

**PROJECT**

Axial Capacity Prediction of Circular Concrete Filled Stainless Steel Tubular Columns Using Machine Learning Algorithms

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# ABSTRACT

Concrete-filled steel tubular (CFST) columns are quite omnipresent in the construction of Civil Structures owing to their great axial capacity and having advantages of both building materials i.e. concrete and steel negating each other’s downside. Nowadays Concrete-filled stainless-steel tubular (CFSST) columns are being preferred over the traditional concrete-filled steel tubular (CFST) columns given their superior corrosion resistance While extensive experimental and numerical research has been conducted to assess the behavior of CFSST columns under various loading conditions, accurately predicting their axial capacity remains challenging. The distinct properties of stainless steel compared to carbon steel render the existing design code equations for conventional CFST columns unreliable for predicting the strength of the CFSST columns. To address this issue, the Machine Learning (ML) approach has been used. In Structural Engineering the use of Artificial Intelligence (AI) has gained some popularity in academia nowadays to circumvent the limitations of the existing design philosophies.

The main aim of this study is to leverage the ML techniques, to overcome the limitations of traditional prediction methods and provide a more reliable solution to estimating the axial capacity of CFSST columns. To achieve this, a comprehensive dataset comprising 422 circular and rectangular CFSST columns has been meticulously compiled from the existing literature about the experimental studies done in the past. This extensive dataset serves as the foundation for developing robust ML models capable of accurately forecasting CFSST column performance.

The accuracy of the model is evaluated using a range of performance metrics to ensure a comprehensive assessment. These metrics include coefficient of determination (R2), root mean square error (RMSE), mean absolute error (MAE), Nash-Sutcliffe Model (NSE), and Index of Agreement (d).

Mention about the ML algorithms used and point out the findings i.e. the best one etc.

To demonstrate the validity and exceptional performance of the top-performing \_\_\_\_\_\_\_\_\_\_\_\_ machine learning model, the predictions/results are then compared against the prediction from the most commonly and widely used design codes around the world.

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# NOTATIONS

| D | Diameter of the Circular Column |
| --- | --- |
|  | Thickness of Stainless-Steel Tube |
|  | Height of the Rectangular Column |
|  | Width of the Rectangular Column |
| L | Length of the Specimen |
|  | Modulus of Elasticity of Stainless Steel |
|  | Cylindrical Compressive Strength of Concrete |
|  | Ultimate Strength of Stainless Steel |
|  | 0.2% Proof Stress of Stainless Steel |
|  | Strain-Hardening Exponent |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# LIST OF ABBREVIATIONS

| AASHTO | American Association of Highway and Transportation Officials |
| --- | --- |
| CSA | Canadian Standards Association |
| CFSST | Concrete Filled Stainless Steel Tubular |
| RMSE | Root Mean Square Error |
| MAE | Mean Absolute Error |
| NSE | Nash-Sutcliffe Model Error |
|  |  |
|  |  |

# CHAPTER 1: INTRODUCTION

# CHAPTER 2: DATABASE FOR CFSST COLUMN AXIAL CAPACITY PREDICTION

A reliable database is essential for developing dependable prediction models and identifying the key factors that influence prediction accuracy. A comprehensive dataset was compiled from multiple peer-reviewed journals and dissertation papers describing their experimental findings based on the studies conducted in the past. In this project, a total of 422 data points has been gathered and are evenly divided between circular and rectangular Concrete-Filled Stainless-Steel Tubular (CFSST) columns, with 211 datasets for each type. This extensive compilation serves as the foundation for the study's analysis and model development.

This study aims to develop a reliable machine learning (ML) model for predicting the axial capacity of Concrete-Filled Stainless-Steel Tubular (CFSST) columns using a data-driven approach. The model's output is the axial compression capacity (N\_Test) measured in kilonewtons (kN), while the input parameters include:

1. Column length (L, mm)
2. Tube thickness (t, mm)
3. Stainless steel proof stress (σ0.2, MPa)
4. Stainless steel ultimate strength (fu, MPa)
5. Stainless steel elastic modulus (Eo, MPa)
6. Strain hardening component (n)
7. Concrete compressive strength (f’c, MPa)
8. Column diameter (D, mm) for circular sections
9. Cross-section width (B, mm) and height (H, mm) for rectangular sections

| **Input** | **Circular Columns** | | **Rectangular Columns** | |
| --- | --- | --- | --- | --- |
|  | **Mean** | **SD** | **Mean** | **SD** |
| *D (mm)* | 134.2 | 68.7 | - | - |
| *t (mm)* | 3.5 | 2.2 | 3.8 | 2.0 |
| *H (mm)* | - | - | 120.9 | 41.5 |
| *B (mm)* | - | - | 124.7 | 44.5 |
| *L (mm)* | 399.9 | 205.5 | 377.6 | 122.6 |
| *L/B* | - | - | 3.2 | 0.8 |
| *L/D* | 3 | 0.5 | - | - |
| *E*o (MPa) | 196780.3 | 7491.6 | 199730.0 | 6793.5 |
| *f*0.2 (MPa) | 324.5 | 72.2 | 433.1 | 101.1 |
| *f*u (MPa) | 692.0 | 58.9 | 674.7 | 120.9 |
| *n* | 6.0 | 1.7 | 6.3 | 2.0 |
| *f*c*’ (*MPa*)* | 52.1 | 29.1 | 48.0 | 20.6 |

*Table 1: Mean and Standard Deviation for Input Parameters*

To Move forward with the development of the data-driven strength prediction ML models for CFSST columns it is imperative to identify the feature’s importance. Therefore, a correlation analysis is done on the dataset. As of now, previous studies involving data-driven approaches for strength prediction have indicated a high degree of significance of the sectional properties like D, B, t, L, etc. on the axial capacity of the specimen.

Correlation analysis is a statistical method that quantifies the relationship between two variables. The Pearson correlation coefficient (r) indicates the strength and direction of this relationship, with values near 1 suggesting a strong positive correlation, those close to 0 indicating a weak correlation, and values approaching -1 signifying a strong negative correlation.

*Figures 1* *and 2* represent the correlation between multiple parameters for circular and rectangular sections in the form of a correlation matrix (heatmap).

* **For circular sections:** Thickness (t) is the most influential dimension, with a correlation coefficient (r-value) of 0.85. Diameter (D) and length (L) follow as the second most important features, both with r values of 0.84.
* **For rectangular sections:** Thickness (t) again proves to be the dominant feature, giving a correlation coefficient of 0.86. Height (H) and width (B) rank as the second and third most significant parameters, with r values of 0.73 and 0.66, respectively.

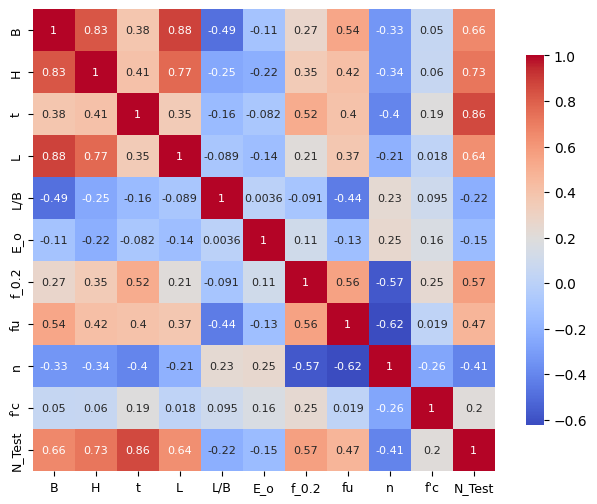
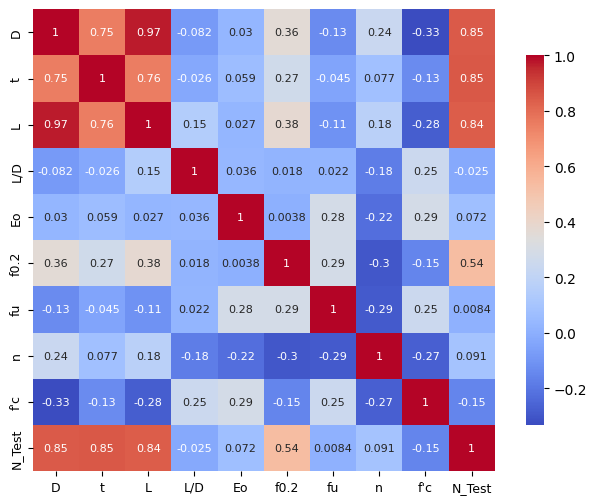
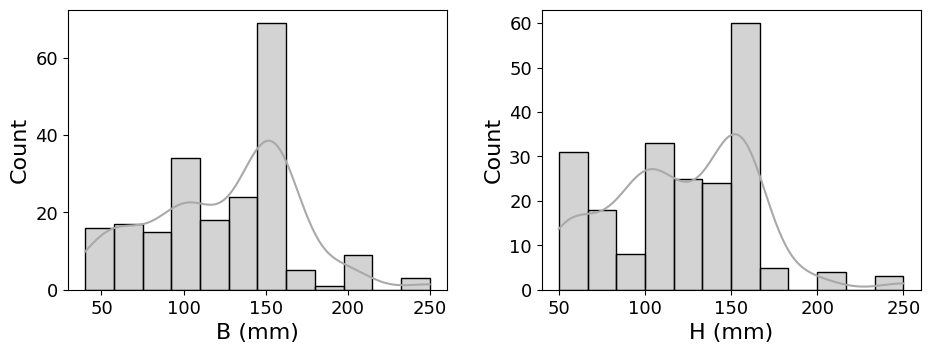
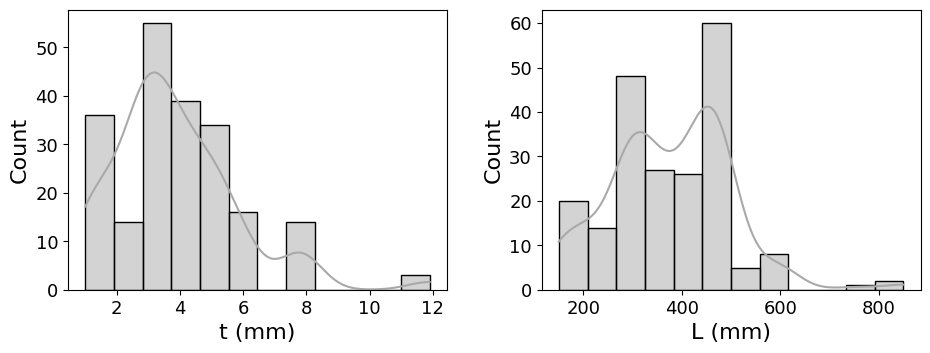


Figure 1: Correlation matrix for Rectangular CFSST columns

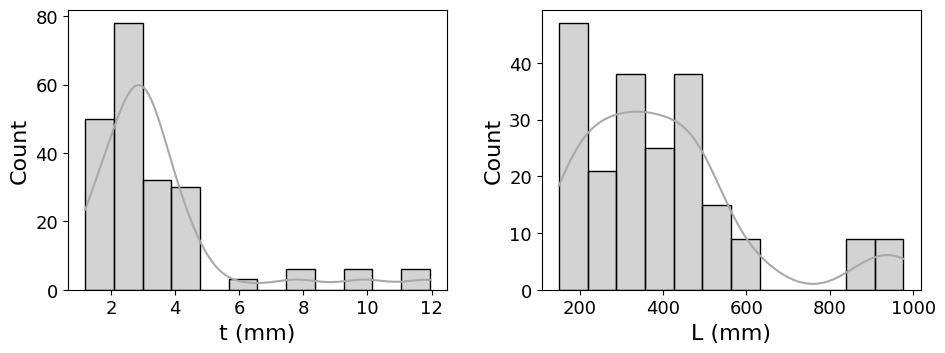
*Figure 2: Correlation matrix for Circular CFSST columns.*

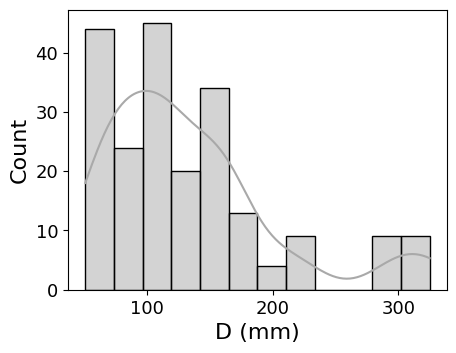
To further visualize the distribution of these highly correlated features, histogram plots were developed and are presented in Figures 3 and 4.





*Figure 3: Histograms for parameters of Rectangular CFSST columns.*





*Figure 4: Histograms for parameters of Circular CFSST columns.*

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