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Self-Compacting Concrete with Recycled Concrete Aggregate

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Abstract

Increased demands for effective waste management technique and new technologies to tackle building-resources pulled out the researchers to concentrate the adoption of new methodologies. Structural applications used the RCA in SCC, ensuring strength and durability. In order to achieve this, RCA's effect on compressive strength for three different mixtures (30MPa, 50MPa & 70MPa) was tested with four grades of recycled cumulative replacements (0 % to 100%) with the intervals of 25%. Also included in the study is the variation of the curing period (28, 56 and 90days) to understand the role of mineral admixtures in inspecting cement content. Durability tests also conducted to explore the service life of each mix prepared by adding recycled aggregates. It was determined that recycled aggregate can be substituted up to 25 % for concrete of medium strength and 20 % for concrete of high strength not more than 10 percent lenience performance compared to concrete of natural aggregate.

Keywords: *Self compacting concrete, recycled concrete aggregates, compressive strength, service life, water sorption, durability*

I. INTRODUCTION

In the last few years, an overview of the increasing focus on sustainable building practice, the value of increasing the acceptability of recycled aggregates has increased. As stated by Padmini et al. [1], the demolition rate for buildings continues to grow, and demolition wastes have to be recycled effectively to conserve natural resources that are not renewable. There are actually disposal of a substantial part of potentially useful building and demolition wastes in sites that cause environmental problems because of their neglect of these sites, unintentional disposal and the transport of urban demolition waste [2]. These problems have been easily resolved by incorporating recycled aggregates in the place of natural aggregates. However the usage of RCA in the place of natural aggregates reduced the concrete quality due to the lower absorption levels of RCA and lower density values [3, 4] than natural aggregates [5].The concrete quality reduction is due to the overlapping of fresh and hardened mortar placed over the recycled aggregates. ITZ placed between surface aggregate and binder particle also influenced the strength properties of concrete [6].However, most work has shown that the decrease in flexibility (i.e. the elastic module) is greater than the decrease in strength [7–10] in view of the RCA[11, 12]. SCC is costlier than conventional concrete [3]. Therefore, it is essential to scrutinize alternate ways in which SCC can be more economically efficient, so that SCC can achieve its full industrial potential. The use of coarse RCA in order to replace coarse RCA with natural SCC aggregates offers the chance to reduce the costs for SCC and the carbon footprint of concrete production. As a result, RCA is used both for business purposes and for the environment in SCCs. This research elaborates the application RCA in SCC in different quantities.

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The research described here by the analysis of the fresh concrete characteristics of RCA SCCs. In recent years a number of researchers have researched this important field [3-5]. The main response of this paper is not only to examine the hardened characteristics of SCC with different RCA proportions and in particular to analyze fracture properties of SCC modified with RCA.Concrete fracture properties, in particular large-scale structures, are considered as fundamental characteristics in the architectural development and safety assessment [13, 14].As Bordelon et al. pointed out [15], evaluation of strength properties alone does not exhibit the entire performance of structural elements due to interaction behaviour between materials, current breaks and geometry structures. Bordelon et al. [15] specifiedthat the characteristics of the fracture properties briefly explains the influence of material potential in load-carryingcapacity of thestructural element.These characteristics of fractures depend on the constituents of SCC mixture[13], and the fracture energy influenced by ITZ performance and aggregate characteristics[16]. There is therefore a significant impact on concrete fracture strength when usingRCA as a substitute for the NCA [17,18].Currently,limited research data is availabletoexposethefracture energy properties of SCC modified with RCA[19].This study aims to resolve this main problem arisen in construction field by examining the energy fractures of SCCs with NCA by RCA at rates of 0% (control), 25%, 50%, 75%, and 100%. Inorder to investigatethe performance of modified SCC strength properties of SCC is to be analysed in each mix.

MATERIALS.

The binder paste made up of Ordinary Portland Cement, fly ash (FA) and silica fume (SF). Fineness and the density of the cement is tabulated in table 1. Recycled aggregate is taken from demolished buildings. Crushed granite is natural aggregate taken from nearby quarry. These natural aggregatesare partially substituted by recycled aggregate taken from demolished buildings. River sand is used as FA in this investigation.

Table 1 Cement Properties

Cement Properties	**Values**
Fineness	3521 cm^2/g
Density	3153 kg/m^3

SCC mixes are produced by adding RCA. Natural aggregates are incorporated with recycled aggregates of 0%, 25%, 50%, 75% and 100%. Table 2 tabulated density and water absorption levels of aggregates. Fine aggregates used in this investigation is river sand. Fineness modulus determined as 2.65.

Table 2: Properties of aggregates.

Type	**Size**	**Density**	**Water absorption**
Natural aggregates	10	2650	1.15
RCA	10	2450	7.75

Table 3: Mix Design

Specimen ID	Cement (kg/m^3)	FA (kg/m^3)	SF (kg/m^3)	Water (kg/m^3)	NCA (kg/m^3)	RCA	Fine Aggregate	SP
Control	445	155	30	220	660	0	815	4.5
RCA1	445	155	30	220	495	152	815	4.5
RCA2	445	155	30	220	330	305	815	4.5
RCA3	445	155	30	220	165	458	815	4.5
RCA4	445	155	30	220	0	610	815	4.5

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For the five mixes tested, the dosages of superplasticizer and w/b ratio is same. For the experimental method mentioned in this paper, the natural and recycled aggregates were submerged within 24 hours in water and left for 1 hour to contact the dry surface before the concrete mixture was made.

TESTING METHODS

Fresh State Tests.

Figure 1 shows the slump flow testing. Slump flow, L-box and segregation resistance tests were the three methods for analyzing the fresh state properties of the SCC. All three tests determine the fresh SCC's main characteristics. A slump flow test and t500 times when no obstruction occurs assessed the flowability and viscosity of an SCC [20].The L-box calculation was tested in accordance with EN 206-9:2010 for each SCC, and is based on the slump flow diameter of slump flow (Figure 1). This test is used to determine SCC's performance.

Figure 1 Slump Flow Test

The final workability test was carried out based on the guidelines given in EN 12350-11:2010.Segregation test also conducted by using 5 mm sieve dumped at an elevation of 50 cm with adding or reducing 5 cm.Fresh state tests are carried out for two times. After mixing, the first test set was performed., before second measurements the mixture is remixed. Results are presented in table 4.

Table 4 Fresh state results

Mix code	Wet Density	Slump flow		t_{500} (s)		L-Box		Sieve Segregation
		Initial	Final	Initial	Final	Initial	Final	
Control	2370	710	640	2.8	3.9	0.95	0.89	9.87
RCA1	2360	700	615	3.6	5.8	0.96	0.87	7.75
RCA2	2350	720	645	3.8	6.3	0.97	0.88	6.35
RCA3	2340	710	615	4.2	6.8	0.93	0.81	6.01
RCA4	2330	700	575	4.3	7.7	0.94	0.80	5.22

Hardened State Properties

Fracture properties are calculated by defining the mechanicalproperties. Bending tests are conducted by using the MTS machine which is a servo-controlled machine.The mid-section of each beam is cut by a penetration of 20 mm and a width of 2 mm before the beam specimens are examined. Crack displacement occured in beam specimens is measured with the help of clip guage placed at the bottom of the beam and two knife edges located at the edges of the beam. Until the samples failed, the displacement rate was regulated at an appropriate rate.

Table 5 Hardened State properties

Mix code	Compressive strength, f_c (MPa)	Tensile strength, f_t (MPa)	Young's modulus, E (GPa)
Control	59.7	4.3	31.6
RCA1	63.9	4.7	30.5
RCA2	64.9	4.2	28.9
RCA3	60.1	3.8	27.5
RCA4	53.7	3.7	23.9

RESULT AND DISCUSSION

Recycled Aggregate Water Absorption Results

The permeability of RCA, shown in Table 1, RCA is higher than natural aggregates, resulting in RCA having a major role in water absorption levels of the SCC mix. As Casuccio et al. reportedthe use of RCA concrete and concrete containing only natural aggregates is an undesirable source of variance because RCA used in the dry state easily absorbs water in a mortar process, and saturated RCA stage can rise the water absorption levels.

Fresh Concrete Test Results.

Table 4 shows and is illustrated in Figures 4–7, respectively, the test results of slump flow and L-box values, and segregation of SSC and SCC control levels with different levels of RCA use.

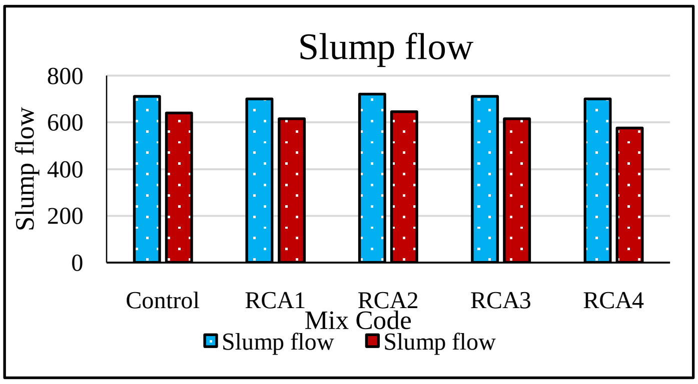

Figure 2 Slump flow results

Figure 2 shows that the initial tests results showed that up to 100 percent RCA addition does not affect the slump diameter. However, addition of RCA increased t500 time values. The flowability values are same as normal SCC at the same time viscocity values are increased with the higher proportions of RCA

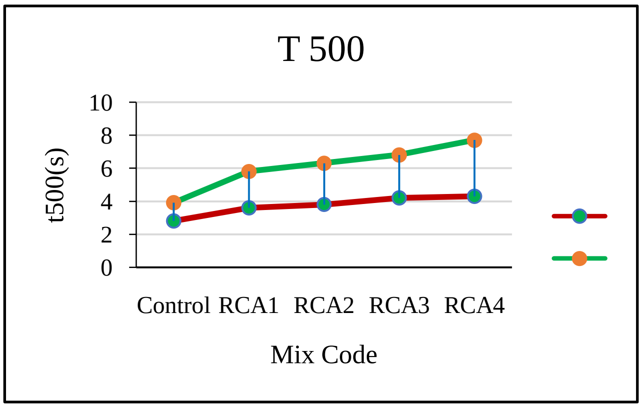

Figure 3 t_{500} Test Results

Slump flow tests are conducted after an hour of mixing. Observation on t_{500} times of modified SCC was noted and the values are increased with increase in RCA content. Compared with normal SCC, modified SCC t500 time is increased by 47% at the initial stage and it touched 93% of increment after 1 hour. The slump flow rate is also significantly lower for 100 % RCA than the SCC. Viscosity values also hiked with the addition of RCA in the place of natural aggregates. RCA shape and the water absorption levels influenced the viscosity and slum

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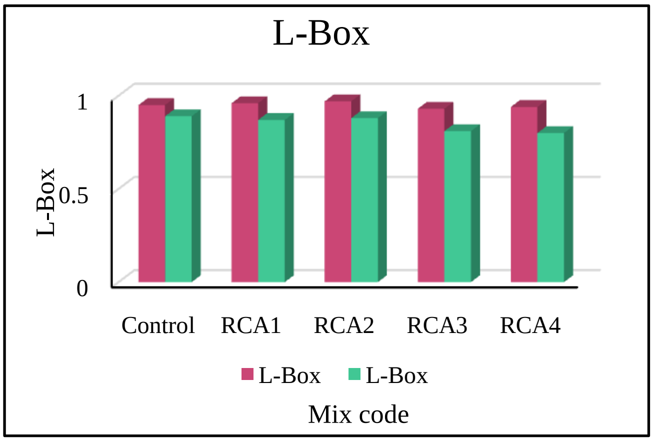

Figure 4 L-Box Test Results

p flow values. From the Table 1,it was evident that the water absorbing capacity of RCA is seven times more than that of normal conventional aggregates. This problem is resolved by soaking aggregates for 24 hours and dried for an hour.

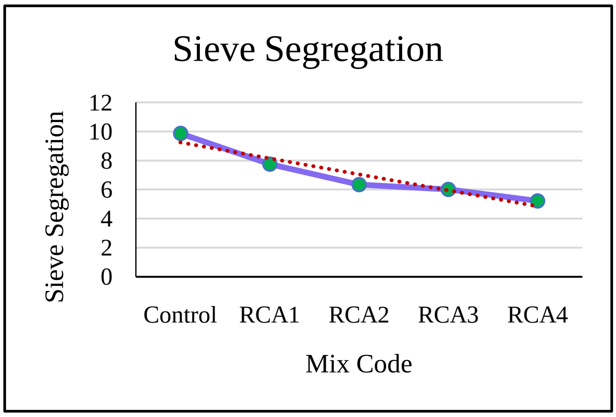

Figure 5 Sieve Segregation Results

Figure 4 shows L-box test results. Suitability and passing ability of the SCC is measured by this test.The figure shows a very low blocking ratio with only a very small decrease in the obstructions ratio at 75% and 100% RCA, replacing natural aggregates with RCA.

Examining Figure 5, it was clear that the substitution of RCA in the place of natural aggregates increased the segregation resistance values.All SCC are considered suitable in compliance with standard consistency levelsand each SCC mix comes under the SR2 (portion of 15%) category of seven segregation resistance groups.

Strength Properties Results

The effects of a control mix and of the RCA mix are compared with other mixes in Figure 8. Compared with RCA control mix RCA1 mix exhibited 107% of relative strength. Figure 8 demonstrates the RCA1 compression bar higher than 100%, with a compressive strength that is higher than the control specimen. Considering the compressive strength resulting from Figure 6, conventional aggregates are replaced by recycled concrete at 25%. the compressive values raised respectively by 50% and by 7% and 10%.

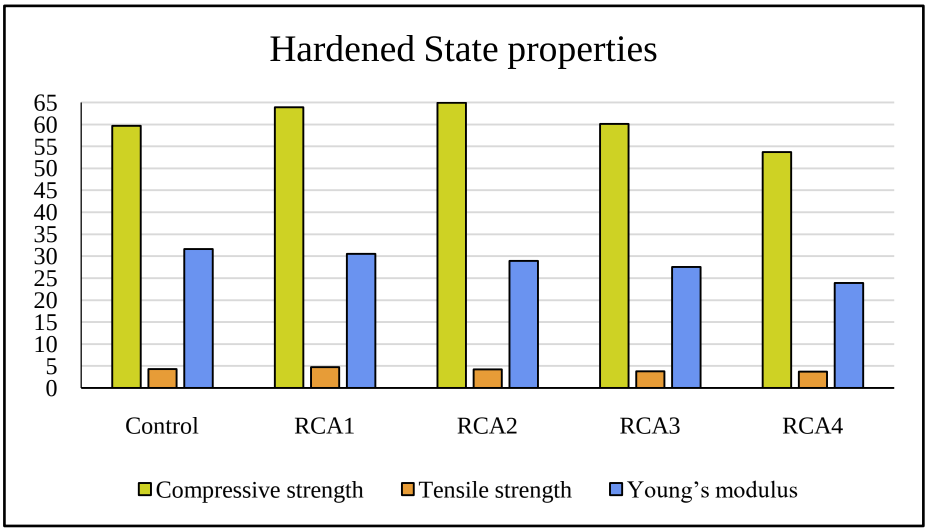

Figure 6 Hardened state Results

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The compressive strength at replacement rates of 75% was almost exactly the same as that of the control specimen, whereas the recycled aggregate replacement rate increased by 100% resulted 10% reduction in compressive strength..Similar findings were obtained for a concrete with a ratio of 0.43 w / b when contrasting SCC concrete with 20%, 40% and 60% RCA [3].The tensile strength results show similar pattern to the strength results shown in Figure 6. At the initial stages of RCA substitution tensile strength values are increased and further increase in RCA in SCC results reduction in tensile strength values. RCA 1 specimens exhibited 20% greater tensile strength than control specimen.Same tests

conductedfortheSCCmixhaving50%RCAand100 % RCA.The outcomes of the investigate on proved that the reduction intensilestrengthis2.5% for 50% aggregate replacement and14% reduction for100% replacement of RCA.

CONCLUSION

The research discussed in this workfigure out on the current SCC works by exploring the effect on fresh, strength characteristics, and most notably fracture properties of integrating different levels of RCA. The workability tests revealed that with increasing RCA material, the viscosity of the SCCs increased, as did sieve resistance to segregation. The SCC's passing capacity was found to be significantly reduced by more than 50 % for RCA use; Nevertheless, within reasonable capacity limits the 75% RCA and 100% RCA SCCs remained. The use of rough RCA at ratios of 25 to 75 % did no significantly influence the performance of the SCC by exterior analyzes of strength characteristics of SCCs such as compressive strength, tensile strength and elastic modulus. Nevertheless, in comparison with thecontrol SCC, the Elasticity factor for 100% RCA SCC was reduced, which indicates a potential problem with SCC fragility.

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