Behaviour of hybrid concrete columns under axial compression loads

Ali Resheq *

Building and Construction Engineering Department, University of Technology, Baghdad, Iraq

Abstract. Hybrid Concrete Column (HCC) is composite column consists of two types of concrete, Normal Concrete (NC) and Self Compacted Concrete (SCC). The main objective of this work is to study the effect of outer to inner diameter ratio of hybrid concrete on the ultimate strength of column under the axial loading. Ten scaled columns (150 mm diameter and 600 mm length) were fabricated and cast with different ratio of NC to SCC and tested under axial loading. The test results were presented in term of loading and the axial and lateral strains at mid span of column length. It was found that the ultimate strength of column increased from 281 kN to 605 kN (215%). Also it was found that the strength of column increased when the SCC is in inner thickness rather than in outer thickness of the column and the strength increased with increasing the inner thickness of SCC.

1 Introduction

Hybrid concrete columns can be defined as a compression member consisting of composite SCC and NC. Hybrid columns have been used to carry high loading with small cross section area as an alternative to ordinary reinforced concrete during the past decades. Concrete columns can be reinforced by wound composites, which are providing circumferential confinements forces as well as higher compressive strength [1, 2]. In last years, using of self compacting concrete SCC gave the structural engineers very favourably. Due to SCC properties many advantages mentioned and developed structural applications can be realizing. Elchalakani, et. Al. was reported that CFDSST column has almost the same advantage as normal CFST member. It has lighter weight, higher bending stiffness's and has best cyclic performances [3]. Tomii found that the axial loads capacity of concrete filling steel tube was better than the nominal capacity, which defined as the total of compressive strength of the unconfined steel and concrete [4]. Wei et. al., was verify the nominal strength of CFDSST column got from experimental work. He had find that the confinement effect of inner and outer tube, the strength from experimental tests are greater than the numerical as shown in figure (1). [5].

Fig. 1. The Comparison between analysis and test results of strength for CFSDT column, [5].

2 Experimental works

The main objective of this experimental work is preparing and testing 10 HCC columns divided to two groups having different ratio of SCC to NC as inner and outer cross section area. Both groups were tested under axial loading. All columns have same length 600 mm and same outer diameter 150 mm and the inner diameter was changed between NC and SCC. Table (1) and Figure (5) show the details of the specimens.

* Corresponding author: dr.ali_sadiq@yahoo.com

Table 1. HC specimen Details.

Group	no.	Column designation	Inner Material (mm)	Inner Diameter (mm)	Di/Do Ratio
1	1	C-NC150-SCC0	NC	150	1
	2	C-NC125-SCC25	NC	125	0.83
	3	C-NC100-SCC50	NC	100	0.67
	4	C-NC75-SCC75	NC	75	0.5
	5	C-NC50-SCC100	NC	50	0.33
2	6	C-SCC50-NC100	SCC	50	0.33
	7	C-SCC75-NC75	SCC	75	0.5
	8	C-SCC100-NC50	SCC	100	0.67
	9	C-SCC125-NC25	SCC	125	0.83
	10	C-SCC150-NC0	SCC	150	1

Where,

C: Column

NC: Normal Concrete

SCC: Self Compacting Concrete.

Di: Inner Diameter.

Do: Outer Diameter (Do=150mm).

3 Materials

3.1 Cement

Ordinary Portland cement was used in the experimental works, the chemical composition and physical properties are tested and found comply with the Iraqi Specifications Standards Specifications IQS No.5/1984[6].

3.2 Fine aggregate

Natural Sands brought from Al-Akhaider Zone was used in concrete mixes. The fine aggregate had fineness modulus of (2.78) and shaped rounded and smooth texture. The lab results showed that fine aggregate is within Iraqi Specifications Standards Specifications IQS No.5/1984[6] and ASTM C33 specification [7].

3.3 Course aggregate

Crushed gravel of Al-Nibay Zone was used in this experimental works. The lab results showed that Course aggregate is within Iraqi Specifications Standards Specifications IQS No.5/1984[6] and ASTM C33 specification [7].

3.4 Water

Ordinary tap water was used for both mixes and curing of all specimens used in this experimental work. It was free from oil and organic material.

3.5 Limestone powder (LSP)

This material is a white grinding material coming from lime stone in the north of Iraq, usually used for the construction process and as filler of concrete production. Fine limestone powder was used in this experimental work, grinded by bowling technical. Size of particles of the limestone powder was less than 125x10-3 mm, and it was conformed to EFNARC [8].

3.6 Superplasticizer

Sulphated Melamine Formaldehyde (SMF) was used in this experimental works. (SMF) was free from chlorides and comply with ASTM C494 [9].

4 Mixing procedure for NC and SCC

4.1 Normal concrete NC

The laboratory mixing used in this work was according to Neville [10] for Normal Concrete. Table (2) presents the quantities by weight for material used per cubic meter of this mix.

Table 2. Mix Properties for NC/m³.

no.	Material	Weight (kg)
1	Cement	400
2	Fine aggregate	740
3	Course aggregate	990
4	Water	180
5	Superplasticizer	0.45

4.2 Self-compacting concrete SCC

The laboratory mixing used in this work was according to Emborg [11] and modified by Al-Jabiri [12] for self-compacting concrete. Table (3) presents the quantities by weight for material used per cubic meter of this mix.

Table 3. Mix Properties for SCC/m³.

no.	Material	Weight (kg)
1	Cement	400
2	Fine aggregate	797
3	Course aggregate	767
4	Limestone powder	170
5	Water	180
6	Superplasticizer	4.9

5 Fresh SCC tests

SCC is approached on the ability to flow under own weight without any vibration and the ability to gain the homogeneity without any segregation of aggregate. Slump flow, V-Funnel and L-box tests are done to show the fresh properties of SCC. All results were within Specifications.

6 Casting and curing of HC specimens

All columns were cast and cured in the laboratory. The Steel mould was containing 2 parts of half circular section and fastens to the base plate with bolts. Then a steel tube with diameter equal to the inner diameter of the experimental works was fastening inside the steel mould. 6 bars with diameter 8mm was used as longitudinal reinforcement and bar with diameter 6mm was used as stirrup with spacing 100mm. At first the outer material was casting and the inner material cast later.

The curing of the specimens was done by submerge the specimen in the water poll for 28 days. Six cubes and six cylinders were also cast and cured with same procedure. Figures (2, 3, 4 and 5) show the preparation of the specimens and Table (4) present the properties of NC and SCC mixes.

Fig. 2. Cylinder and Cubic specimens under compressive strength tests.

Fig. 3. Results of compressive strength tests for NC and SCC.

Table 4: NC and SCC Properties

Type	f_c' (Mpa)	f_t (Mpa)	f_r (Mpa)
NC	47	3.45	4.25
SCC	53	3.65	4.5

Fig. 4. Reinforcement Details of the columns.

Fig. 5. HC Columns Details.

7 Results and discussion

Respecting to the experimental works the ten specimens were tested under uniaxial compressive loadings. Table (5) shows the summary of the experimental results.

Table 5: Summary of experimental test results

no.	Column designation	Ultimate Load (kN)	Axial Strains at Ultimate Load
1	C-NC150-SCC0	281	0.00063
2	C-NC125-SCC25	320	0.00064
3	C-NC100-SCC50	354	0.00066
4	C-NC75-SCC75	405	0.00072
5	C-NC50-SCC100	480	0.00089
6	C-SCC50-NC100	503	0.00120
7	C-SCC75-NC75	532	0.00085
8	C-SCC100-NC50	550	0.00075
9	C-SCC125-NC25	573	0.00069
10	C-SCC150-NC0	605	0.00062

A study of the structural behaviour of HCC is conducted, the effect of SCC to NC ratio on the axial strength of the column is considered. All columns were failed in compression mode of failure, figures (6, 7, and 8).

Fig. 6. Failure of Column C-SCC50-NC100

Fig. 7. Failure of Column C-SCC75-NC75

Fig. 8. Failure of Column C-SCC150-NC0

Figures from (9 to 18) show the relationship between the loading and the axial deformation in the columns.

Fig. 9. Load-deformation curve for C-NC150-SCC0.

Fig. 10. Load-Deformation curve for C-NC125-SCC25.

Fig. 14. Load-Deformation curve for C-SCC50-NC100.

Fig. 11. Load-Deformation curve for C-NC100-SCC50.

Fig. 15. Load-Deformation curve for C-SCC75-NC75.

Fig. 12. Load-Deformation curve for C-NC75-SCC75.

Fig. 16. Load-Deformation curve for C-SCC100-NC50.

Fig. 13. Load-Deformation curve for C-NC50-SCC100.

Fig. 17. Load-Deformation curve for C-SCC125-NC25.

Fig. 18. Load-Deformation curve for C-SCC150-NC0.

7.1. Effect of SCC/NC ratio on HCC under axial compressing loads

7.1.1 Group 1 (NC inner and SCC outer)

As the ratio of inner diameter to outer diameter (D_i/D_o) decreased, the load capacity of column increased from 281 kN to 480 kN and the axial deformation was increase also from 0.00063 to 0.00089 as shown in figure (19).

Fig. 19. Load-Deformation curve for GROUP 1.

7.1.2 Group 2 (SCC inner and NC outer)

As the ratio of inner diameter to outer diameter (D_i/D_o) increase, the load capacity of column was increased from 503 kN to 605 kN and the axial deformation was decreased from 0.0012 to 0.00062 , as shown in figure (20).

Fig. 20. Load-Deformation curve for GROUP 2.

7.1.3 Group 3 (Same ratio of D_i/D_o)

For the same ratio of inner diameter to outer diameter (D_i/D_o) for NCC and SCC , the load capacity of column was increased from 354 kN to 550 kN and the axial deformation also increased from 0.00066 to 0.00075.

The load capacity of column was increased from 281 kN to 605 kN when you change it from fully NC to fully SCC and the axial deformation almost equal

8 Conclusions

In this study, the experiment investigation of behaviour of Hybrid Concrete Column under axial compressing loads. The testing of specimens considers the effect of outer to inner diameter ratio on the capacity of the columns.

The experimental program yields following conclusions:

1. All columns were failed in compression mode of failure.
2. The load capacity of column was increased 70% when the NCC inner diameter decrease and SCC outer dimeter increased.
3. The load capacity of column was increased 20% when the SCC inner diameter decrease and NC outer dimeter increased.
4. it's better to use SCC as outer material because the its work as confinement layer and increasing of load capacity compared with control column.

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