Evaluating the Structural Performance of Self Consolidating Concrete Made with Concrete Debris as Aggregate

T.V. Arul Prakash, M. Natarajan, N. Balasundaram, V.Karthik

Abstract - Concrete is the widely used building material which is adopted for all types of Civil Engineering works. Annually, 8 to 12 billion tones of natural aggregates were consumed by the construction industry around the world. In today's world, environmental protection is a major issue which is caused by depletion of natural aggregates from river beds and quarries. Thus, there is an urgent need to determine the replacement material for natural aggregates. The main objective of this study is to evaluate the structural performance of self consolidating concrete (SCC) made with concrete debris as a replacement for natural coarse aggregate. Concrete debris aggregate was replacing the natural coarse aggregate at percentage ranges from 0% to 30%, at an interval of 5%. In order to check the structural performance of SCC with concrete debris, reinforced concrete beams were prepared with M30 grade concrete and the experimental results were compared. Class F Flyash was utilized as a viscosity modifying agent.

Index terms: Recycled aggregates, Self-compacting concrete/ Self-consolidating concrete, Structural Performance.

I. INTRODUCTION

Self-compacting or consolidating concrete is one of the extraordinary and innovative developments in the construction field recent. The main benefit of using SCC in construction. It will run at its own weight without the need for vibration required for placement and compaction with overburdened reinforcement and complexity of the formwork. In view of these potential benefits, this method has been followed in many countries in building construction. Due to rapid growth rate in construction of buildings, roadways and bridges, there is an enormous amount of consumption of natural aggregates by the construction industry. Development of infrastructural facilities of the nation not only depends on construction of new structures, it also involves in remodeling and demolition of existing structures. Figure 1 indicates that volume of concrete waste is around 65% of the total construction debris in India. In this study a sustainable solution has been proposed on the reuse of concrete debris as course aggregate in concrete for construction.

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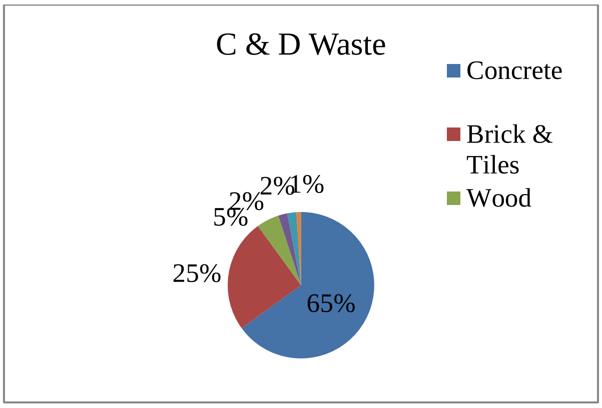

Fig. 1. Elements of debris from construction demolition in India

II. LITERATURE REVIEWED

(*S.K.Bhattacharya, 2013)

Dhir (1999) investigates the ability of recycled aggregates (ACR) to be used in BS 5328 mixtures. Results on aggregate properties have shown that smooth concrete and reinforced concrete residues can be milled with existing equipment to provide RCA with physical properties that meet the current requirements of BS882[1].

Prakash (2006) discusses many practices in the concrete industry that pose a potential threat to our environment and give rise to grave concern. Alongside the increase in consumption, the volume of waste from companies using concrete is increasing.

N R Gayawala (2011) obtained maximum compressive strength by adding amount of fly ash by 15% and for tensile strength they also got maximum tensile strength by adding 15% amount of fly ash in self-compacting concrete. They also found that SCC had good durability properties than normal concrete. For flexural strength and pull out strength addition of 15% of fly ash in mix is enough for maximum strength.

Edwin Fernando (2014) carried out an experimental investigation on SCC y replacing the fly ash as a filler material and copper slag as river sand at a percentage of 5 - 25%. Mix design is done as per EFNARC specification by keeping w/c ratio of 0.40 and super plasticizer was used to increase the flow ability.
The properties of concrete

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were tested as per the standards and compared for normal SCC and SCC with partial replacement of fly ash and copper slag. The result shows a marginal improvement in the replacement of cement by fly ash up to 40%[2].

III. MATERIALS USED

The various physical and chemical properties of the materials used in the self-consolidating concrete by using recycled concrete aggregate was mentioned below and cited in Table 1 and Table 2.

a. Fine aggregate – Natural river sand

Coarse aggregate – Locally available granite crushed stones passing through 20mm sieve and retained on 12.5mm

b. Super plasticizers –Conplast 420 of 3.5% was used

Concrete Debris Aggregate – Acquired from the demolished construction waste and concrete cubes which are more angular and higher absorption capacity.

TABLE 1. PHYSICAL PROPERTIES

Parameter		Cement	Fly ash	Fine aggregate	Coarse aggregate	Concrete Debris aggregate
Color		Greenish grey	Dark grey	-	-	-
Specific gravity		3.13	2.10	2.55	2.75	2.44
Grade		53	Class F	II	-	-
Fineness (m^2/kg)		310	425	2.56	-	-
Fineness modulus		-	-	-	6.95	6.55
Setting time	Initial (Min)	43	-	-	-	-
	Final (Min)	340	-	-	-	-
Consistency (%)		29	-	-	-	
Bulk density (kg/m^3)		-	1157	1885	1485	1246
Water absorption (%)		-	-	1.40	0.80	3.45

TABLE 2 – CHEMICAL PROPERTIES OF OPC 53 AND FLY ASH

Component	SiO_2	Fe_2O_3	SO_3	Na_2O	K_2O	MgO	Al_2O_3	CaO
OPC 53	24.51	3.49	1.41	0.44	0.62	2.15	6.86	63.11
Fly ash	54.01	7.36	0.22	0.42	0.74	1.73	26.80	3.23

Mix Proportions – Mix design was made to produce M30 grade SCC.

TABLE 3 – CONCRETE MIX PROPORTIONS (KG/M^3)

Description	RCA replacement %	Cement	Fine Aggregate	Coarse Aggregate	Concrete Debris aggregate	VMA (Fly ash)	Water
SCC	0	310	910	890	0	138	185
CD SCC 05	5	310	910	845	45	138	185
CD SCC 10	10	310	910	801	89	138	185
CD SCC 15	15	310	910	756	134	138	185
CD SCC 20	20	310	910	712	178	138	185
CD SCC 25	25	310	910	667	223	138	185
CD SCC 30	30	310	910	623	267	138	185

IV. EXPERIMENTAL INVESTIGATION

a. Fresh and Hardened properties of SCC

The concrete mix has recently been tested in accordance with EFNARC recommendations and strength of concrete cubes under compression was listed in Table 4 and Table 5.

TABLE 4 – FRESH PROPERTIES OF SCC

Description	Slump flow (mm)	T50cm Slump (Sec)	V-Funnel (Sec)	L-Box (H1/H2)	J-Ring (H1-H2)
EFNARC		2 – 5	6 – 12	0.8 – 1.0	0 – 10
SCC	770	2.4	6.9	0.9	4
CDSCC05	752	2.49	7.15	0.91	4.5
CDSCC10	731	2.64	7.3	0.93	6
CDSCC15	708	2.67	7.4	0.92	6.5
CDSCC20	694	2.73	7.65	0.93	7
CDSCC25	678	2.8	7.88	0.94	8
CDSCC30	660	2.93	8.1	0.94	8.5

TABLE 5 – COMPRESSIVE STRENGTH

Description	Compressive strength in N/mm^2			
	3 days	7 days	14 days	28 days
SCC	12.87	26.51	32.4	36.83
CDSCC05	12.71	26.35	32.27	36.6
CDSCC10	12.54	26.22	32.03	36.55
CDSCC15	12.38	26.1	31.92	36.37
CDSCC20	12.21	25.99	31.75	36.11
CDSCC25	12.19	25.9	31.68	35.99
CDSCC30	11.30	25.43	30.79	35.22

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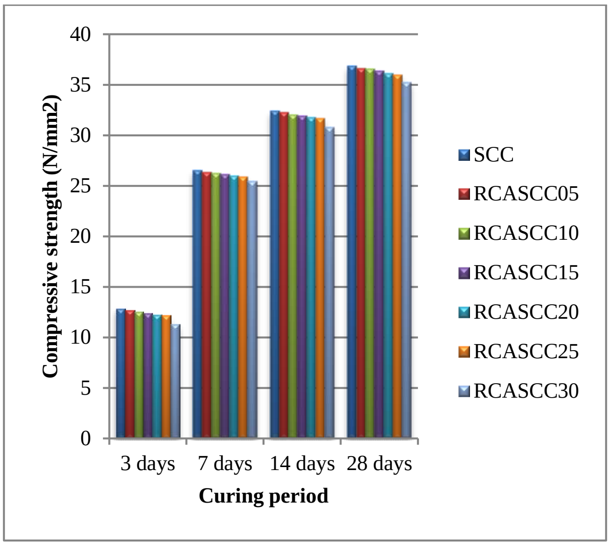

Fig. 2. Compressive strength

b. Elastic Modulus of Concrete

Elastic Modulus of concrete was one of the major parameters used in the structural design, the testing on specimens were done as per the Indian Standard code of practice[5]. The observed results on elastic modulus of concrete were mentioned in the Table 6.

TABLE 6 ELASTIC MODULUS VALUE OF CONCRETE AT 28 DAYS

Description	**Elastic Modulus of Concrete at 28 days (GPa)**
As per IS 456-2000 (5000 x $\sqrt{f_{ck}}$)	27.386*
SCC	35.681
CDSCC05	33.742
CDSCC10	31.558
CDSCC15	29.945
CDSCC20	27.594
CDSCC25	25.773
CDSCC30	22.918

* Elastic modulus for M30 grade concrete

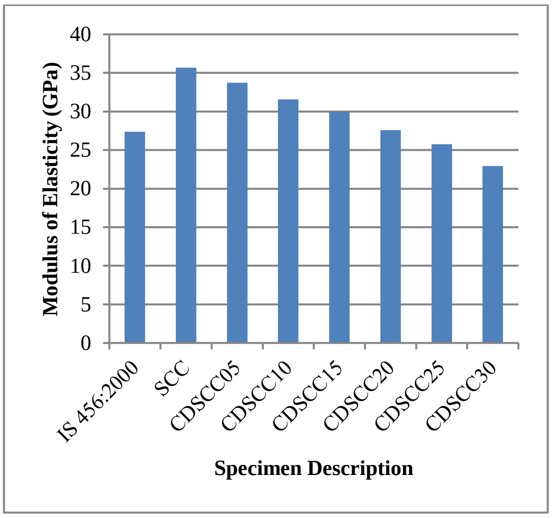

Fig. 3. Elastic Modulus of Concrete

c. Structural Performance of Reinforced concrete beam

Beam specimens were cast with a size of 150 x 200 x 2000 mm with a clear cover of 25mm and they were tested under 28 days of curing period. The beam specimens were casted with Fe415 grade steel[3].

TABLE 7. DETAILING OF REINFORCED CONCRETE BEAMS

Description	**Reinforcement Details**
Tension zone reinforcement (Bottom)	2 # - 20mm Dia
Compression zone reinforcement (Top)	2 # - 12mm Dia
Shear reinforcement (Stirrups)	8mm Dia bars @ 200mm c/c

TABLE 8 FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAM

Specimen	First Cracking Load (kN)	Deflection at First Crack (mm)			Ultimate Load (kN)	Deflection at Ultimate Load (mm)			Mode of Failure
		L/3	L/2	L3		L/3	L/2	L3	
SCC	27	1.43	1.77	1.39	75	10.74	12.84	10.77	Flexural
CDSCC05	26	1.4	1.85	1.38	73	12.38	14.31	12.40	Flexural
CDSCC10	25	1.89	2.02	1.93	72	12.99	14.89	13.01	Flexural
CDSCC15	25	2.34	2.58	2.38	70	13.53	15.58	13.58	Flexural
CDSCC20	24	2.77	2.99	2.81	68	14.26	16.12	14.29	Flexural
CDSCC25	23	3.08	3.34	3.10	66	14.91	16.84	14.96	Flexural
CDSCC30	21	3.56	3.87	3.61	63	15.88	19.59	15.91	Flexural

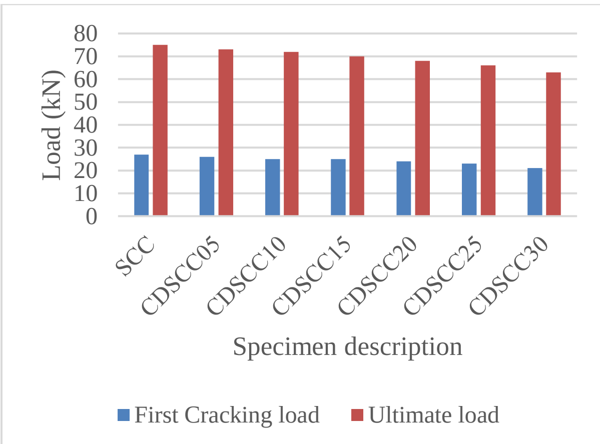

Fig. 4 -First Cracking load and Ultimate load of RCC

Table 9. Comparison of load carrying capacity when initial crack occurs

Description	**Load at initial crack (kN)**	**Difference in Strength (kN)**	**Percentage Decrease in Strength**
SCC	27	-	-
CDSCC05	26	1	3.70
CDSCC10	25	2	7.41
CDSCC15	25	2	7.41
CDSCC20	24	3	11.11
CDSCC25	23	4	14.81
CDSCC30	21	6	22.22

Table 10. Stiffness of the Beam specimens

Description	**Ultimate Load (kN)**	**Ultimate Deflection (mm)**	**Stiffness (kN/mm)**
SCC	75	12.84	5.84
CDSCC05	73	14.31	5.10
CDSCC10	72	14.89	4.84
CDSCC15	70	15.58	4.49
CDSCC20	68	16.12	4.21
CDSCC25	66	16.84	3.92
CDSCC30	63	19.59	3.22

Table 11. Deflection behavior of Self Consolidating Concrete made with Concrete Debris aggregates

Load (kN)	**Mid Span Deflection (mm)**						
	SCC	**CDSCC05**	**CDSCC10**	**CDSCC15**	**CDSCC20**	**CDSCC25**	**CDSCC30**
0	0	0	0	0	0	0	0
1	0.10	0.15	0.24	0.32	0.42	0.59	0.83
5	0.24	0.28	0.37	0.49	0.58	0.68	0.99
11	0.38	0.45	0.59	0.72	0.81	1.08	1.67
15	0.59	0.63	0.81	0.89	1.10	1.76	2.10
19	0.71	0.80	0.96	1.05	1.28	2.07	3.02
21	0.84	0.97	1.13	1.26	1.87	2.92	3.87 (F)
23	0.98	1.14	1.49	1.75	2.04	3.34 (F)	3.54
24	1.15	1.35	1.82	2.29	2.99 (F)	3.67	3.99
25	1.47	1.59	2.02 (F)	2.58 (F)	3.14	3.91	4.17
26	1.53	1.85 (F)	2.20	2.79	3.54	4.21	4.39
27	1.77 (F)	1.90	2.57	3.11	4.09	4.52	4.78
30	2.17	2.31	2.91	3.43	4.25	4.92	5.11
33	2.98	3.27	3.44	3.98	4.96	5.04	6.15
38	3.76	4.24	4.71	5.08	5.87	6.10	7.01
45	4.94	5.49	6.01	6.68	6.95	7.67	8.99
51	6.25	7.13	7.81	7.99	8.57	9.01	13.76
59	7.58	8.23	8.79	9.10	9.97	12.66	16.93
63	8.47	8.99	9.52	10.89	11.78	14.36	19.59 (U)
66	9.19	9.89	10.61	11.24	14.89	16.84 (U)	-
68	10.21	11.45	12.11	13.95	16.12 (U)	-	-
70	11.38	12.67	13.74	15.58 (U)	-	-	-
72	11.83	13.19	14.89 (U)	-	-	-	-
73	12.11	14.31 (U)	-	-	-	-	-
75	12.84 (U)	-	-	-	-	-	-

**** (F) – First Crack; (U) – Ultimate Crack**

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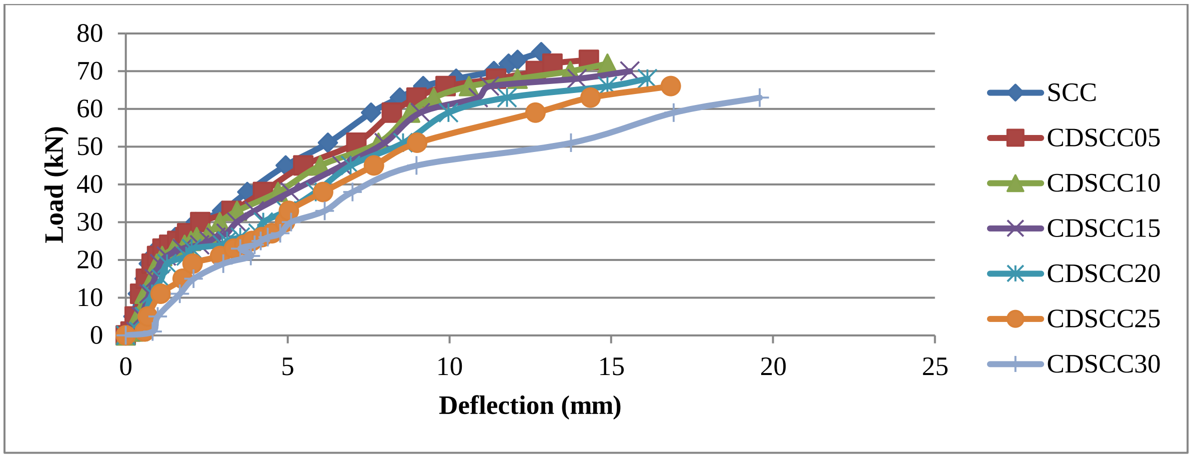

Fig. 5 - Load vs Deflection curve for SCC

Table 6. First crack and ultimate loads of SCC composite beams in flexure

Description	Initial Cracking load P_{cr} (kN)	Ultimate load P_u (kN)	P_{cr}/P_u (%)
SCC	27	75	36
CDSCC05	26	73	35.62
CDSCC10	25	72	34.72
CDSCC15	25	70	35.71
CDSCC20	24	68	35.29
CDSCC25	23	66	36.51
CDSCC30	21	63	33.33

V. RESULTS AND DISCUSSIONS

The results show that when concrete debris aggregate partly replaced for coarse aggregate, a sustainable concrete could be manufactured[6][7][8].

Self-consolidating concrete manufactured with concrete debris aggregate has reached the target strength in all mixtures and meets the guidelines given in the EFNARC specifications.

There was a reduction in the strength properties by increasing the amount of RCA replacement in SCC at all Stages of curing though the optimum results were identified at 20-25%[9][10].

The failure load was not affected by the initial cracking.

The increase in addition of recycled concrete debris as coarse aggregate in SCC will results in reduction in ultimate load carried by the reinforced concrete beams instead the deflection produced at ultimate load was higher than the conventional SCC.

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