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Development of Structural Elements using Modified Self Compacting Concrete (SCC) With Partial Replacement of Recycled Concrete Aggregate

B. Vidyasekar[1], Dr.K.G.Selvan[2]

[1]Research Scholar, PRIST University, Thanjavur.
[2]Research supervisor, PRIST University, Thanjavur.

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Abstract

Managing manufacturing and structural waste for afresh developed infrastructure contributes to an ecosystem that is environmentally sustainable.Recycled Coarse Aggregate (RCA) is being used to produce environmentally conscious concrete in this research process. Self-Compacted Concrete (SCC) is an innovative solution for positioning extremely flowable concrete and filling the frame with no compaction and segregation tolerance.RCA is compelled through smashing aged concrete waste from construction and demolition sites as well as combining mineral admixtures such as super plasticizers (SP). RCA is immersed in waters 24 hours until the concrete mix is being used; because RCA requires additional water as a consequence of abided cement mortar to aggregate.Workability and hardened tests of the M40 grade of SCC are conducted per each combination. The test results are performed at 7, 28 and 90 days respectively for hardened properties. The observed research proposes that SCC achieves the compressive strength expected to substitute RCA by up to 40 percent considerably.The Natural Coarse Aggregate (NCA) is substituted by varying proportions of up to 50 percent recycled coarse aggregate. This paper includes various trials and the results are inscribed. The structural elements (beams) were produced and validated using the modified SCC.The data gathered from the developed beam models were analyzed with the finite element model and contrasted with the observational data.

***Keywords:** Self-Compacted Concrete, Recycled Coarse Aggregate, Construction and Demolition Concrete Wastes, Superplasticizer, Structural Element, Finite Element Analysis.*

1. INTRODUCTION

The choice of Self-Compacting Concrete (SCC) with Recycled Concrete Aggregates (RCA) is regarded to be a standard concrete that can be put in all Concrete Construction activities and compressed against vibration intervention in its self-weight. It is also practiced to promote and guarantee appropriate filling and excellent concrete reliability of constrained regions and highly enhanced structural members.It is conceivable for creating an RCA-based SCC of adequate quality through embracing correct mixing, the ratio of the constituent and incorporating mineral admixtures (Singh and Singh, 2019). SCC's mixture tolerance to satisfy the

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different reliability criteria at the lowest price concurrently entails modifying numerous mixtures constituent that has a defined impact on quality. An additional option for extra cutting the expense of SCC is the use of recycled concrete aggregates (RCA) as a substitute for natural aggregates (NA) in the concrete specification. By means of the Ecological Cost Accounting (ECA) strategy, the subsequent concern of ecological, economic and social facets of environmental sustainability is possible.(Passarini et al., 2014) demonstrated that constructing waste could be reprocessed to tidy sewerage and acquire residues that have been effectively employed as organic soil cultivation modifications. Various results showed minimal effect as NCA was substituted by up to 25 % RCA on strengthened concrete beam and column features (Rilem, 2013).Composed entirely-scale beams constructed from concrete with RCA subsistence rates of 50 and 100 percent attained respectively compiled code-predicted optimal capabilities once the volume of steel specified by specific criteria was incorporated (Etxeberria et al., 2007). For quicker build periods and smoother flow between complex reinforcement, SCC provides a fast concrete placement rate. SCC's resilience to fluidity and separation guarantees an elevated degree of uniformity, limited concrete gaps as well as standardized concrete endurance, offering the framework with the capacity for supreme build up and reliability (Nalanth et.al, 2014) and . Curbing vibrating devices enhances the condition on-site as well as nearby building sites and prefabricated localities whereby concrete is laid, thus minimizing worker's exposure to turbulence and vibration.(Silva et al., 2015) have shown that water transfer to nearby paste relies on the performance of the RCA, mainly the scale of aggregate moisture such as the capability to soak up or supply the mixture with water.(Hu et al., 2016) stated that an environmentally-efficient SCC might be produced by improving the application of powder and RCA sample dimensions using chemical admixtures accordingly. The engineered eco-SCC compounds displayed strong flowability, ability to pass, and durability together with technological characteristics relative to conventional SCC, even further eco-friendly.In this evaluation, an attempt was rendered to understand the effectiveness of recycled aggregate if employed as a coarse aggregate for concentrations of the self-compacting concrete mixture. The purpose was indeed to define the relevant and important characteristics of modified aggregate as substituting natural aggregate with recycled aggregate with 0 percent to 50 percent, with an increase of 10 percent at each phase, as well as the mechanical properties of self-compacting concrete.

2. MATERIALS USED & MIXING

A 53-grade OPC confirming IS 12269-1987 has been used in the analysis and its characteristics are listed in table 1. Multiple laboratory tests performed in compliance with IS 4031-1996 (part-1).The local river sand is used as a fine aggregate with a fineness module of 2.81 and a specific gravity of 2.66 which confirms IS

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383-1970. For SCC with a fineness module, specific gravity and density of 7.29, 2.93 and 1560 kg / m respectively, the coarse aggregates of size 10 mm to 12.5 mm are used.

Table 1: Cement Properties

Properties	Values
Specific Gravity	3.12
Normal Consistency	32%
Fineness Modulus	5%

Table 2: Mix Proportion

Mix ID	Cement	CA (Kg)	FA(Kg)	SP	W/B ratio	RCA (Kg)
Control (0%)	270	1220	915	2.1	0.35	0
RCA 1 (10%)	270	1098	915	2.1	0.35	705
RCA 2 (20%)	270	976	915	2.1	0.35	822.5
RCA 3 (30%)	270	854	915	2.1	0.35	940
RCA 4 (40%)	270	732	915	2.1	0.35	1057.5
RCA 5 (50%)	270	610	915	2.1	0.35	1175

RCA was obtained from a wide range of sources such as building and demolition waste, tested samples used in concrete engineering laboratories and discarded concrete components with 2.58, 6.89 and 1353 kg / m of fineness module, specific gravity, and density. The sample mixture could be cured and mixed with fresh water. Masterglenium sky 8233 is the superplasticizer utilized. The principal purpose of utilizing superplasticizer in SCC is to provide better flowability of a high slump that can be included in a massively strengthened structural component. The SCC mix preparation of several varying percentages of RCA as a partial substitution of the coarse aggregate for testing the consequences of workability, compressive strength, and tensile strength is given in table 2.

3. EXPERIMRNTAL INVESTIGATION

The components are measured precisely to the ratios in the particular mix and afterward, the components are completely mixed in the dried state until introducing water. The formulated mix is later employed to test the workability of the fresh concrete mix promptly. The samples are cast of regular l00 mm dimensional cubes. The cast-iron molds were also rinsed before concrete is spilled into the molds to prevent scraps of dust and all sides were coated with oil. On an even surface, the molds are placed. The molds are loaded with well-mixed concrete. The molded samples are kept at ambient temperatures in the lab after casting. Following these phases, the samples were extracted from the molds and immersed for the requisite period in a clean,

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freshwater curing tub. For 7 days, 28 days, and 90 days, the samples are cured.

3.1 Tests for Workability

The slump-flow test time to achieve the 500-mm extent, the L-box test, and the V-Funnel test were performed on fresh concrete mixes to assess the characteristics of SCC's workability, i.e. filling ability, passing ability and separating resistance, accordingly. Such experiments were carried out in line with EFNARC (2002) approved protocols. With the Abrams cone, the slump-flow test was conducted. It is evaluated for the requirements of SCC's filling capacity. It was capable to withstand the segregation. The nominal and peak slump values are 650 mm and 800 mm accordingly as per the EFNARC standards. The better the slump value, the greater the potential to flow. L-Box Testing is often utilized to assess SCC's ability to pass. The lowest and highest L-Box test values are 0.8 and 1.0 including both as per the EFNARC guidelines. V-Funnel testing is performed for SCC's filling capacity criteria. It can withstand segregation and obstruct. The low and high V-funnel test values are 8 seconds and 12 seconds, respectively, according to the EFNARC directives. The outcome of the test is shown in table 3. The chart is a curve displaying the flow potential as shown in figure 1 between time in sec and percentage change in RCA. It is possible to note that as RCA percent increases the flow time by up to 40% and then declines.

Table 2: Results on Workability

Mix ID	Slump flow test (t_{500})(sec)	L- Box test (H_2/H_1)	V- Funnel test (sec)
Control (0%)	2	0.8	10.3
RCA 1 (10%)	2.1	0.81	10.1
RCA 2 (20%)	2.3	0.83	9.5
RCA 3 (30%)	1.7	0.91	8.1
RCA 4 (40%)	2.9	0.97	10.9
RCA 5 (50%)	2.1	0.86	10.7

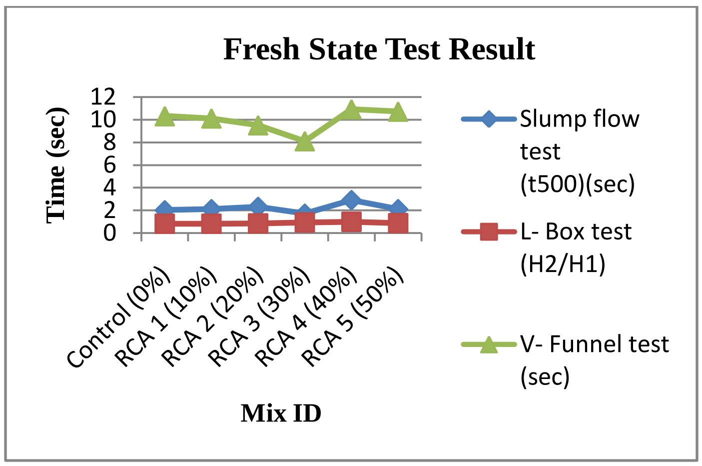

Figure 1: Workability Test Results

3.2 Hardened State Tests

Upon cooling the samples to standard room temperature, the samples of 100 mm cubes were tested regarding compressive strength. The sample cubes were positioned in the Compression Testing Machine (CTM) to apply the load on the alternate ends of the cube as seen in figure 2.The cube axis was closely coordinated with the test machine's steel plate core. Without shock, the load was introduced slowly and boosted until the sample

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collapsed. During the experiment, the cumulative load imposed on the sample was documented.

Figure 2: Specimen subjected to Compression in CTM

Table 3: Results for Compressive strength

Mix ID	7 days	28 days	90 days
Control (0%)	31.65	48.38	59.44
RCA 1 (10%)	31.72	48.44	59.69
RCA 2 (20%)	31.77	48.59	59.78
RCA 3 (30%)	31.83	48.74	59.98
RCA 4 (40%)	31.97	48.99	59.99
RCA 5 (50%)	30.91	47.90	58.93

The specimen's compressive strength was determined by splitting the specimen's peak load with the cross-sectional area. By assuring that the individual deviation was not higher than 15 percent of the average value, a total of three results of the specimen was regarded as the compressive strength. The split tensile and flexural strength test was obtained from the compressive strength measurement. The range across the fracture line and the closest end supports was assessed and measured along the tensile side of the sample.

Table 4: Results for Split tensile strength

Mix ID	7 days	28 days	90 days
Control (0%)	3.15	4.80	5.91
RCA 1 (10%)	3.16	4.81	5.93
RCA 2 (20%)	3.18	4.83	5.95
RCA 3 (30%)	3.19	4.85	5.96
RCA 4 (40%)	3.21	4.89	5.99
RCA 5 (50%)	3.08	4.77	5.83

Test results for 7days, 28days, and 90 days are shown in Table 3, 4, and 5, and from the data obtained and the chart illustrated for the 90-day cured specimen in figure 3, can be seen that as the RCA percentage improves, the strength boosts to a substitution of up to 40 percent, on which the strength falls consistently with the RCA percentage rise.

Table 5: Results for Flexural strength

Mix ID	7 days	28 days	90 days
Control (0%)	3.42	5.31	6.57
RCA 1 (10%)	3.43	5.32	6.60
RCA 2 (20%)	3.45	5.34	6.62
RCA 3 (30%)	3.47	5.37	6.64
RCA 4 (40%)	3.49	5.39	6.67
RCA 5 (50%)	3.33	5.25	6.37

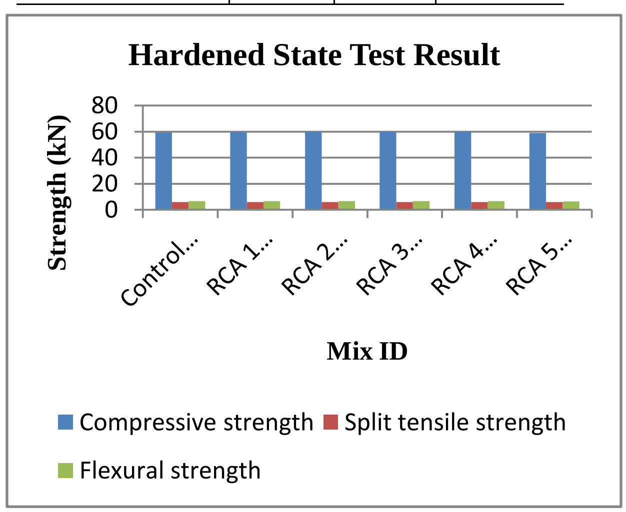

Figure 3: Hardened State Result for 90 days

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4. BEAM TESTING

In addition to the cubes, the concrete beam was cast in another batch from the concrete mixer. The beams are submitted to testing as shown in figure 4 after curing for 90 days under the shaded region and protected with wet burlap sack to attain the necessary compressive strength of concrete.

Figure 4: Casting and curing of the Concrete Beams

The figure 5 displays the specifications of the test system for the concrete beams. The test was carried out with a loading rate of 1 mm/min within the deflection control mode. To assess the deflection, the beam specimen was fitted with Linear Variable Differential Transducers (LVDTs) from both external sides. Two LVDTs were mounted on the beam at the mid-span and two below each loading point. A concretestrain gauge was placed at the mid-span position at the top of the concrete beam to measure the strain. The electric strain and the LVDT have been linked to a data processing unit via the control board. Through the data processing structure, the analog electrical deflection and strain pulses were transformed into digital signals and then depicted and documented per each load rise. The beam was loaded by a hydraulic testing machine as shown in figure 6 till it approaches failure. The sensor is capable of loading up to 1300 KN.

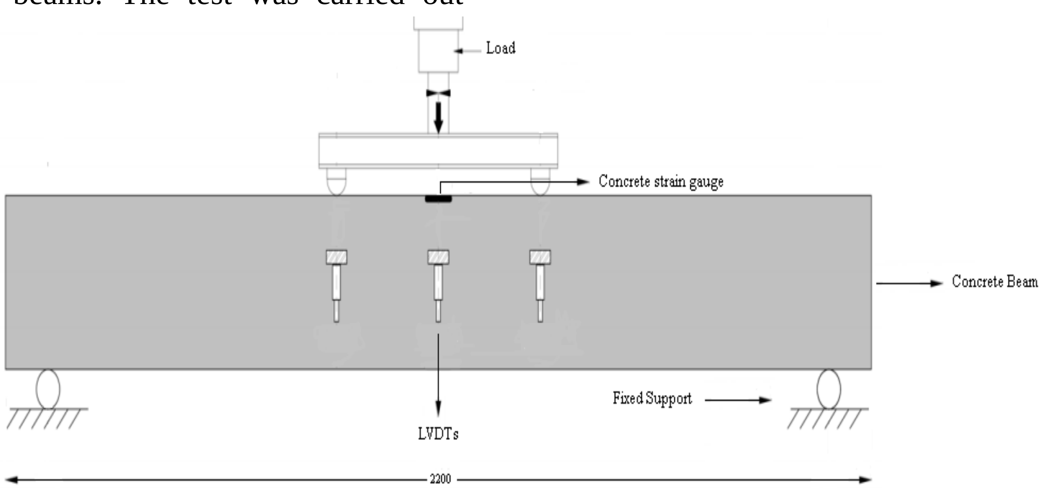

Figure 5: Beam Experimental Setup with Sensors

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The beams were progressively and evenly loaded until the failure load was breached. The deflection, concrete compressive strain at the mid-span of the beam was captured using a data acquisition system. The crack formation in each concrete beam was continuously monitored and recorded. The mode of failure was registered in the tested beam after the failure appeared. The point of cracking,yielding phase and the ultimate load were analytically estimated.

Figure 6: Hydraulic Testing Machine with Data Acquisition System

Beam specimen was tested in flexure with 50 percent of RCA. Upon slowly introducing the load, the first crack was observed at a load of 21.76 kN at the center of the beam inside the steady moment area of the beam specimen. When the load improved, new flexural cracks constantly extended along the beam in which the fractures shifted farther outward, with a noticeable rise in deflection. Most flexural cracks formed vertically and thereafter started to show inclination flexural-shear cracks. The concrete collapsed in the compression zone and the beam failed as the load introduced expanded further. Figure 7 shows the relationships of load-deflection observed at distinct beam locations at the bottom surface. The mid-span load-deflection responses show a linear elastic pattern until the first flexural cracks are initiated. Once the load escalated outside the cracking point, due to the break in the concrete in the stress area, the nearly straight-line slope dropped slightly. The estimated moment of Yielding is 41. In the compression field, 21 kN and the concrete crushed with a maximum load of 103.19kN and the highest midspan deflection of 33 mm. Figure 8 demonstrates the compressive load-concrete strain relationship determined at the mid-span of the sample at the top surface. The peak compressive stress registered was 0.00253.

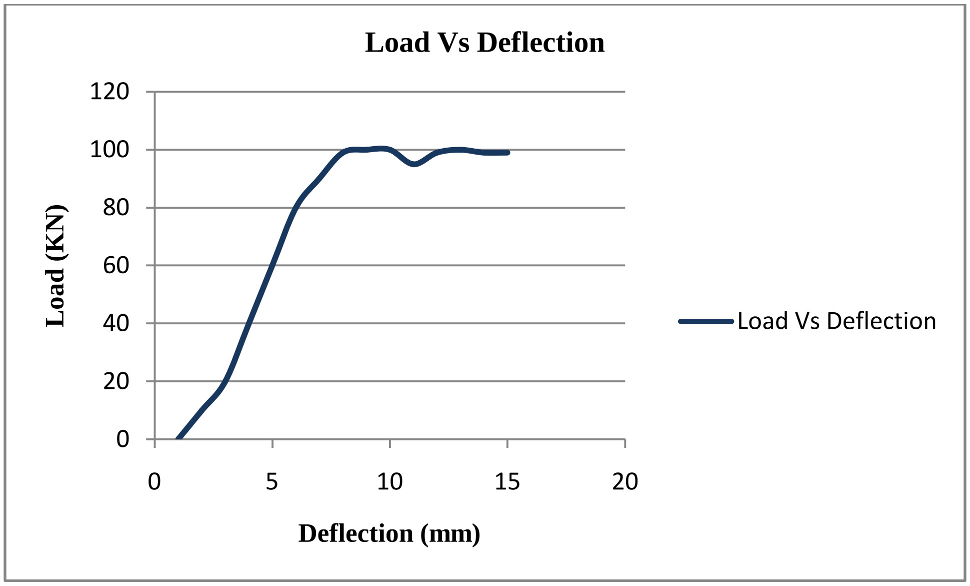

Figure 7: Load Vs Deflection

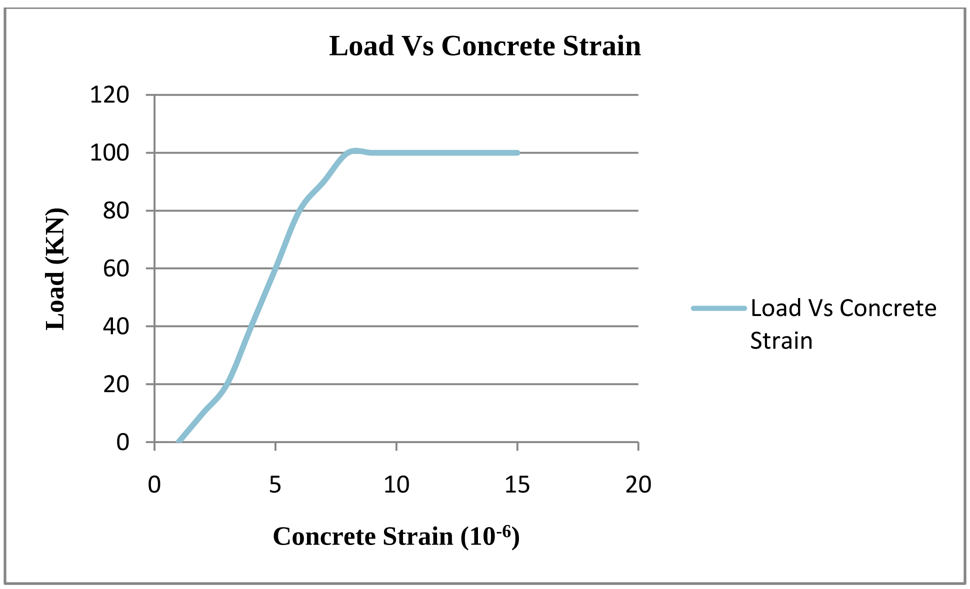

Figure 8: Load Vs Concrete Compressive Strain

4.1 Results of FEA Analysis

In order to analyze the accuracy of the developed model, the model used for finite element analysis of the concrete beam was regarded as comparable to the observational model. The finite element model used ANSYS 14.5 was established. Before cracking, the FEA beam model must be calibrated in such a way that the loads imposed are appropriate. To acquire the data, strains were examined immediately after concrete cracking. From finite element analysis by ANSYS with RCA of 50 percentages, the values of crushing concrete load, stress, beam deflection are acquired.

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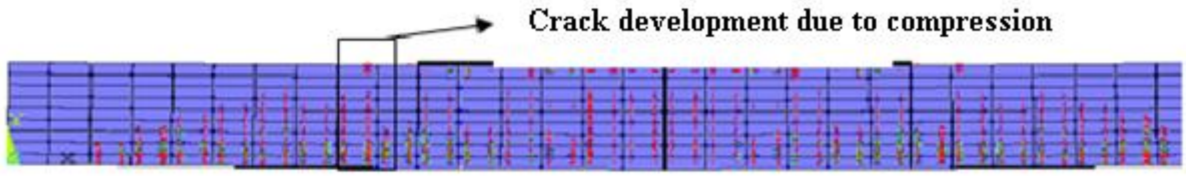

Figure 9: Compressive crack signs in the beam model using ANSYS

The finite element concrete model cracking takes place at a load of 21kN. According to Ali chahrour and Khaledsoudki (2005), the test beam's cracking load was observed. The wrecking of the concrete model begins once all the primary and compressive stresses are in the exterior region of the failure zone.The circle tends to be complementary to the major strains in the system around the loading positions at interconnected points in the compressive crack region, as shown in Figure 9. At each load, ANSYS recognizes the progression of cracks and retains them for the documentation.When loads imposed on each stage escalate, the cracks begin to emerge under the loads imposed as well as from the mid-span stretch to the defined support end, the flexural cracks emerge. ANSYS ' comparison of conceptual concrete beams for implemented load and FEA research by chahrour and soudki (2005) demonstrated reasonable agreement with conceptual beam performance.

5. CONCLUSION

Including recycled coarse aggregate lowers economic consequences and regulates pollution as waste is recycled. The proposed analysis incorporates the recycled coarse by up to 50 percent replacing the natural coarse aggregate. The SCC's workability is accomplished with recycled coarse aggregate for the concrete grade of M40. The maximum w / b ratio has been selected as 0.35 by weight as the ratio beyond or below this may result in separation and obstructing tendency in SCC mixtures. All three workability tests, nevertheless, were within EFNARC's permissible boundaries. Because of the existence of partially hydrated cement attached to the recycled aggregate, SCC mixes with RCA promotes accelerated early strength.Testing of SCC's hardened properties such as compressive and split tensile strength showed that the highest strength for SCC combination was achieved at 40% RCA replacements. The deflection and strain measurement was carried out by confining the cast beam sample to a hydraulic testing machine and contrasted to the finite element analysis.

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