Behaviour of Rectangular Concrete Filled Tubes and Circular Concrete Filled Tubes under Axial Load

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Abstract

This paper presents the result behavior of two different type of Concrete Filled Tubes: Rectangular Concrete Filled Tubes (RCFT) and Circular Concrete Filled Tubes (CCFT). In this model, the column end is fixed and the axial load, P_{axial}, are applied to the column end. The amount of axial load is divided into 5 steps, which increasing continuously. The dimension of the column is 300x300x10 for RCFT and 300x10 for CCFT. As the results, stress distribution, load-deformation curve, load-stress curve, and weight calculation are compared. And it shows that the CCFT gives better performance than the RCFT.

Keywords: *axial load, behaviour, composite, concrete filled tubes, finite element*

1. Introduction

Column is a structural element that transmit weight of the structure from the beam through compression. It plays an important role on the building, because the strength of a column can affects the performance of the structure. Concrete Filled Tubes is expected to strengthen the structure, because of its interaction between steel material and concrete material, which each material has advantages of their characteristics [1], the strength of the column will be increased and local buckling can be avoided due to the presence of the concrete core [2], the amount of creep and shrinkage strain considerably lower than ordinary concrete [3]. Another design to eliminate creep and shrinkage by adding fiber in the mixture ingredient was conducted by previous researcher using engineered cementitious composite [4] and additive [5]–[7] but not shown a good result due to service condition. Several researches investigated that CFT connection can provide good performance [8], especially if additional connection modifications are installed, such as adding Reduced Beam Sections [9].

Three codes are used as standard, those are SNI 03-1726-2012 [10] for designing building structures, SNI 03-1729-2015 [11] and SNI 03-2847-2013 [12] material properties of steel and concrete, respectively. The purpose of this research is to explain the behavior of Rectangular Concrete Filled Tubes (RCFT) and Circular Concrete Filled Tubes (CCFT) under axial load under improvement of serive circumtances.

2. Proposed Model Details

Table 1 provide the dimension of the column.

Table 1. Details of model

Model	Column size	fy (MPa)	fu (MPa)
RCFT	300x300x10	250	410
CCFT	300x10		

The model of Rectangular Concrete Filled Tubes (RCFT) and Circular Concrete Filled Tubes (CCFT) are shows in this figure below.

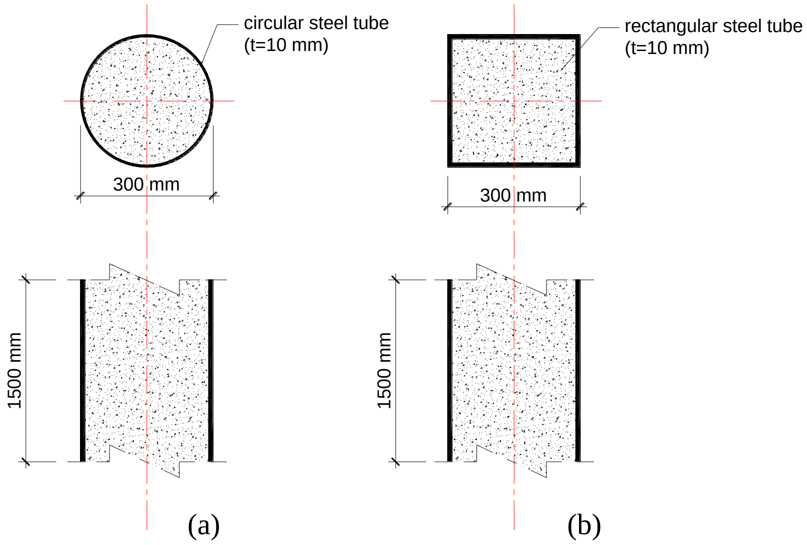


Figure 1. Cross section of (a) RCFT, (b) CCFT

3. Material Properties

3.1 Steel

The value of Elastic Modulus of steel, *E* is 200000 MPa and for Poisson's ratio, *v* is 0.3. Stress-strain value of steel obtained as seen in Table 2 by using formulations of Eurocode 3 [13].

Table 2. Stress-strain value of steel (fy 250 MPa)

Stress (MPa)	Strain	Plastic Strain
0	0	
250	0.00125	0
250	0.02	0.018
303.87	0.03	0.028
358.013	0.05	0.048
383.55	0.07	0.068
39 7.09	0.09	0.088
404.48	0.11	0.108
408.30	0.13	0.128
409.83	0.15	0.148
410	0.16	0.158

3.2 Concrete

For concrete material, the value of Elastic Modulus, *E*, and for Poisson's ratio, *v*, is 0.2 and 25742.96, respectively.

There are three categories of concrete behaviour: plasticity, compressive behaviour and tensile behaviour. Table 3 shows the value of plasticity in concrete, which obtained from Jankowiak [14]. Eurocode 2 [15] and Pavlovic [16] equations as seen in Figure 2, is used for defining the value of compressive and tensile behaviour, which had been written in Table 4 and Table 5 below.

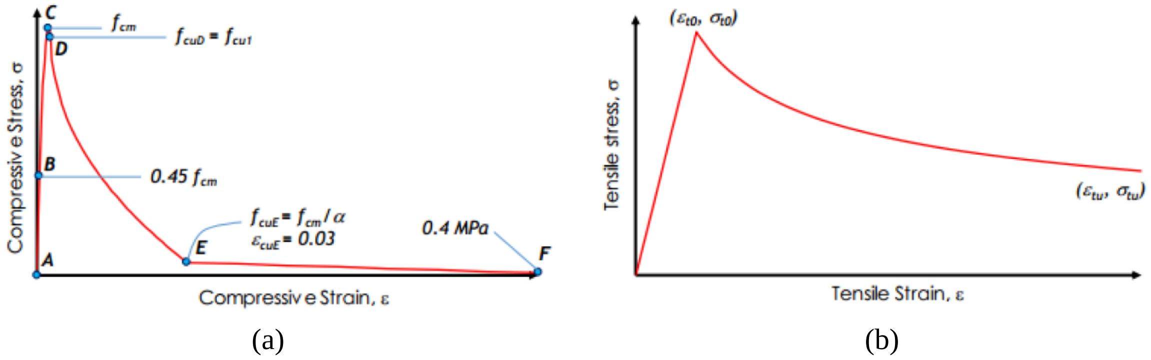


Figure 2. (a) Compressive behaviour of concrete, (b) Tensile behaviour of concrete

Table 3. Concrete Damage Plasticity

Dilatation Angel	Eccentricity	fb0/fc	K	Viscosity Parameter
38	1	1.12	0.666	0

Table 4. The value of Compression Behaviour

Stress (MPa)	Strain	Plastic Strain
0.000	0.000	
9.255	0.000	0.136
16.288	0.001	0.273
21.524	0.001	0.409
25.284	0.001	0.545
27.820	0.002	0.682
29.326	0.002	0.818
30.000	0.002	1.000
29.848	0.002	1.091
29.092	0.003	1.227
27.779	0.003	1.364
25.978	0.003	1.500
24.536	0.004	1.591

Table 5. The value of Tensile Behaviour

Stress (MPa)	Strain	Plastic Strain
0.000	0.000000	
3.412	0.000123	0.00000
2.877	0.000173	0.00005
2.817	0.000223	0.00010
2.766	0.000273	0.00015
2.721	0.000323	0.00020
2.680	0.000373	0.00025
2.643	0.000423	0.00030
2.610	0.000473	0.00035
2.578	0.000523	0.00040
2.549	0.000573	0.00045

4. Finite Element Analysis

4.1 Boundary condition and loading

The axial load, P_{axial}, is applied to the column end, while the other column end is fixed. The amount of the axial load is divided into 5 steps, starts from 20 MPa to 40 MPa, and which is increasing 5 MPa continuously.

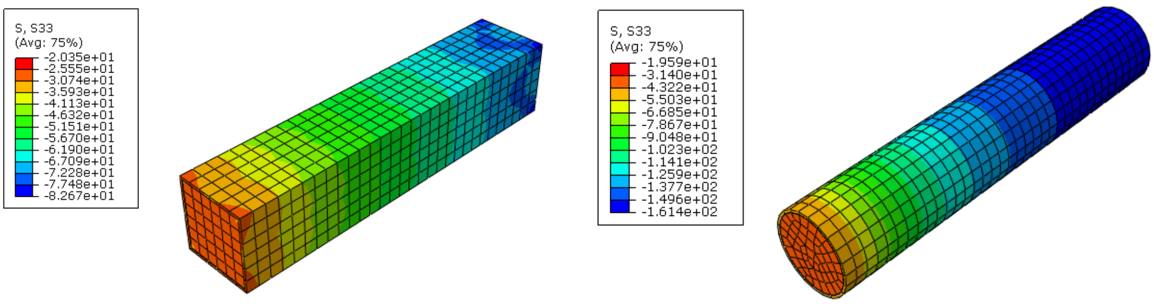
The amount of the load are provided in Table 6.

Table 6. The amount of axial load

Step	P_{axial} (MPa)
1	20
2	25
3	30
4	35
5	40

4.2. Stress distribution

The stress distribution of RCFT and CCFT are shown in Figures 3.



(a) (b)

Figure 3. Stress distribution (S33) of (a) RCFT (b) CCFT due to axial load

4.3 Load - Stress Curve

Comparison of the load – stress curve of RCFT and CCFT shows in Figure 5 and Figure 6. In concrete material, the compressive stress reaches the critical cracking stress, otherwise the steel material not yet reaches the plastic state. From the figures below, it can be cocluded that CCFT has smaller stress value than RCFT when the same value of load is applied.

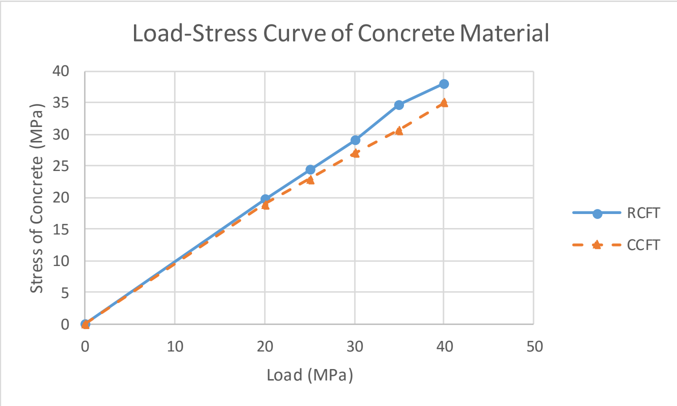


Figure 4. Load – stress curve of concrete material

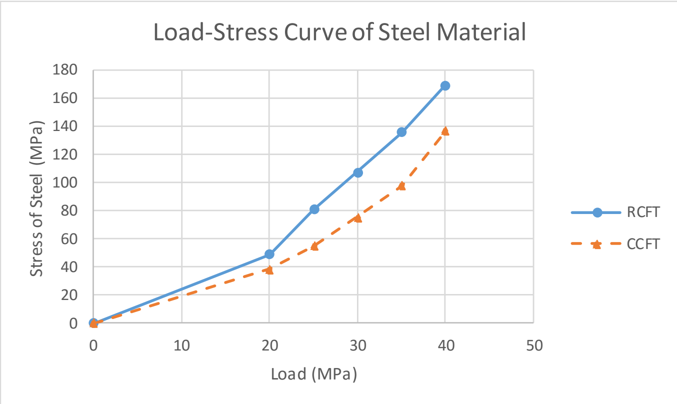


Figure 5. Load – stress curve of steel material

4.4. Load - Deformation Curve

Figure 7 shows comparison of the load – stress curve of RCFT and CCFT. It showed that deformation (mm) is directly proportional to Load (MPa). Figure 7 shows that the largest deformation occures in RCFT.

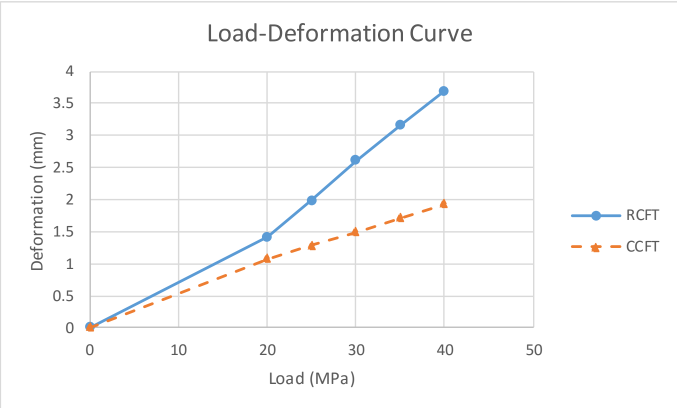


Figure 6. Load – deformation curve

5. Weight Details Calculation

Density of concrete and steel material had been written in Table 7.

Table 7. Material density

Name of Material	Density (N/mm^3)
Concrete	2.4×10^{-5}
Steel	7.85×10^{-5}

5.1 RCFT

The weight calculation of RCFT model can be seen below.

$W_{concrete\ core}$ = Density x $V_{concrete}$
= $(2.4\ x\ 10^{-5})\ x\ (b^2)\ x\ h$
= 2822.4 N
$W_{steel\ tube}$ = Density x V_{steel}
= $(7.85\ x\ 10^{-5})\ x\ [(b^2) - (b_o^2)]\ x\ h$
= 1365.9 N
W_{RCFT} = $W_{concrete\ core} + W_{steel\ tube}$
= 2822.4 N + 1365.9 N
= 4188.3 N

The calculation above shows that the weight of RCFT model is 4188.3 N.

5.2 CCFT

The weight calculation of CCFT model can be seen below.

$W_{concrete\ core}$ = Density x $V_{concrete}$
= $(2.4\ x\ 10^{-5})\ x\ (¼\ x\ \pi\ x\ d^2)\ x\ h$
= 2217.6 N
$W_{steel\ tube}$ = Density x V_{steel}
= $(7.85\ x\ 10^{-5})\ x\ [(¼\ x\ \pi\ x\ d^2) - (¼\ x\ \pi\ x\ d_o^2)]\ x\ h$
= 1073.2 N
W_{CCFT} = $W_{concrete\ core} + W_{steel\ tube}$
= 2217.6 N + 1073.2 N
= 3290.8 N

The calculation above shows that the weight of CCFT model is 3290.8 N.

6. Conclusion

According to the analysis above, following conclusions can be drawn:

1. When the same value of load is applied, both of the model reaches the critical cracking stress in concrete material, otherwise the steel material not yet reaches the plastic state. But the CCFT has smaller stress value than RCFT.
2. The curve of load–deformation above shows that CCFT has smaller amount of deformation, it can be concluded that the creep of CCFT quite lower than RCFT.
3. From the weight calculation of those two model, it shows that CCFT is lighter than RCFT.
4. 4. With CCFT, lighter structure with smaller deformation and higher stress capacity preservation can be achieved. Futher load combination and varying dimension are needed to validate the workability.

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