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Research paper

Durability Behavior of Self Compacting Concrete Made with Recycled Concrete Aggregate

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Abstract

This article presents the influence of the Recycled Concrete Aggregate (RCA) on the durability behavior of self-compacting fly ash concrete (M30 Grade). The RCA from local construction demolition site wereemployed as a replacement for natural coarse aggregate (0% - 30%) in self-compacting concrete(SCC). The Viscosity modifying material used in this study was Class F fly ash. Different kinds of tests were conducted on the concrete specimens such as water absorption test, sulphate attack, chloride attack, carbonation test,sorptivity test, etc., When the durability behavior was taken into consideration,the summary of results indicate that recycled concrete aggregate different percentage of replacements as the optimal percentagein the manufacture of SCC without much affecting strength and durability.

Keywords: *Recycled aggregates, Self compacting concrete, Durability parameters.*

1. Introduction

Self-compacting or consolidating concrete is one of the extraordinaryand innovative developments in the construction field recently. 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 applicable in many countries in building construction and construction.

RCA uses concrete demolition materials and calcined clay masonry aggregates.Reuse of demolition waste disposal and isalso helpful in reducing the gap between the demand and supply of crushedgranite fresh aggregate. RCA from construction demolition site may be replaced in whole or in part by natural aggregates in the manufacture of SCC. The use of concrete waste as a coarse aggregate (CA)reduces the emission of CO_2(15-20%)by reducing the utilization of lime stone by 60%[1].While the amount of demolition waste materialsgenerated in India has not yet been quantified properly, it is thought thatpresently the yearly rate of demolition of buildings and other structures in themajor cities has reached one to 2%.Therefore, though the research on RCA in concrete is going on for past 70 years, the use of recycled aggregate (RA) is of great importance to save resources, to protect the environment and to achieve sustainable development in the construction sector[2].

2. Literature reviewed

Ravindrajah (1987) describes the main problems in the demolition of concrete structures. The demolition of old buildings is on the rise, either because they are outdated, dangerous, need to be repaired and rehabilitated, or to allow the construction of new larger and larger structures. As a result, a large amount of concrete demolition is generated as waste and disposed of by landfill or landfill. Transport costs and the lack of landfills, however, make disposal a major problem.

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.

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 by 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 result shows a marginal improvement at 40% fly ash replacement.
The use of recycled aggregates in the production of new concrete has gradually increased from an environmental and economic point of view. Nevertheless, there arevery few details related to the quality of recycled concrete is available. Hence, in this study an attempt was made tounderstand the durabilitybehavior of self-compacting concretewithRCA.

3. Materials used

The physical and chemical properties of the materials used in this studyare cited in Table 1 and Table 2.

a. Cement – OPC 53
b. Viscosity modifier (VMA) - Class F fly ash.
c. Fine aggregate – Natural river sand
d. Coarse aggregate – Locally available granite crushed stones passing through 20mm sieve and retained on 12.5mm
e. Super plasticizers –Conplast 420 of 3.5% was used
f. Recycled Concrete Aggregate – It was acquired from the demolished construction waste and concrete cubes which are more angular and higher absorption capacity.
g. Mix Proportions – Mix design was made to produce M30 grade SCC.

Table 1: Physical properties

Parameter		**Cement**	**Fly ash**	**Fine aggregate**	**Coarse aggregate**	**Recycled concrete 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

Table 3: Concrete Mix Proportions (kg/m^3)

Description	**RCA replacement %**	**Cement**	**Fine Aggregate**	**Coarse Aggregate**	**Recycled concrete aggregate**	**VMA (Fly ash)**	**Water**
SCC	0	310	910	890	0	138	185
RCASCC05	5	310	910	845	45	138	185
RCASCC10	10	310	910	801	89	138	185
RCASCC15	15	310	910	756	134	138	185
RCASCC20	20	310	910	712	178	138	185
RCASCC25	25	310	910	667	223	138	185
RCASCC30	30	310	910	623	267	138	185

4. Experimental investigation

4.1. Fresh and Hardened properties of SCC

M30 grade self-compacting concrete was produced by partially replacing natural aggregates with recycled concrete aggregates. The concrete has been freshly examined and hardened. SCC is characterized by its flow, passing and resistance to separation. 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	650 – 800	2 – 5	6 – 12	0.8 – 1.0	0 – 10
SCC	770	2.4	6.9	0.9	4
RCASCC05	752	2.49	7.15	0.91	4.5
RCASCC10	731	2.64	7.3	0.93	6
RCASCC15	708	2.67	7.4	0.92	6.5
RCASCC20	694	2.73	7.65	0.93	7
RCASCC25	678	2.8	7.88	0.94	8
RCASCC30	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
RCASCC05	12.71	26.35	32.27	36.6
RCASCC10	12.54	26.22	32.03	36.55
RCASCC15	12.38	26.1	31.92	36.37
RCASCC20	12.21	25.99	31.75	36.11
RCASCC25	12.19	25.9	31.68	35.99
RCASCC30	11.30	25.43	30.79	35.22

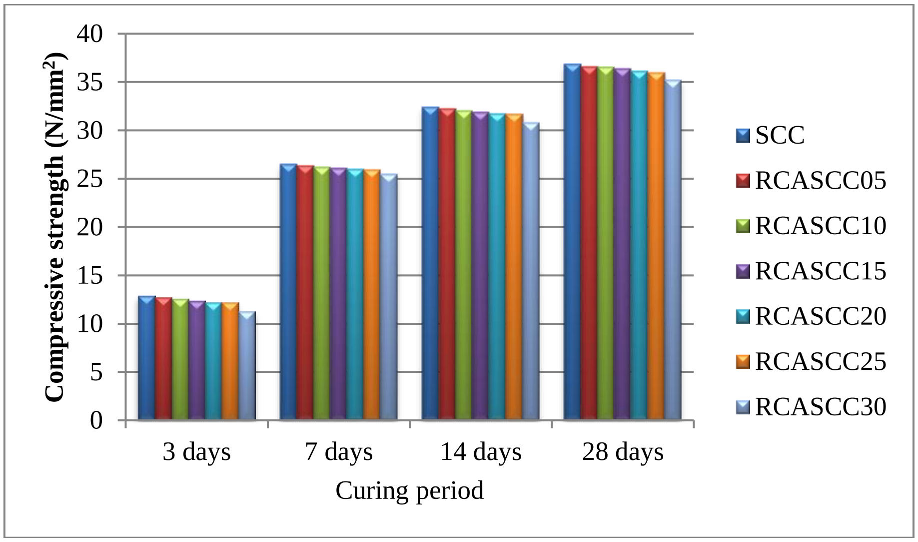

Figure 1: Compressive strength

4.2. Durability Properties

The following are the various tests were conducted on self compacting concrete made by recycled concrete aggregate (SCC-RCA) with different percentage of replacing natural coarse aggregate. The test results are cited in Tables 6 to 12 and Figure 2 to 9.

4.2.1. Water absorption test

Table 6: Water Absorption results

Description	Weight of Concrete cubes (kg)		Amount of water absorption		Density (kg/m^3)	
	Dry	Wet	Grams (g)	Percentage (%)	Dry	Wet
SCC	8.165	8.591	426	5.22	2419.26	2545.48
RCASCC05	8.201	8.651	450	5.49	2429.93	2563.26
RCASCC10	8.287	8.767	480	5.79	2455.41	2597.63
RCASCC15	8.305	8.812	507	6.10	2460.74	2610.96
RCASCC20	8.308	8.822	514	6.19	2461.63	2613.93
RCASCC25	8.379	8.896	517	6.17	2482.67	2635.85
RCASCC30	8.398	8.916	518	6.17	2488.30	2641.78

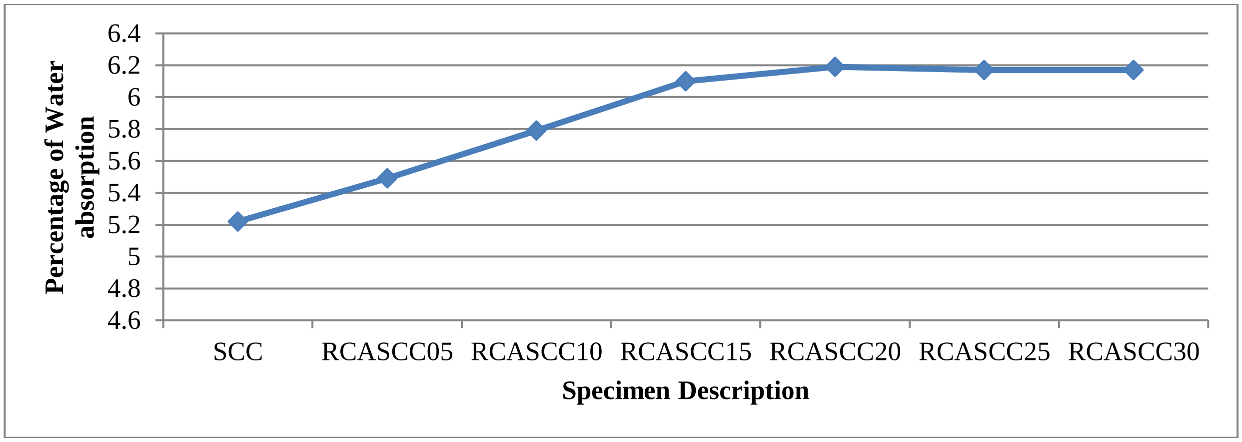

Figure 2: Effect RCA on Water absorption of SCC mixes

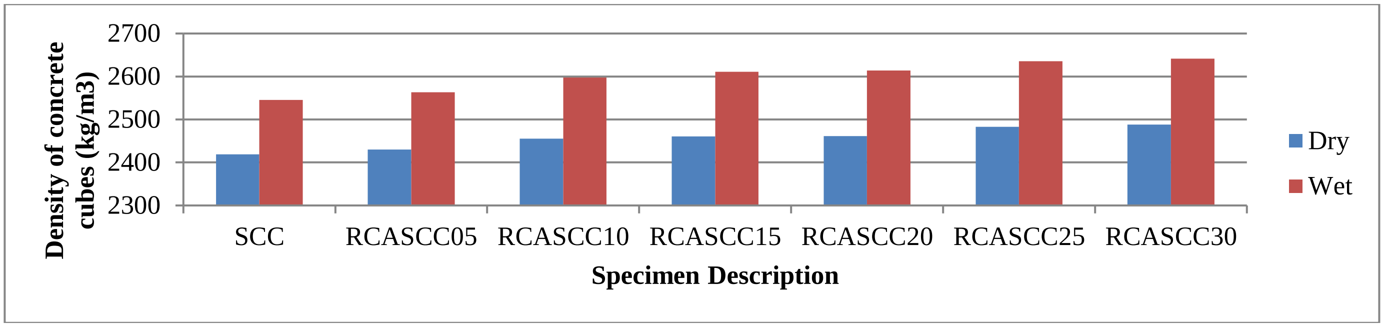

Figure 3: Effect RCA on Density of SCC mixes

4.2.2. Sorptivity test

Sorptivity of concretesamples weretested after 28days of curing.

Table 7: Effect of RCA on sorptivity on SCC

Description	Sorptivity ($mm^3/mm^2/min^{0.5}$)	
	7 days	28 days
SCC	0.065	0.058
RCASCC05	0.077	0.060
RCASCC10	0.087	0.064
RCASCC15	0.104	0.079
RCASCC20	0.112	0.091
RCASCC25	0.139	0.111
RCASCC30	0.168	0.134

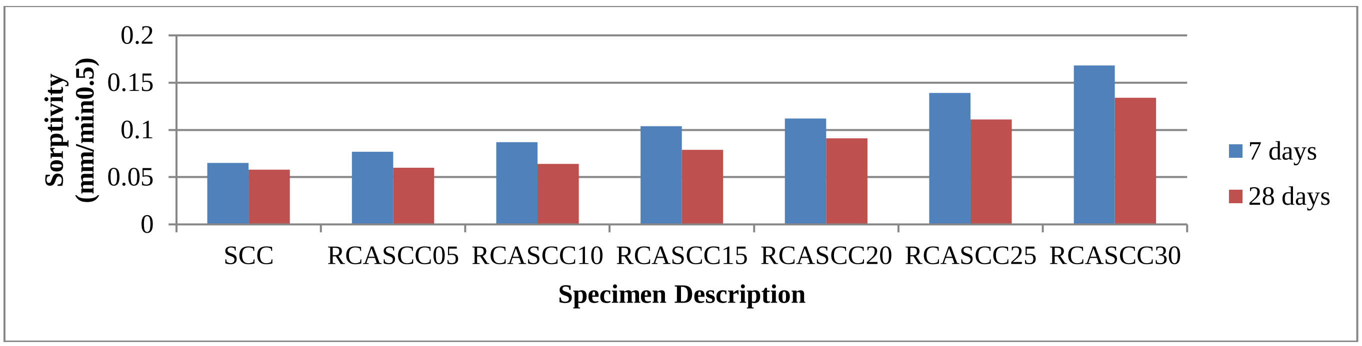

Figure 4: Sorptivity results

4.2.3. Accelerated Carbonation Test

The accelerated carbonation test on SCC-RCA specimens were measured as per the guidelines mentioned in ISO 1920-12:2015

Table 8: Carbonation test results

Description	Carbonation depth (mm)			
	4 weeks	8 weeks	12 weeks	16 weeks
SCC	21	26	31	37
RCASCC05	19	25	29	34
RCASCC10	18	24	27	31
RCASCC15	16	22	24	28
RCASCC20	14	21	22	25
RCASCC25	14	20	21	24
RCASCC30	12	18	20	21

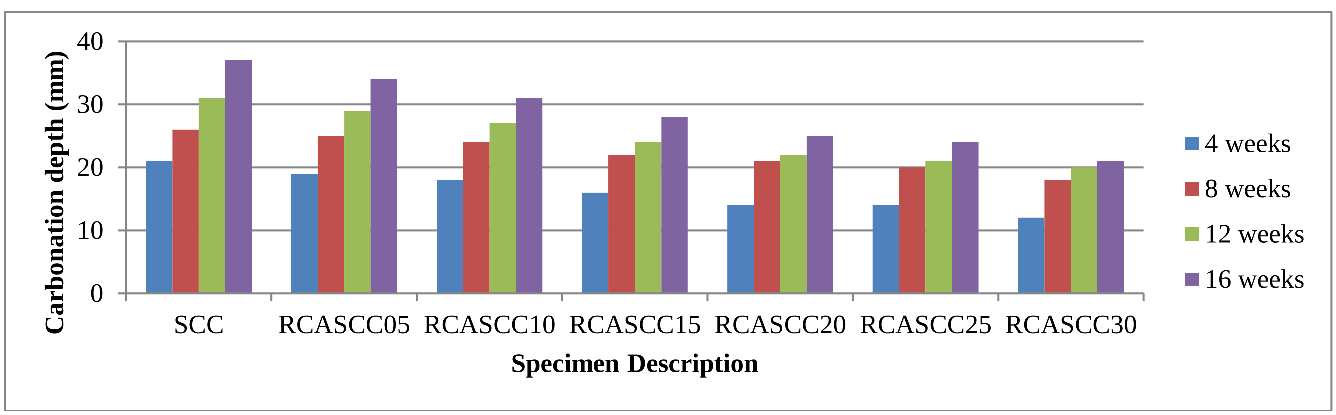

Figure 5: Carbonation test results

4.2.4. Ultrasonic pulse velocity(UPV) test

The UPV of SCC-RCA specimens were measured as per the guidelines mentioned in IS 13311 – Part 1.

Table 10: Velocity of Ultrasonic waves at various curing ages

Description	Ultrasonic pulse velocity (m/sec)			
	3 days	7 days	14 days	28 days
SCC	4217	4366	4565	4717
RCASCC05	4316	4415	4601	4769
RCASCC10	4368	4497	4655	4852

RCASCC15	4451	4582	4698	4899
RCASCC20	4482	4621	4751	4947
RCASCC25	4573	4689	4793	5026
RCASCC30	4588	4737	4846	5147

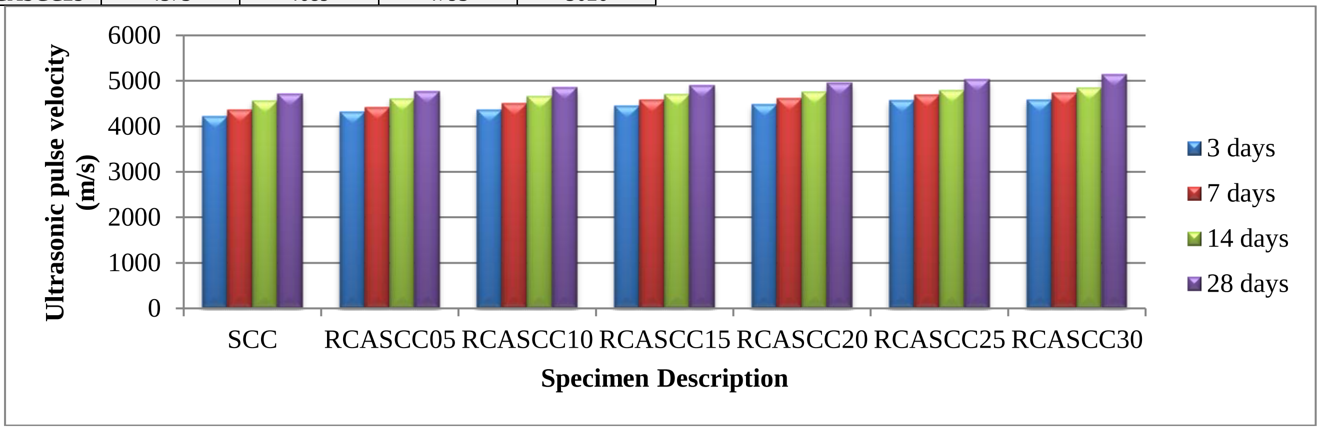

Figure 8: Ultrasonic pulse velocity results

4.2.5. Sulphate attack test

The test was conducted in 5%Na_2SO_4 solution for a period of 28 days after initial water curing of 28 days. A remarkable gain in mass was achieved on SCC-RCS specimens, when they are exposed to sulphate environment for 28 days.

Table 9: Effect of RCA on SCC under sulphate attack

Description	Mass of concrete cubes		Change in mass content		Compressive strength (N/mm^2)		Loss of compressive strength	
	Before (W_1)	After (W_2)	(W_1-W_2)	%	Before (σ_1)	After (σ_2)	(σ_1 - σ_1)	%
SCC	8.165	8.18	0.015	0.184	36.83	35.21	1.62	4.40
RCASCC05	8.201	8.224	0.023	0.280	36.6	34.79	1.81	4.95
RCASCC10	8.287	8.318	0.031	0.374	36.55	34.65	1.9	5.20
RCASCC15	8.305	8.344	0.039	0.470	36.37	34.28	2.09	5.75
RCASCC20	8.308	8.359	0.051	0.614	36.11	34.02	2.09	5.79
RCASCC25	8.379	8.476	0.097	1.158	35.99	33.89	2.1	5.83
RCASCC30	8.398	8.658	0.26	3.096	35.22	32.86	2.36	6.70

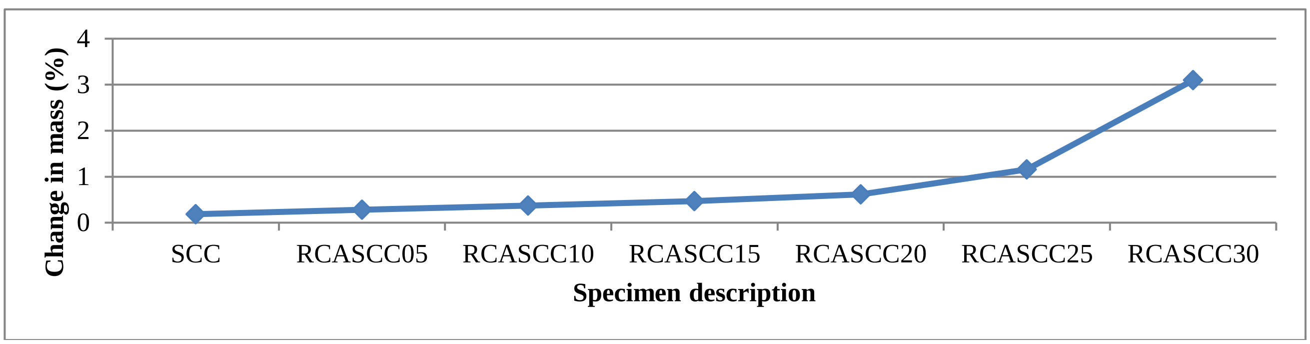

Figure 6: Change in mass after sulphate exposure

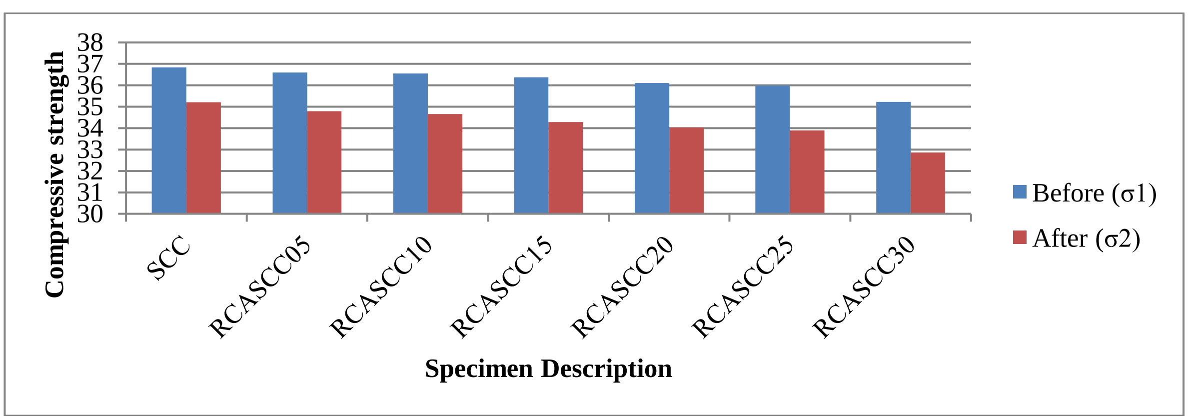

Figure 7: Change in compressive strength after sulphate exposure

4.2.6. Rapid Chloride Permeability Test (RCPT)

The RCPT test on the SCC-RCA samples were done as per ASTM C1202.

Table 13: Chloride Ion Permeability test results

Description	Duration (Minutes)	Charge Passed (Coulombs)	Chloride Ion Permeability as per ASTM 1202-97
SCC	30	3740	Moderate
RCASCC05	30	3812	Moderate
RCASCC10	30	3875	Moderate
RCASCC15	30	3921	Moderate
RCASCC20	30	3987	Moderate
RCASCC25	30	4159	High
RCASCC30	30	4320	High

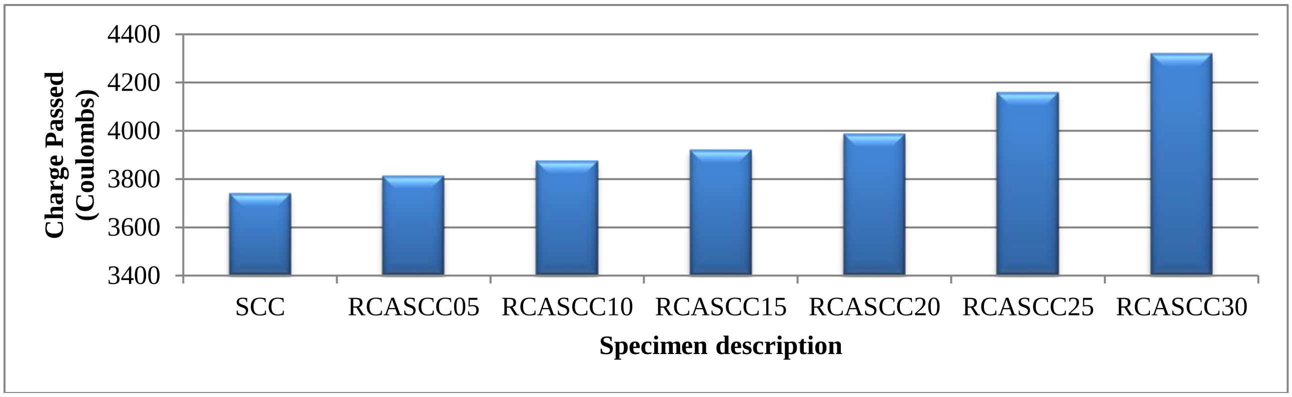

Figure 9: Chloride Ion Permeability test results

5. Results and discussions

The results show that the when RCA partly replaced for coarse aggregate, a sustainable concrete could be manufactured.
Self-compacting concrete manufactured with RCA 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 ages of curing thought the optimum results were identified at 20-25%.
The carbonation test results on the SCC-RCAshows reduction in carbonation depth while increasing the percentage of RCA.
The water absorption and sorptivity of SCC-RCA shows higher water absorption and sorptivity than conventional SCC.
The SCC-RCA results on UPV test, shows good quality indicating that there was not much influence on the quality of concrete by using RCA as course aggregate.
SCC-RCA was not preferred to use in marine environment. Because they are subjected to high amount of chloride ion permeation than the conventional SCC.

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