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*Research Article*

# Study of Concrete-Filled Square and Circular Tubes Subjected to Axial Compression Load

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**Abstract:**

*This study investigated the behavior of concrete filled tube (CFT) under axial compression load, focusing on specimens with different steel-to-concrete ratios and tube thicknesses. The load-deflection behavior, failure mode, and ultimate strength of the CFT specimens were analyzed for different tube sections, including circular and square hollow sections. The results showed that the CFT specimens exhibited a ductile behavior with stable load carrying capacity up to failure. The ultimate strength of the CFT specimens was found to increase with increasing steel-to-concrete ratio and tube thickness. The study provides useful insights into the behavior of CFTs under axial compression load, which can be used in the design of CFT structures. The use of high-strength steel in CFSTs can further enhance their strength and durability. The study also highlighted the influence of factors such as the size and shape of the steel tube and the compressive strength of the concrete on the strength of short CFST columns. Overall, this research can be valuable to engineers and researchers working in the field of structural and construction engineering.*

*Keywords— axial load, steel tube, ductility, column*

## INTRODUCTION

### 1.1 Background

Concrete-filled tubes (CFTs) have become increasingly popular in construction due to their superior structural performance compared to other structural systems. The combination of steel and concrete in CFTs creates a hybrid composite material with excellent strength, ductility, and durability, making them ideal for use in high-rise buildings, unique architectural structures, and infrastructure projects such as bridges and railway stations [1,2]. While CFTs have been the subject of many investigations, relatively little research has been done on their behaviour under axial compression loading.

This paper aims to study the behaviour of CFTs under axial compression loading, with a focus on mid-strength concrete columns with circular and square cross-sections, as well as infilled columns. The study will compare the results of the experiment with design codes to determine if improvements or adjustments are necessary. The research will involve casting 18 concrete cubes for testing at 7, 14, and 28 days, and creating 12 CFT study specimens to measure compression load, mode of failure, load-deformation graph, and ductility index of the columns. The results will provide valuable insights into the design of CFT structures and the accuracy of current design codes.

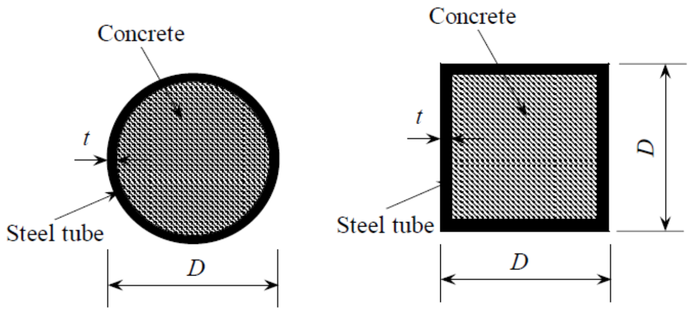


**Figure 1.**Concrete-filled steel tubular columns

The use of CFTs in construction has a significant impact globally. With the country's rapid urbanization and infrastructure development, CFTs could prove to be a valuable solution for creating structures that can withstand dynamic loads brought on by earthquakes and other natural disasters [3]. By understanding the behavior of CFTs under axial compression loading, designers and engineers in Nepal and other countries can optimize their use of this composite material to create safer, more efficient, and more sustainable structures.

Nepal is situated in a region prone to earthquakes, and as such, the country has experienced significant damage to its infrastructure in the past [4]. The use of CFTs in construction could help to create structures that are more resilient to seismic activity [5] For example, the use of CFTs in the construction of buildings and bridges could help to reduce the risk of collapse during earthquakes. Additionally, CFTs could be used in the construction of railway stations and other infrastructure projects to improve their resistance to dynamic loads brought on by vibration. By understanding the behavior of CFTs under axial compression loading, designers and engineers can optimize the use of this composite material to create safer, more efficient, and more sustainable structures that can withstand the country's unique environmental challenges.

The study of CFT behavior under axial compression loading is significant globally, as CFTs are becoming increasingly popular in construction due to their superior structural performance. By understanding the behavior of CFTs, designers and engineers can optimize their use of this composite material to create structures that are safer, more efficient, and more sustainable [6]. This knowledge is especially relevant in countries that are prone to seismic activity, such as Nepal, where the use of CFTs in construction could help to create structures that are more resilient to earthquakes and other natural disasters. The findings of this study will be useful for designing and perfecting CFT structures for a variety of applications, and may also lead to improvements in design codes.

### 1.2 Objective

This study aims to investigate the load-bearing capacity and optimum design parameters of concrete-filled tubes (CFT) through experimental testing specifically to determine the load-carrying capacity of CFTs under axial loading and compare it with non-CFTs, study the optimum cross-sectional area and grade of the concrete infill in CFTs, and identify the failure modes of CFTs and evaluate their ductility, and the findings from this research will contribute to a better understanding of the effectiveness of CFTs and their potential as a cost-effective and environmentally friendly alternative to traditional reinforced concrete columns.

### Methodology and test setup

The methodology presented in the experiment provides an overview of the material specifications and research techniques used in the investigation. The main objective of the study is to increase the load-bearing capacity of composite steel-concrete columns, with a focus on a column that does not require formwork to fill with concrete, using steel tubes.

The study utilized M20 and M25 grade concrete in accordance with IS 10262:2019, along with OPC 53-grade cement, river sand, and 20 mm down coarse aggregate. The properties of the materials, including the modulus of elasticity and Poisson ratio of the concrete and steel.

The experimental investigation involved loading circular tube of 100mm diameter with 2mm thick and Square 100*100*2 tubes with M20 and M25 grade concrete and specimens, testing the compressive strength of the cube for a curing period of 7, 14, and 28 days. The infilled concrete and tube were used to compare the column's loading failure pattern and load carrying capacity.

Prior to the experimental investigation, preliminary tests were conducted on the specimens to demonstrate that it is possible to produce concrete that demonstrates the strength and durability qualities required by the design using the anticipated materials, dose, and building processes. The particle size distribution, specific gravity, absorption, aggregate crushing value, and aggregate impact value of the coarse aggregate were also measured.

**Figure 2.**Test setup and final output

Overall, the methodology provides a clear and detailed explanation of the materials and methods used in the investigation and gives understanding of the experiment and the results obtained.

**Test Results**

**3.1 Cube Test**

The compressive strength of concrete cubes with nominal mixed design was tested at different curing periods of 7, 14, and 28 days. The average compressive strength values were determined for each curing period.

**Table 1.** Compressive Strength Test Result for 28 days

| Cube | Failure Load (KN) | Compressive Strength (N/mm²) | Max Displacement (mm) | AVERAGE Compressive Strength (N/mm²) |
|---|---|---|---|---|
| M20 | 636.87 | 28.305 | 4.15 | |
| M20 | 668.31 | 29.703 | 3.85 | 28.49 |
| M20 | 617.9 | 27.462 | 3.45 | |
| M25 | 803.41 | 35.707 | 4.63 | |
| M25 | 768.69 | 34.164 | 3.81 | 34.79 |
| M25 | 776.73 | 34.521 | 3.5 | |

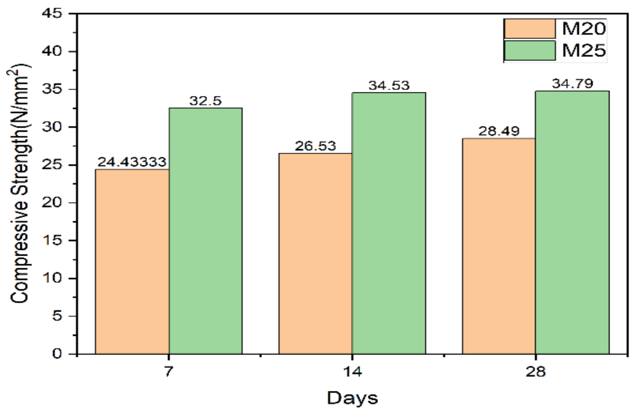


**Figure 3.**Compressive Strength of M20 and M25 Grade of Concrete for 7, 14 and 28 days

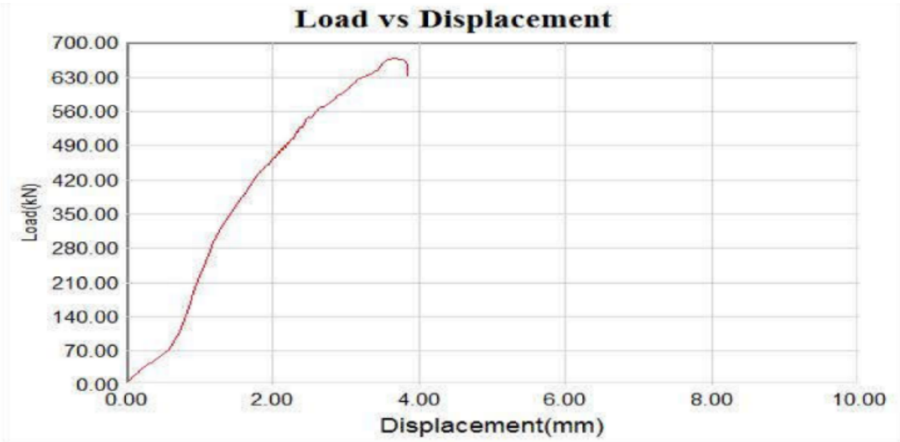


**Figure 4.**Load Vs Displacement of 28 days M20 Cube

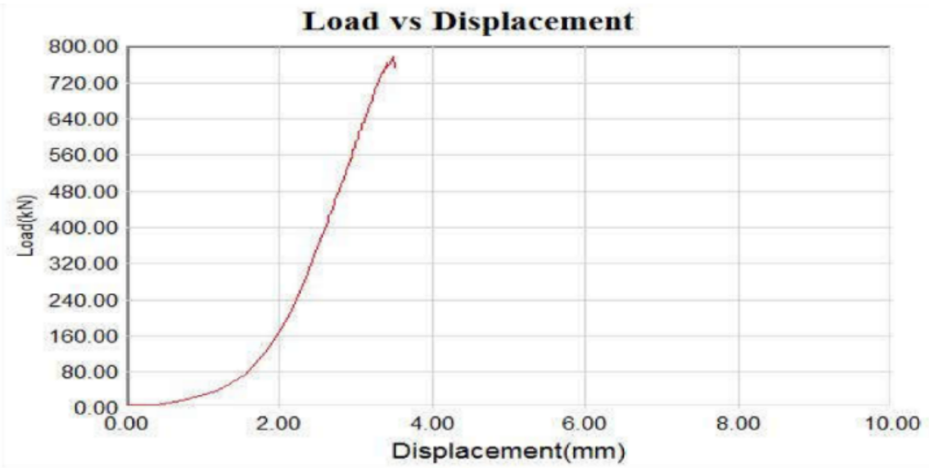


**Figure 5.**Load Vs Displacement of 28 days M25 Cube

The results showed that the highest average compressive strength of 34.79 N/mm² was obtained at 28 days of curing for M25 and 28.49 N/mm² was obtained at 28 days of curing for M20. The average compressive strengths at 14 and 7 days of curing were 25.48 N/mm² and 33.51 N/mm² for M20 and M25 grade concrete, respectively. The experimental procedure and results can be used for further analysis and comparison with other concrete mix designs.

**3.2 CFT test**

The result presented that the compressive strength and maximum displacement of circular tube specimens were higher than that of square tube specimens. The data presented in Tables 2 and 3 show that for circular tube specimens, the compressive strength of M25 concrete tube (CS2) is higher than that of M20 concrete tube (CS1). Similarly, for square tube specimens, the compressive strength of M25 concrete tube (SS2) is higher than that of M20 concrete tube (SS1).

**Table 2.** Load Capacity of M20 and M25 Circular Tube

| Mark ID | Failure Load (KN) | Compressive Strength (N/mm²) | Max Displacement (mm) | AVERAGE Compressive Strength (N/mm²) |
|---|---|---|---|---|
| CS1 | 555.84 | 70.772 | 21.14 | 69.93 |
| CS1 | 559.23 | 71.203 | 13.5 | |
| CS1 | 532.62 | 67.815 | 18 | |
| CS2 | 610.55 | 77.738 | 14.83 | 72.94 |
| CS2 | 525.03 | 66.849 | 16.35 | |
| CS2 | 583.08 | 74.24 | 21.06 | |

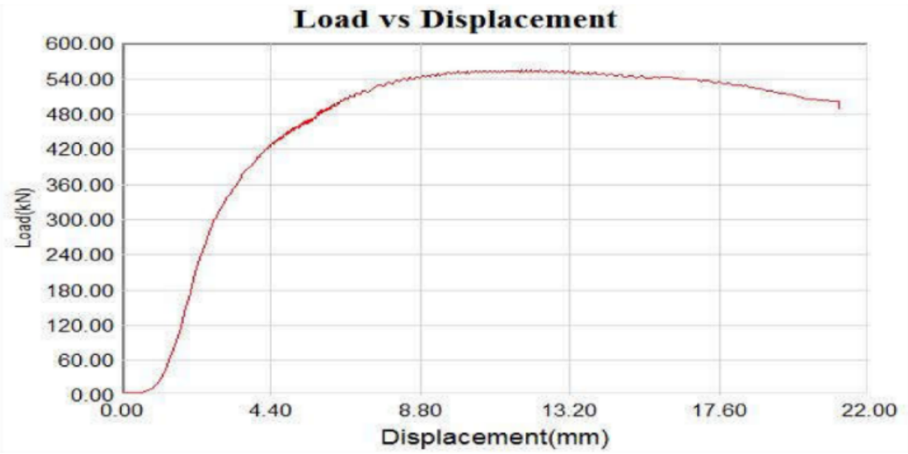


**Figure 6.** Load Vs Displacement of M20 Circular Tube

**Table 3.** Load Capacity of M20 and M25 Square Tube

| Mark ID | Failure Load (KN) | Compressive Strength (N/mm²) | Max Displacement (mm) | AVERAGE Compressive Strength (N/mm²) |
|---|---|---|---|---|
| SS1 | 414.33 | 41.433 | 21.27 | 43.54 |
| SS1 | 440.42 | 44.042 | 18.78 | |
| SS1 | 451.5 | 45.15 | 29.07 | |
| SS2 | 508.47 | 50.847 | 23.84 | 50.08 |
| SS2 | 496.6 | 49.66 | 13.45 | |
| SS2 | 497.38 | 49.738 | 21.81 | |

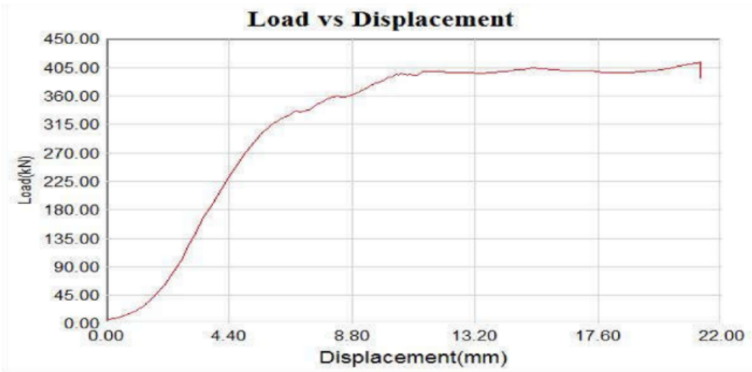


**Figure 7.** Load Vs Displacement of M25 Circular Tube

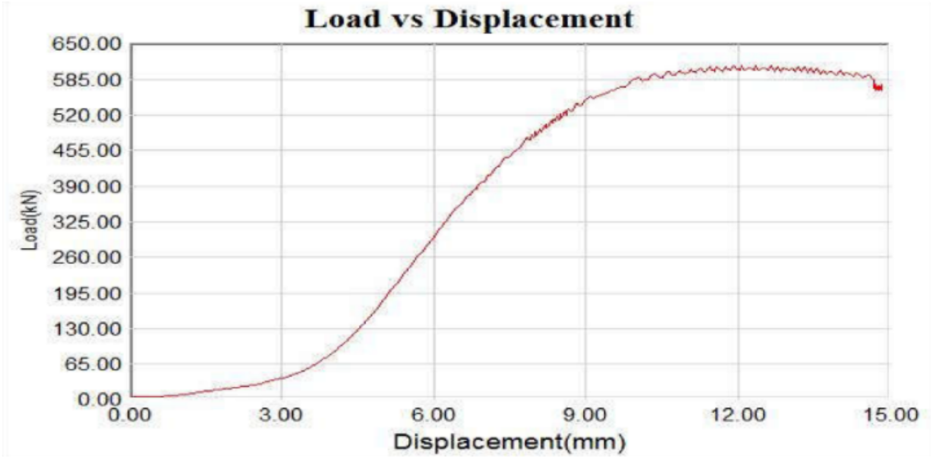


**Figure 8.** Load Vs Displacement of M20 Square Tube

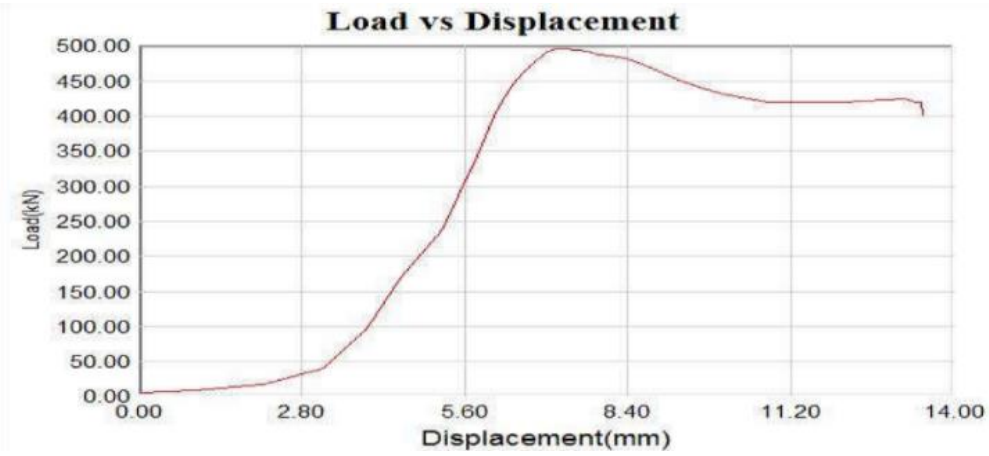


**Figure 9.** Load Vs Displacement of M25 Square Tube

However, even though the compressive strength of the circular tube specimens was higher, the maximum displacement was observed in the square tube specimens. Therefore, the choice between circular and square tubes should depend on the specific requirements of the project, considering factors such as compressive strength and maximum displacement.

### 3.3 Ductility Index of CFT

The result presented in the article is that the ductility of concrete specimens varies significantly depending on the type of concrete and confinement method used when utilizing the ductility index. The ductility index is a measure of the effect of repression on the ductility of constrained sections based on the amount of energy.

The study presented in the article found that specimen C1-M20 had the highest ductility of 1.52 in a 2mm thickness tube, which enables the column to withstand significant deformations without failing.

**Table 10.** Ductility Index

| Specimens | Thickness (mm) | Load Point | | Ductility Index |
|---|---|---|---|---|
| | | Ultimate load (KN) | Initial crack load (KN) | |
| C1-M20 | 2 | 549 | 360 | 1.52 |
| S1-M20 | 2 | 435 | 315 | 1.38 |
| C2-M25 | 2 | 572 | 455 | 1.25 |
| S2-M25 | 2 | 500 | 385 | 1.29 |

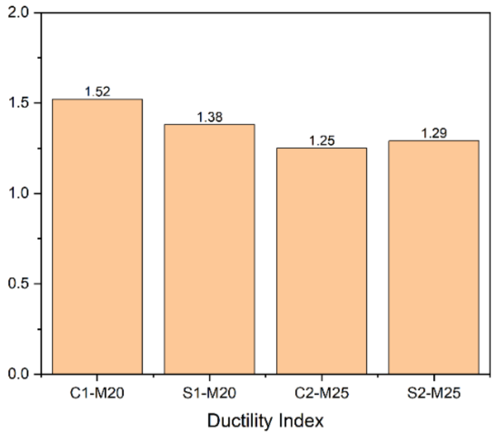


**Figure 10.** Ductility Index

## Discussion and Conclusion

The study investigated the load-bearing capacity and ductility of circular and square CFT columns. Load capacity tests were conducted on M20 and M25 concrete tubes, and the results showed that circular tubes had a higher compressive strength than square tubes. The average compressive strength for CS1 (M20) was 69.93 N/mm², and for CS2 (M25) it was 72.94 N/mm², while for SS1 (M20) it was 43.54 N/mm², and for SS2 (M25) it was 50.08 N/mm². In terms of ductility, the ductility index was calculated based on the area under the load-displacement curve before and after the peak load. The study found that the ductility index varied depending on the type of concrete and the confinement method used [7]. Overall, the results suggest that circular tubes have a higher load-bearing capacity and ductility than square tubes.

Based on the results of this study, it can be concluded that circular CFTs have a higher load-bearing capacity and ductility than square CFTs [8]. The compressive strength values obtained from the experimental tests are consistent with those reported in the literature, and the results suggest that the compressive strength of CFTs is influenced by the curing period and the type of concrete used [9]. The ductility index varied depending on the type of concrete and the confinement method used. The findings of this study are relevant to the design and construction of CFTs. Engineers and designers can use the results to optimize the design of CFTs, taking into account factors such as shape, concrete strength, and confinement method. The results of this study can also be used to validate and improve existing prediction methods for the axial capacity of CFTs. Future research in this area could investigate the effect of other factors, such as steel tube thickness and diameter-to-thickness ratio, on the load-bearing capacity and ductility of CFTs [10]. Furthermore, researchers could explore the use of other materials, such as fiber-reinforced polymers (FRP), to improve the ductility and load-bearing capacity of CFTs [11].

Overall, the results of this study indicate that circular CFT columns have higher compressive strength, while square CFT columns have higher maximum displacement. The findings of this study can be useful in designing and selecting CFT columns for various applications in civil engineering.

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