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# Strength of CFST at Elevated Temperature

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***Abstract:*** *This paper deals the strength behavior of concrete filled steel tubes at elevated temperature. The main purpose of such a research is to figure out the significance of various structural parameters on the strength of CFST at elevated temperature. Two separate models have been prepared. The first to deal with temperature distribution within the CFST section, when subjected to interfacial ISO 834 fire. The second to determine buckling load of the CFST using a composite frame element model, considering structural material properties, compatible with Euro-code models, based on temperature outputs resulting from the first model.*

***Keywords*** *CFST, buckling, fire*

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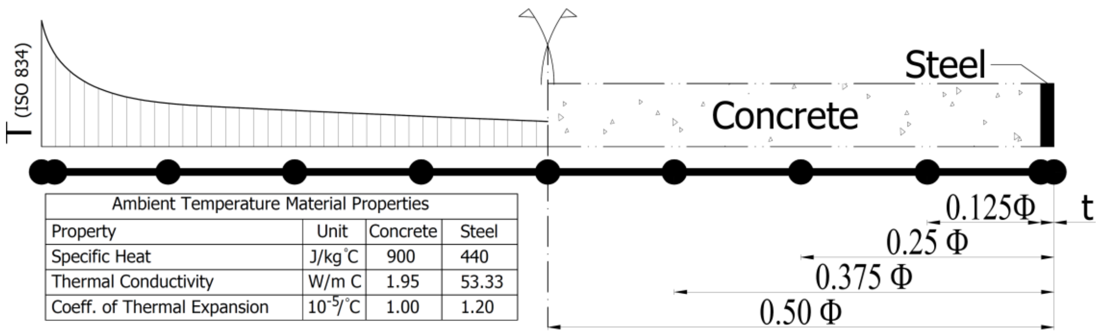
## I. Introduction

Concrete filled steel tubes are commonly used as columns due to their perfect form, ease of construction; due to using the steel tube as both shuttering and structural element. The main concern regarding using CFST as structural elements is their low fire endurance; resulting from concentration of steel reinforcement, in the form of a tube and bars, at the outer boundary of the column. Steel vulnerability to fire loads limits such an application. This research concerns in detail the failure behavior of CFST at elevated temperatures, through studying temperature distribution within the CFST, then studying their structural failure, whether it is a yield or buckling mode.

## II. Thermal-structural Modelling

The philosophy of the research was based on establishing two separate models, by which the problem was attacked. The first is a heat transfer model, by which temperature distribution within the CFST was determined as a function of time. The ISO 834 has been chosen as a fire load at the surface of the CFST. Material properties models for specific heat and thermal conductivity have been chosen compatible with the EURO code. Figure (1) represents the thermal model, used in determining temperature distribution within the CFST.




| Ambient Temperature Material Properties | | | |
|---|---|---|---|
| Property | Unit | Concrete | Steel |
| Specific Heat | J/kg˚C | 900 | 440 |
| Thermal Conductivity | W/m C | 1.95 | 53.33 |
| Coeff. of Thermal Expansion | $10^{-5}$/˚C | 1.00 | 1.20 |

Figure (1) CFST Thermal Model

After extracting temperature distribution curves from the thermal model as shown in figures (2) up to (9), another model has been prepared for the structural analysis.

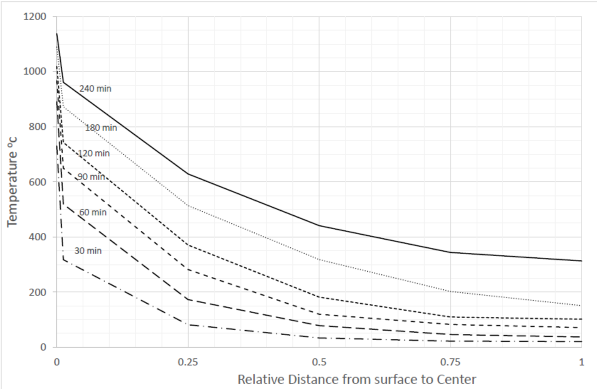



Fig. (2) Φ 400 mm CFST Temp. Distribution

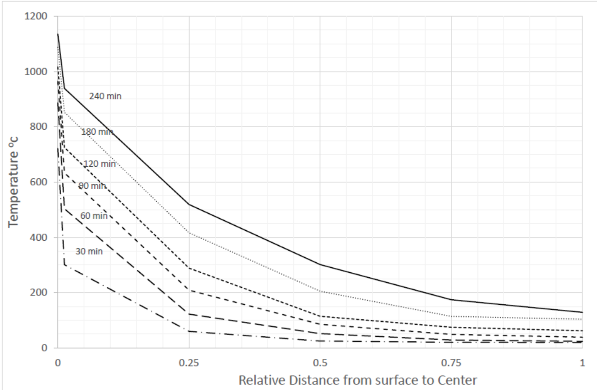



Fig. (3) Φ 500 mm CFST Temp. Distribution

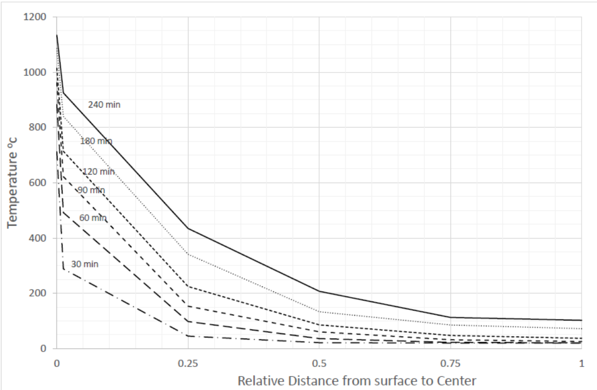



Fig. (4) Φ 600 mm CFST Temp. Distribution

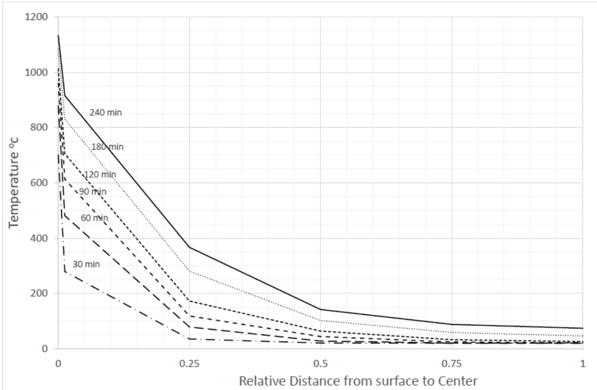



Fig. (5) Φ 700 mm CFST Temp. Distribution

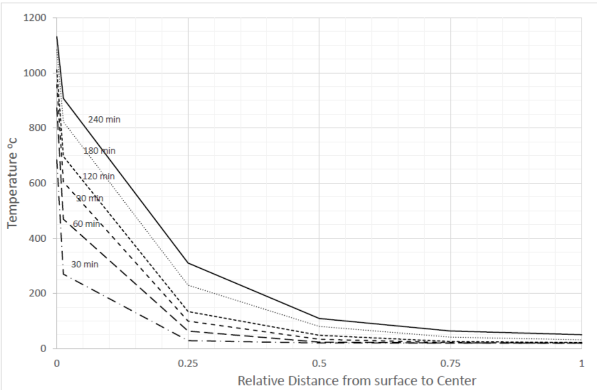



Fig. (6) Φ 800 mm CFST Temp. Distribution

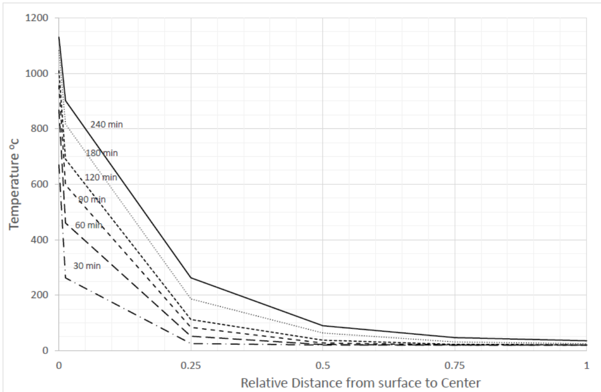



Fig. (7) Φ 900 mm CFST Temp. Distribution

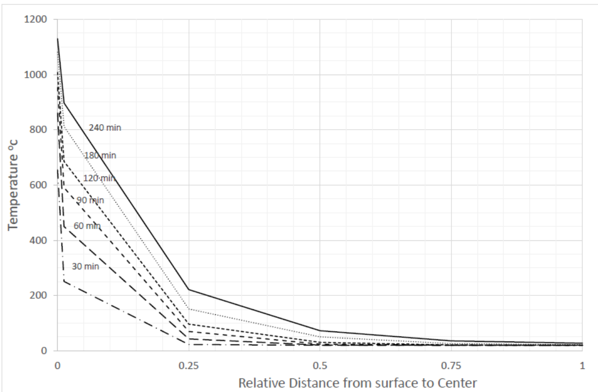



Fig. (8) Φ 1000 mm CFST Temp. Distribution

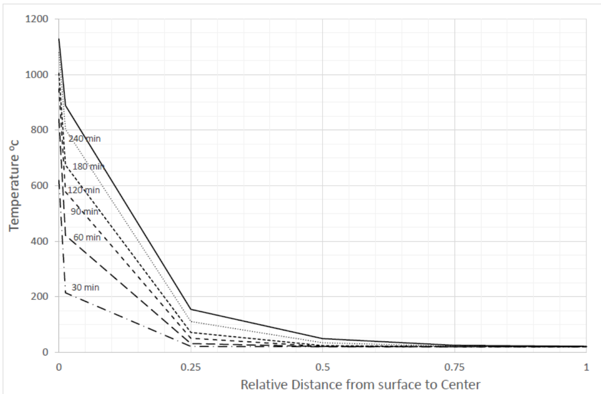



Fig. (9) Φ 1200 mm CFST Temp. Distribution

The second model concerned the buckling behavior of the CFST. Composite frame element has been chosen to model CFST buckling behavior. Multi-layered element structure has been chosen to model the variation in material properties throughout the section. EURO code models for structural material properties degradation have been adopted. Material properties at each step per layer have been considered based on thermal model temperature distribution within the section, in conjunction with EURO code strengths and moduli of elasticity models. Figure (10) shows a cross-section of the multi-layered frame element used to model CFST.

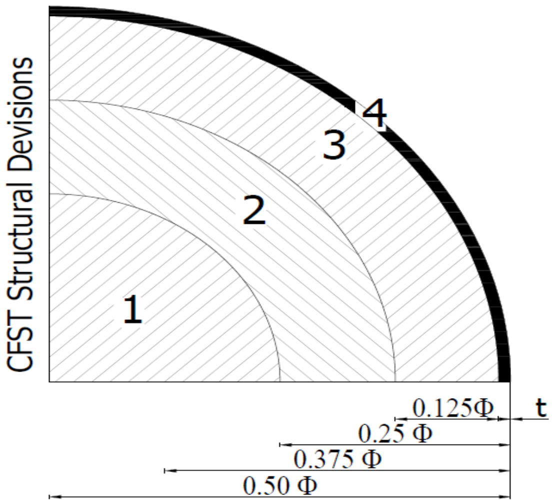



Figure (10) CFST Multi-layered Model

## III. Parametric Study

It was essential, once the model has been established to run a parametric study; to figure out the significance of various structural parameters on the strength of CFST at elevated temperatures. Concrete characteristic strengths of 25, 50, and 75 MPa have been considered as a structural parameter; to cover the practical spectrum of concrete strength. Column's diameter ranging from 400 up to 1200 mm has been considered. Three slenderness ratios have been considered to study the behavior of short, intermediate, and slender columns respectively. The last parameter was the application time of fire load, which ranged from zero up to four hours. Figures (11) up to (34) represent the fall –down of load ratio, as a function of time, for various slenderness ratios. While figures (35) up to (52) represents that fall-down as a function of column diameter, for various slenderness ratios.

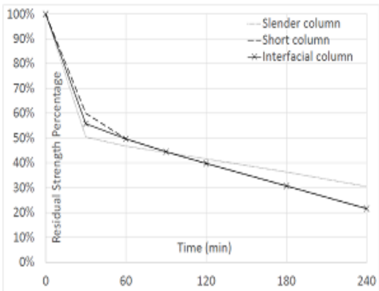



Fig.(11) Φ400mm CFST strength (f'c 25MPa)

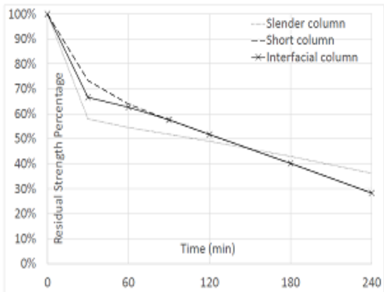



Fig.(12) Φ400mm CFST strength (f'c 50MPa)

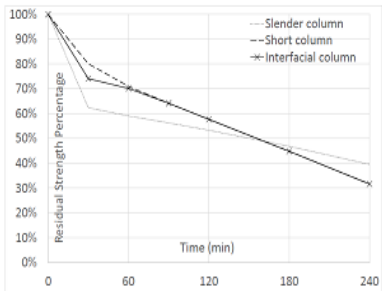



Fig.(13) Φ400mm CFST strength (f'c 75MPa)

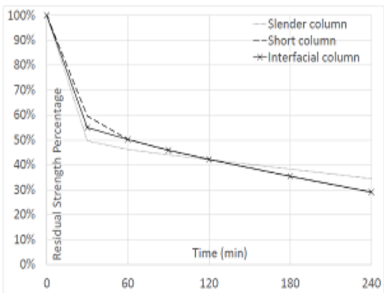



Fig.(14) Φ500mm CFST strength (f'c 25MPa)

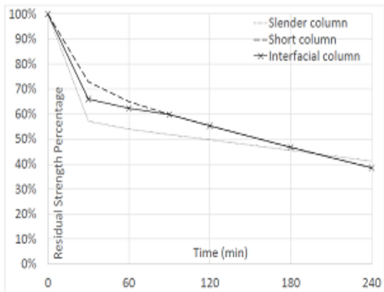



Fig.(15) Φ500mm CFST strength (f'c 50MPa)

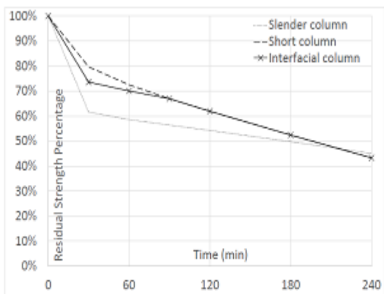



Fig.(16) Φ500mm CFST strength (f'c 75MPa)

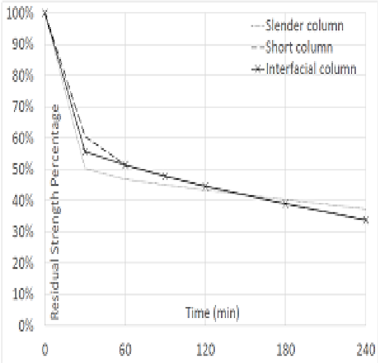



Fig.(17) Φ600mm CFST strength (f'c 25MPa)

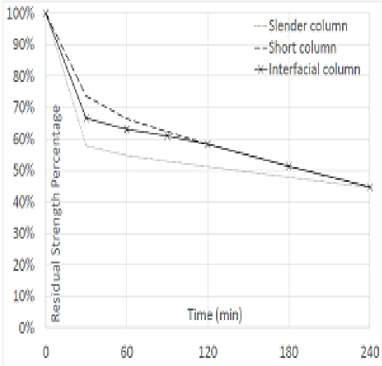



Fig.(18) Φ600mm CFST strength (f'c 50MPa)

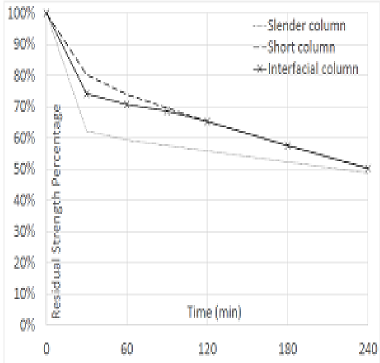



Fig.(19) Φ600mm CFST strength (f'c 75MPa)

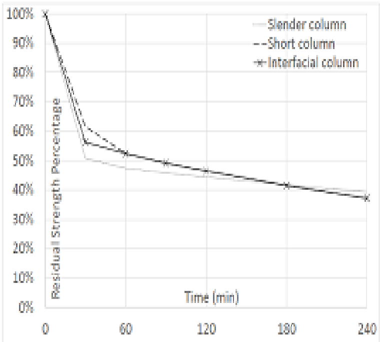



Fig.(20) Φ700mm CFST strength (f'c 25MPa)

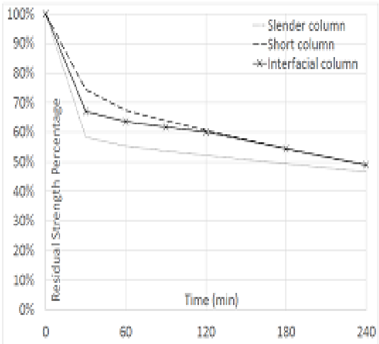



Fig.(21) Φ700mm CFST strength (f'c 50MPa)

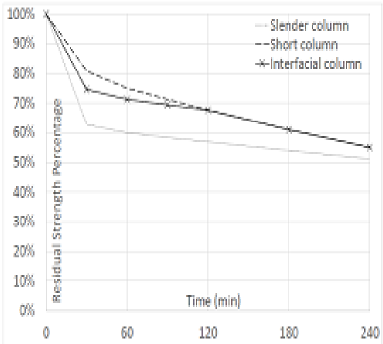



Fig.(22) Φ700mm CFST strength (f'c 75MPa)

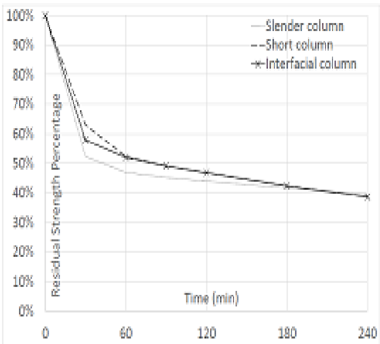



Fig.(23) Φ800mm CFST strength (f'c 25MPa)

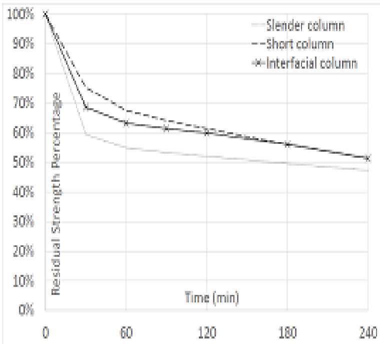



Fig.(24) Φ800mm CFST strength (f'c 50MPa)

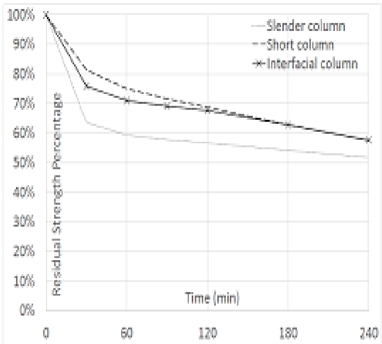



Fig.(25) Φ800mm CFST strength (f'c 75MPa)

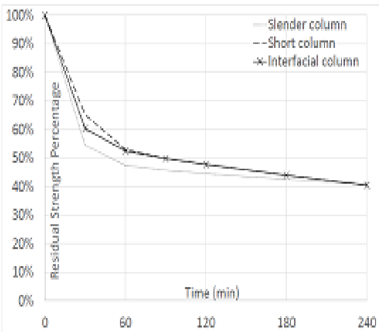



Fig.(26) Φ900mm CFST strength (f'c 25MPa)

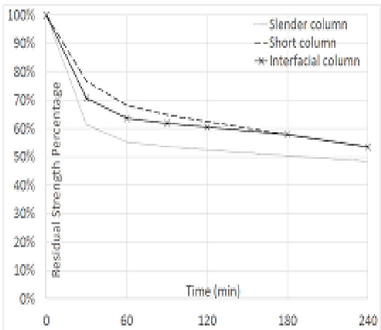



Fig.(27) Φ900mm CFST strength (f'c 50MPa)

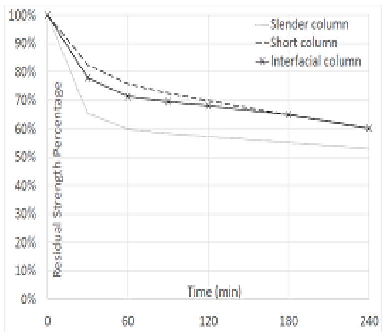



Fig.(28) Φ900mm CFST strength (f'c 75MPa)

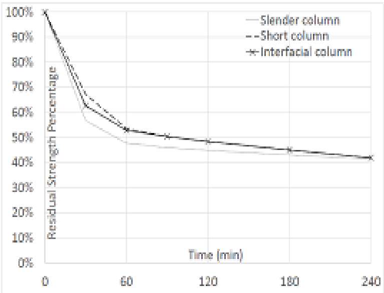



Fig.(29) Φ1000mm CFST strength (fc 25MPa)

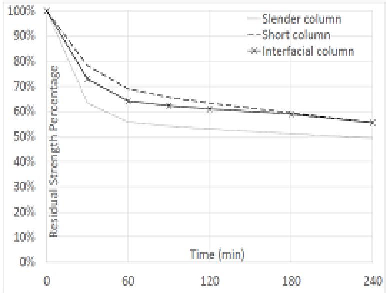



Fig.(30) Φ1000 mm CFST strength (fc 50MPa)

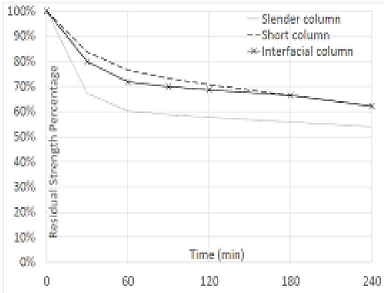



Fig.(31) Φ1000 mm CFST strength (fc 75MPa)

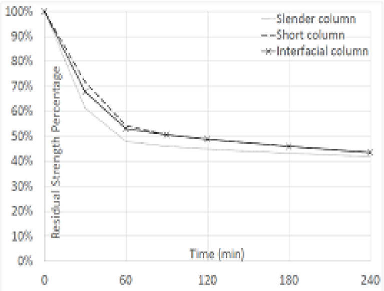



Fig.(32) Φ1200 mm CFST strength (fc 25MPa)

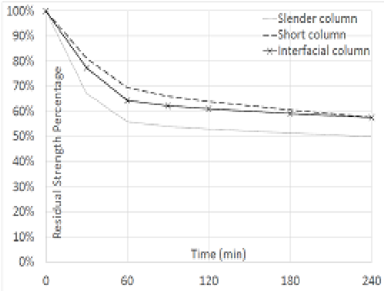



Fig.(33) Φ1200 mm CFST strength (fc 50MPa)

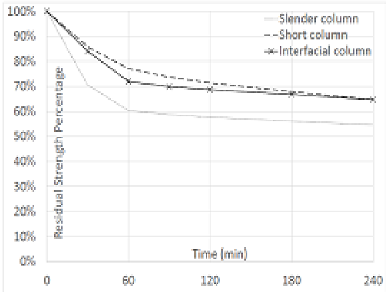



Fig.(34) Φ1200 mm CFST strength (fc 75MPa)

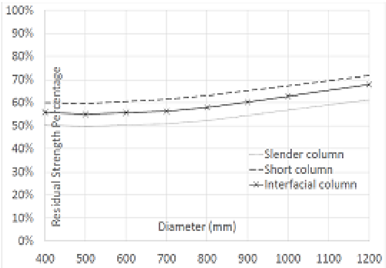



Fig.(35) CFST strength at 30 min (fc 25MPa)

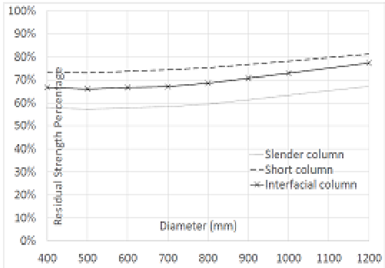



Fig.(36) CFST strength at 30 min (fc 50MPa)

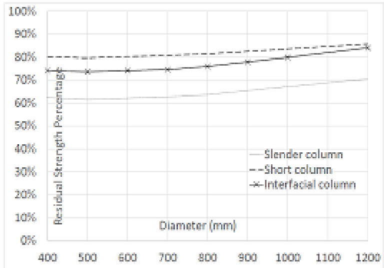



Fig.(37) CFST strength at 30 min (fc 75MPa)

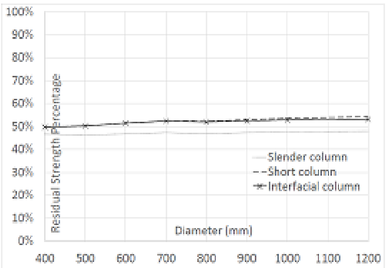



Fig.(38) CFST strength at 60 min (fc 25MPa)

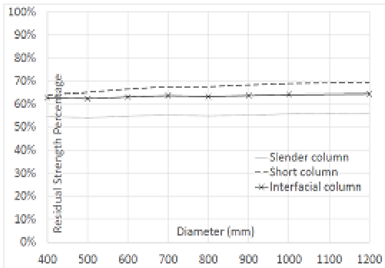



Fig.(39) CFST strength at 60 min (fc 50MPa)

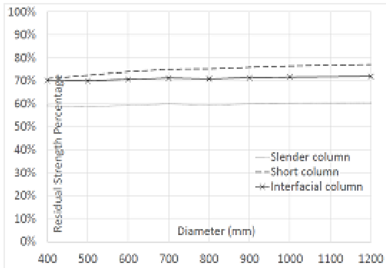



Fig.(40) CFST strength at 60 min (fc 75MPa)

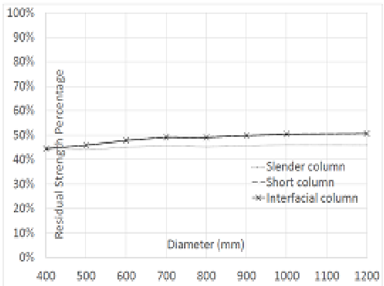



Fig.(41) CFST strength at 90 min (fc 25MPa)

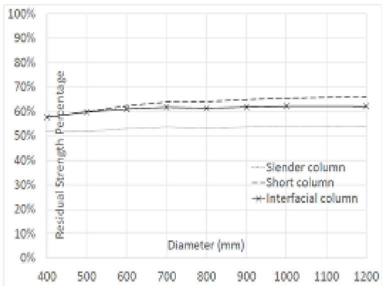



Fig.(42) CFST strength at 90 min (fc 50MPa)

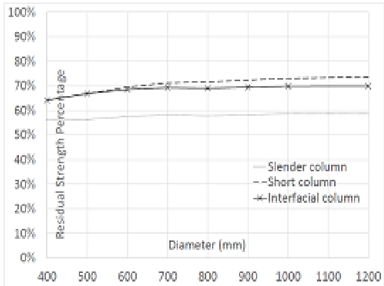



Fig.(43) CFST strength at 90 min (fc 75MPa)

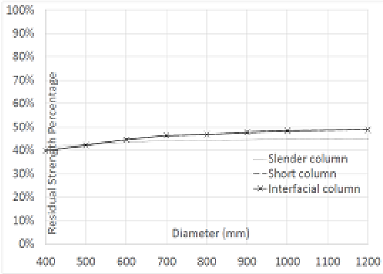



Fig.(44) CFST strength at 120 min (fc 25MPa)

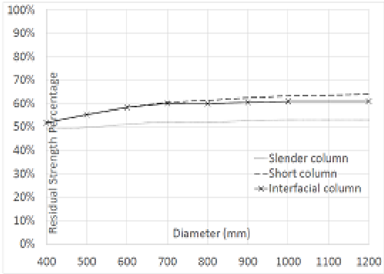



Fig.(45) CFST strength at 120 min (fc 50MPa)

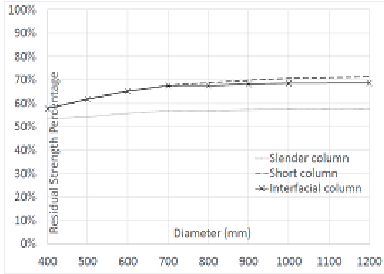



Fig.(46) CFST strength at 120 min (fc 75MPa)

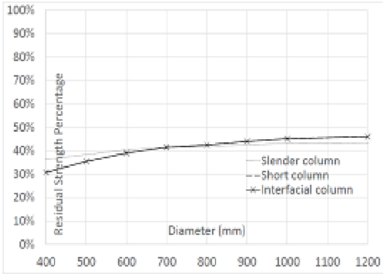



Fig.(47) CFST strength at 180 min (fc 25MPa)

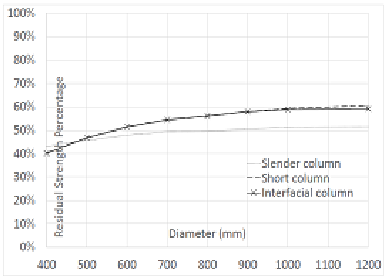



Fig.(48) CFST strength at 180 min (fc 50MPa)

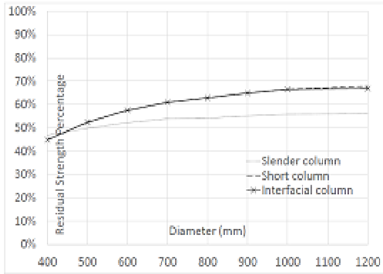



Fig.(49) CFST strength at 180 min (fc 75MPa)

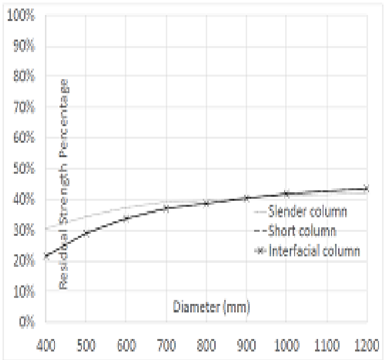



Fig.(50) CFST strength at 240 min (fc 25MPa)

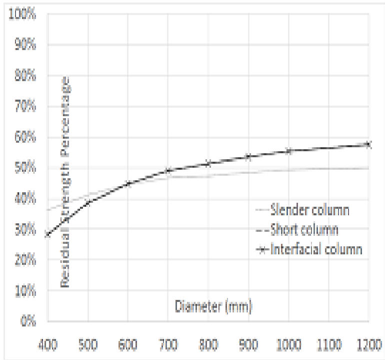



Fig.(51) CFST strength at 240 min (fc 50MPa)

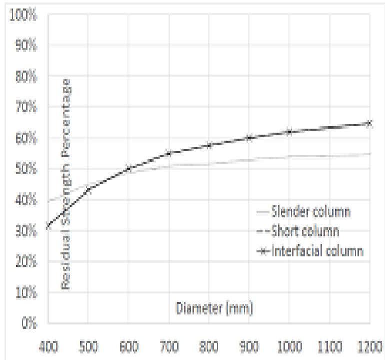



Fig.(52) CFST strength at 240 min (fc 75MPa)

## IV. Conclusions

Studying outputs of the parametric study, resulted in the following conclusions.

1- Strength degradation, as a function of time, is about to be bi-linear
2- Crushing and buckling residual strength converge by time.
3- The more the concrete characteristic strength, the less the degradation in CFST strength.
4- Increase in residual strength is about to be linear, especially for diameters exceeding 700mm.
5- Short columns always retain more residual strength than slender ones

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