

# "Analyzing Compression Strength Variations Rate in Concrete-Filled Steel Tubes: Impact of Changes in Steel Cross-Sectional "

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**Abstract:** This study investigates how changes in the cross-sectional shapes of steel tubes affect the compression strength of concrete-filled steel tubes (CFST). The study analyses the common shapes of square, rectangular, and circular tubes, each with the same thickness. Understanding the impact of shape variations on compression strength is crucial for optimizing the design and structural performance of CFST elements in construction projects. The research aims to provide insights into the relationship between steel cross-sectional changes and CFST compression strength through comprehensive analysis and experimentation, contributing to enhanced structural design methodologies and more resilient infrastructure. This study offers practical guidelines for engineers and architects to effectively utilize CFST in various construction applications, ensuring safety and durability in building structures, by examining the variations in compression strength across different shapes. Moreover, the findings of this research could potentially lead to advancements in construction materials and techniques, promoting sustainable and efficient infrastructure development.

**Key Words:** CFST structures, Axial-load, Residual Bond, stainless-steel, compressive strength, bearing capacity.

## 1. Introduction

In recent years, Concrete-filled steel tubes (CFST) have gained popularity in the construction industry due to their remarkable strength and capacity to endure heavy loads. The structure of CFST consists of a steel cylinder that is filled with concrete, resulting in a combination of the robustness of steel and the enduring properties of concrete. This combination renders CFST an increasingly favoured choice for engineers and architects who seek to erect structures that are not only resilient but also cost-effective.

This research delves into the intricate relationship between the shape of CFST and its strength, with a particular focus on three common shapes: circular, square, and rectangular. The significance of understanding how the shape of these tubes impacts their strength cannot be overstated, as it directly correlates with the safety and longevity of constructed edifices. By comprehensively investigating this relationship, we aim to provide invaluable insights that will inform future construction practices and enhance structural design methodologies.

To conduct our experimentation, we fabricated a total of nine CFST tubes, meticulously ensuring uniformity in thickness at 2.5 millimetres. Each shape – circular, square, and rectangular – was represented by three tubes. We chose M35 grade concrete, known for its reliability and robustness in construction applications, to ensure consistency and reliability in our findings.

The overarching objective of this research is to elucidate how variations in CFST shape influence its strength when combined with concrete. We plan to achieve this by conducting a series of tests on each of the three shapes of CFST

tubes. These tests will include bending, compression, and diagonal tension tests. We will measure the strength of each tube by determining the load capacity until failure occurs.

The findings of this study hold significant implications for engineers and architects tasked with designing buildings that meet stringent safety standards while optimizing material usage and structural integrity. By identifying the most robust CFST shape through our experimentation, we aim to facilitate the construction of buildings capable of withstanding heavy loads without compromising the safety and well-being of occupants.

Furthermore, we anticipate that our research outcomes may inspire advancements in construction methodologies, fostering increased efficiency and promoting environmental sustainability within the industry. This research will also contribute to the development of new design standards for CFST, which could lead to the creation of more innovative and efficient structures.

In summary, this study embarks on a quest to unravel the intricate interplay between CFST shape and strength, with the ultimate aim of contributing to the construction of safer, sturdier, and more environmentally conscious buildings. Through rigorous experimentation and analysis, we endeavour to provide actionable insights that will shape the future of structural engineering and construction practices.

## 2. Literature Review

The literature review is a pivotal component of this research paper, synthesizing insights from a diverse array of studies that collectively contribute to the understanding and advancement of Concrete-Filled Steel Tube (CFST) structures.

2.1 Talha Ekmekyapar and Baraa J.M. AL-Eliwi (August 2016) contributed to the understanding of CFST columns by examining their experimental Behaviour and design specifications. Their findings revealed an inverse relationship between the strength of the core concrete and the structural integrity of the column, shedding light on optimization strategies for CFST design.

2.2 In 2023, Sun and Liang conducted a study exploring the seismic Behaviour of I-beams bolted to CFST (Concrete Filled Steel Tube) column connections using extended TSOBs (Through-Stiffened Outstand Bolts). Through extensive experimentation and finite element modeling, several significant findings were revealed. Firstly, two distinct failure modes were identified: bolt pulling-out coupled with concrete crushing in the absence of an H-steel stiffener, and endplate fracture accompanied by H-steel stiffener shearing.

2.3 In 2022, Zhang W-H., Wang R., Zhao H., Dennis Lam, and Chen P. conducted a study on the axial-load response of CFST stub columns with external Stainless-Steel and recycled aggregate concrete (RAC). Their objective was to examine the axial-load responses of RAC-filled CFST stub columns and assess the applicability of design codes. Various failure modes were observed, and strain-softening and strain-hardening responses were identified. The authors concluded that the design codes applicable to normal CFSTs also applied to RAC-filled CFST columns, with concrete strength and steel ratios influencing the failure modes.

2.4 In 2021, Xi-Feng Yan, M.F. Hassanein, Fangying Wang, and Meng-Nan He examined the Behaviour and design of high-strength concrete-filled rectangular ferritic Stainless-Steel tubular short columns subjected to axial compression. Their aim was to examine the axial performance of CFFSST columns and assess the impact of concrete strength and dimensions. They concluded that increased strength and cost savings were achievable with concrete filling, noting that high-strength concrete was economical for thin columns, with concrete strength influencing stiffness, strength, and ductility.

2.5 In Gupta, P. K., Khandhair, Z. A., & Ahuja, A. K. (2014). Three-dimensional nonlinear finite element model accurately simulates load-carrying capacity and deformation of circular CFST columns. Verification against experimental data confirms its reliability. Numerical investigations elucidate load-carrying mechanisms for different concrete grades. This selection of studies delves into various aspects of concrete-filled Stainless-Steel tube columns, covering Behaviour under different loading conditions, design considerations, and the influence of parameters like welding quality, partial compression, and connections to beams.

2.6 Faridmehr, I., Nehdi, M. L., & Farokhi Nejad, A. (2024). Parametric study confirms that the axial load capacity of high-strength CFST columns is primarily influenced by concrete compressive strength ( $f_c$ ) rather than section yield strength ( $f_y$ ). This implies varying P-M interaction curve configurations based on geometric and material properties.

### 3. Materials And Methods (Methodology)

The method and methodology employed for the development and testing of Concrete Filled Steel Tubes (CFST) in this research are outlined below.

#### 3.1 Concrete Mix Design:

The concrete mix design was conducted to achieve the desired grade and characteristics suitable for CFST construction. The following specifications were utilized:

- Grade Designation: M-35
- Cement Type: Ordinary Portland Cement (O.P.C-43 grade)

#### Calculation Steps:

##### 3.1.1. Target Mean Strength:

- The target mean strength for M-35 grade concrete was determined based on this equation Target Mean Strength (T.M.S.) =  $F_{ck} + 1.65 \times S.D.$

##### 3.1.2. Selection of Water Cement Ratio:

- From Table 5 of IS 456:2000, the maximum water-cement ratio is 0.45.

##### 3.1.3. Calculation of Water:

-From Table 2 of IS 10262-2009, the maximum water content = 186 liters (for a 25 mm – 50 mm slump range and 20 mm aggregates).

##### 3.1.4. Calculation of Cement Content:

- Water content per cubic meter of concrete/ Water-cement ratio

##### 3.1.5. Calculation for Coarse Aggregate and Fine Aggregate:

- The proportions of coarse aggregate and fine aggregate were calculated according to the mix design for M-35 grade concrete.

The ratio of M35 grade concrete = 0.45:1:1.18:2.34

If the total weight required for the concrete mix is 50 kg, we can adjust the quantities accordingly based on the given ratios. Let's recalculate the mix design:

Given ratio: 0.46:1:1.17:2.35

Total weight required: 50 kg

- Cement:

Cement ratio = 0.46

Cement quantity =  $0.46 \times 50 \text{ kg} = 23 \text{ kg}$

- Fine Aggregate (Sand):

Fine aggregate ratio = 1

Fine aggregate quantity =  $1 \times 50 \text{ kg} = 50 \text{ kg}$

- Coarse Aggregate:

Coarse aggregate ratio = 1.17

Coarse aggregate quantity =  $1.17 \times 50 \text{ kg} = 58.5 \text{ kg}$

- Water:

Water ratio = 2.35

Water quantity =  $2.35 \times 50 \text{ kg} = 117.5 \text{ kg}$

Therefore, for a total weight requirement of 50 kg, the mix design for M-35 grade concrete with the given ratio (0.46:1:1.17:2.35) is as follows:

- Cement: 23 kg

- Fine Aggregate (Sand): 50 kg

- Coarse Aggregate: 58.5 kg

- Water: 117.5 kg

These quantities should provide the desired proportions for preparing M-35 grade concrete with a total weight of 50 kg.

### 3.2 Steel Selection and Characteristics & CFST Development:

- Stainless steel was chosen as the material for the steel column.

- The thickness of the stainless steel utilized was 2.5 mm.

- The concrete-filled steel tubes (CFST) were constructed using the calculated concrete mix design and stainless-steel columns.

- square, rectangle and circular shapes of steel columns were employed in the CFST construction.

### 3.3 Compression Test:

- Compression tests were conducted on the developed CFST specimens using a compression testing machine.

- The machine applied a steadily increasing compressive force until failure occurred, allowing for the determination of the compressive strength of the CFST specimens.

This methodology ensured the systematic development and testing of CFST specimens, providing valuable insights into their structural performance and suitability for various engineering applications.

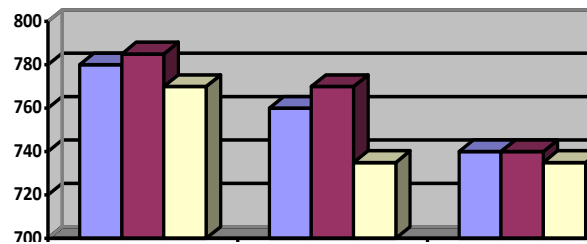
## 4. Results & Discussion

The compression testing results of Circular, Square, and Rectangular CFST specimens, each featuring a steel case thickness of 2.5 mm filled with M-35 grade concrete, are summarized as follows:

**Table 4.1: Result of compression testing**

| S.N<br>O | SPECIMEN<br>TYPE | ULTIMATE LOAD (KN) |
|----------|------------------|--------------------|
| 1        | Circular 1       | 780                |
| 2        | Circular 2       | 785                |
| 3        | Circular 3       | 770                |
| 4        | Square 1         | 760                |

|   |               |     |
|---|---------------|-----|
| 5 | Square 2      | 770 |
| 6 | Square 3      | 755 |
| 7 | Rectangular 1 | 740 |
| 8 | Rectangular 2 | 740 |
| 9 | Rectangular 3 | 735 |



**Chart -4.1: Comparison b/w diff shape CFST Compression strength**

The compression tests on Concrete Filled Steel Tube (CFST) specimens highlighted significant differences based on column shape. Square specimens consistently exhibited higher ultimate loads compared to rectangular ones, while circular columns surpassed both in strength.

These findings emphasize the critical role of column geometry in CFST performance and have implications for design and construction practices. Prioritizing geometric factors can optimize load-bearing capacity and structural integrity in CFST applications. Further research is needed to refine design guidelines and enhance CFST performance in diverse engineering contexts.

## 5. Conclusions

In summary, the compression testing of Circular, Square, and Rectangular Concrete Filled Steel Tube (CFST) specimens, filled with M-35 grade concrete and featuring a 2.5 mm steel case thickness, revealed distinct performance characteristics.

Circular CFST specimens demonstrated the highest load-bearing capacity, followed by square specimens, while rectangular specimens exhibited the lowest strength. This highlights the influence of column shape on CFST performance under compression.

The superior performance of circular CFSTs, attributed to their uniform stress distribution, suggests their suitability for structural applications. However, further research is needed to refine design guidelines and optimize CFST performance across diverse engineering contexts.

These findings underscore the importance of considering column geometry in CFST design and construction, ensuring the development of resilient and efficient structures.

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