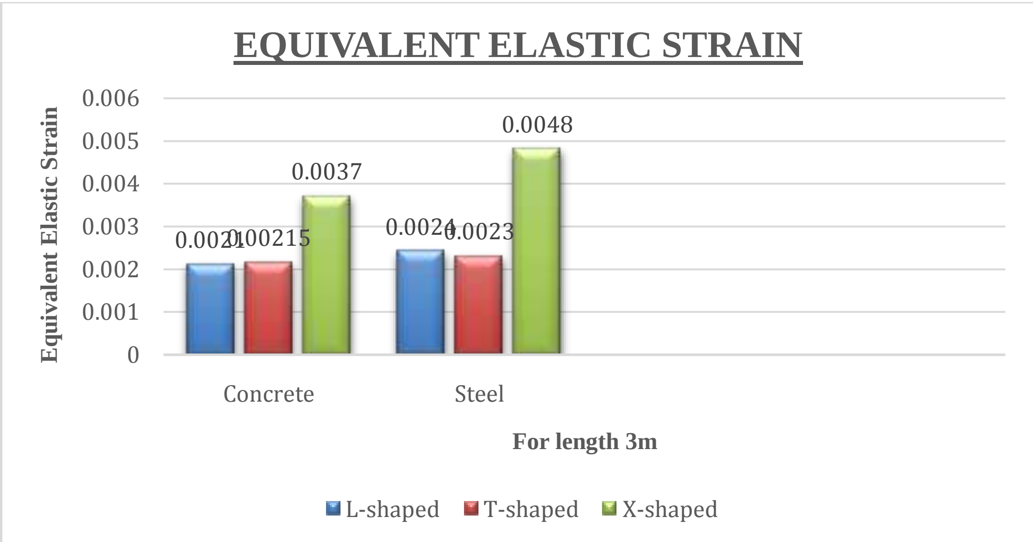

Fig 8: Equivalent Elastic Strain chart for both Axial and Blast load of 1kg TNT

IV. CONCLUSION

Looking back on this project, the overall outcome of results to be observed are, whenaxial load and blast load of 50kg and 1kg TNT equipment are applied on L, T and X-shaped columns,where the X-shaped columns perform 11.26% better than the L and T-shaped columns.

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