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Durability Properties of Modified Self Compacting Concrete with Recycled Concrete Aggregate

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Abstract: In recent years, sustainable construction materials are highly recommended in construction projects due to reduce the degradation of natural resources. An experimental investigation with varying percentages of coarse recycled concrete aggregate was conducted on self-compacting concrete. The primary goal was to explore the suitability and impact of coarse recycled aggregate in concrete fresh generation. The demand for building products has risen tremendously in latest years, so the quantity of building and demolition waste has increased, placing enormous stress to the atmosphere. The use of recycled aggregate in concrete is a suitable solution to extend the lifetime of natural resources and thereby lead to sustainable developments in construction field. In this investigation, SCC is modified by recycled coarse aggregate (RCA) in various percentages of natural coarse aggregate (NCA) substitutes from 0 percent to 100 percent with a 20 percent increase. Durability and the mechanical properties of modified SCC was determined. From the results it is revealed that the substitution of RCA in the place of NCA significantly improved the durability properties.

Keywords: Recycled concrete aggregate, strength properties, durability properties, acid attack, permeability

I. INTRODUCTION

In construction sector, sustainable materials gaining more attention due to the exploitation of natural resources. By decreasing the consumption of non-renewable natural resources, sustainability protects the environment. Concrete the world's second most utilized material after water and it uses a considerable quantity of non-renewable resources As a consequence, number of scientists studied the use of recycled materials in concrete manufacturing such as fly ash [1], [2] and recycled aggregate[3], [4]. Due to important population growth and urbanization, large quantities of building and demolition waste are produced in latest times. Most developed/developing nations, therefore, face the issue of building and demolition waste management. Considering this aspect, reusing of building waste products and by-products in building operations has been increasingly emphasized. The use of waste products not only benefits to make them used, but also has countless advantages such as energy savings and environmental protection.

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Large amounts of experimental work have been carried out over the last few decades to explore the material characteristics [5], [6], [7] , [8], [9] and durability of recycled aggregate concrete (RAC) [10], [11]. Compared with NAC the RAC exhibited greater porosity, lower density, lower strength properties [12], As a result, the structural components constructed using recycled aggregate concrete exhibited lower physical and mechanical properties compared to the normal aggregate concrete [13]. Concrete specimens made with 100% recycled aggregates significantly reduced the compressive strength by 9 to 40%. [14]. Normally recycled aggregates have lower modulus elasticity in such a way that the concrete made with recycled aggregate exhibited lower modulus of elasticity this is due to the weaker transition zone between old mortar and fresh mortar [15]. Even though RCA has number of inferior properties, many researchers suggested recycled aggregate is the best alternative for the construction of SCC. This type of SCC provided number of environmental and economic benefits. This paper investigated the durability properties of SCC modified with recycled aggregate.

II. RESEARCH SIGNIFICANCE

Due to environmental and economic factors, the use of recycled aggregates in fresh concrete manufacturing has gradually increased. However, there is still limited investigations on the recycled aggregate in modified SCC. This research tries to observe the impact of recycled aggregate on self-compacting concrete's strength, permeability, acid attack, chloride penetration, and alkalinity. This study aims at providing very helpful information in advance for the practical use of recycled aggregates.

III. SIGNIFICANCE OF DURABILITY STUDIES

When developing a concrete mix or concrete structure, it is necessary to evaluate the exposure situation in which the concrete should stand. Especially in urban regions and industrial atmospheres, environmental pollution is growing day by day. It is recorded that over 40% of the total funds of the construction sectors are spent on repairs and maintenance in industrialized nations. The durability factors of SCC structures therefore assume much more significance.

IV. MATERIALS AND MIXTURE DESIGN

In all compositions an ordinary Portland cement (Grade 53) accordance with IS12269:1987 was used. The specific gravity value of cement is 2.68 and the compressive strength value at 28 days period is 380 m^2/kg.

The powder content of SCC used in this investigation is silica fume, attained from Elkem Company and the specific gravity is 2.3. Locally available river sand is used as fine aggregate and the coarse aggregate is taken from nearby quarry. The RCA was taken from demolished buildings and immersed in water for 24 hours, dried properly before use, to compensate higher water absorption levels of recycled aggregate. The assembly was tested in accordance with IS 383-1970. Table 1 reports the outcomes of different aggregate physical characteristics. The superplasticizer used was a polycarboxylic-ether-based polymer admixture, was utilized. In this investigation

Table 1 Physical properties of NCA and RCA

Characteristics	RCA	NCA
Specific Gravity	2.14	2.68
Water Absorption	5.32	1.25
Bulk Density	1234	1632
Impact Value	9.57	18.25
Fineness Modulus	5.85	6.5

V. TEST RESULTS

Fresh state Properties

In the absence of obstructions, the flowability and flow rate of SCC was evaluated using the tests such as slump-flow and T500 time. The result is an evidence of SCC's filling capacity. The primary test considered for SCC is Slump flow test and this test specification meets the consistency of fresh concrete. Flow rate and the viscosity of SCC was measured using T500 time. In slump cone test the fresh concrete is placed into the cone. When the cone is removed upward, the time taken from starting upward measure of the cone to measuring the concrete flow to a diameter of 500 mm; this is the time of T500. The time of the T500 is recorded as close as 3 sec. The biggest diameter of the concrete flow spread and the spread diameter are then measured at the correct angles to it and the slump-flow is the mean. L-box, J-ring and V-funnel tests are conducted in SCC trial mixes. These testes are required for accessing passing ability of the SCC mix. Viscosity and filling ability of SCC was determined by conducting V-funnel test on SCC mixtures modified with recycled concrete aggregate. V-Funnel test was conducted using V-shaped funnel and time taken to flow the fresh concrete fully through the funnel is noted and tabulated in Table2.

Table 2 Typical range of fresh state properties of SCC

Method	Range	
	Minimum	Maximum
Slump flow (mm)	620	720
T500 (sec)	2	4
V-Funnel (sec)	8	11
L-box (sec)	0.8	1.0

Table 3 Fresh state Properties

MIX ID	Fresh state test				
	Slump flow		J-ring (mm)	L-Box (mm)	V-Funnel (Sec)
	D (mm)	T_{500} (Sec)			
NSCC	720	2	7.3	1.0	8.31
RC1	678	2.19	7.7	0.97	8.92
RC2	653	2.94	7.9	0.95	9.22
RC3	648	3.25	8.1	0.87	9.47
RC4	637	3.65	8.9	0.85	10.22
RC5	620	3.92	9.7	0.82	10.89

Viscosity and filling ability is measured using V-funnel apparatus. It is expressed as tv and reported to the nearest 11 sec.The test results are tabulated in table 3

Table 4 Hardened state Properties

Mix Type	Hardened state test								
	Compressive strength (N/mm²)			Flexural strength (N/mm²)			Split tensile strength (N/mm²)		
	7day	14 days	28 days	7day	14 days	28 days	7day	14 days	28 days
NSCC	18.41	24.78	37.54	2.52	3.32	3.58	1.99	2.68	2.98
RC-1	17.72	21.18	34.42	2.38	2.75	3.27	1.82	2.45	2.87
RC-2	14.68	18.98	28.15	2.31	2.58	3.15	1.78	2.33	2.75
RC-3	11.58	17.94	27.12	2.15	2.55	2.88	1.65	2.27	2.68
RC-4	11.10	17.50	25.36	2.02	2.32	2.56	1.47	2.14	2.52
RC-5	10.15	17.15	24.02	1.98	2.07	2.38	1.39	2.07	2.33

I. Hardened State Properties of SCC

SCC specimens are produced using cube moulds and cylinder moulds for determine the compressive, split tensile and flexural strength values. The specimens are cured for 28 days and subjected to compression testing machine the load was gradually applied over the specimens and the readings are tabulated in table 4. Hardened state tests are conducted in accordance with IS 516 (1959). Compressive strength results are illustrated in figure 1.and the flexural strength values are exhibited in figure 2. Split tensile strength values are presented in figure 3.

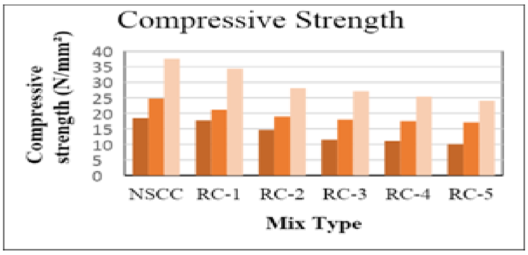

Figure 1 Compressive strength test Results

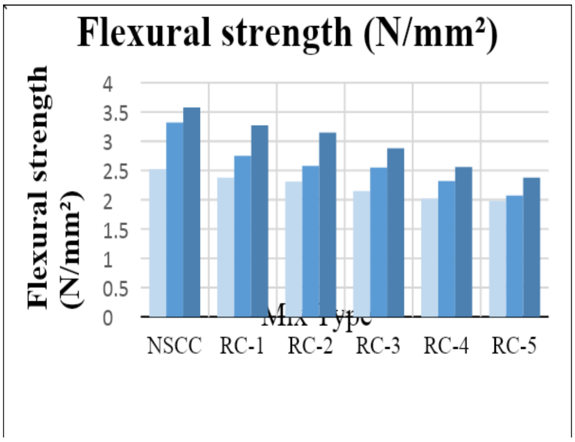

Figure 2 Flexural Strength of Specimens

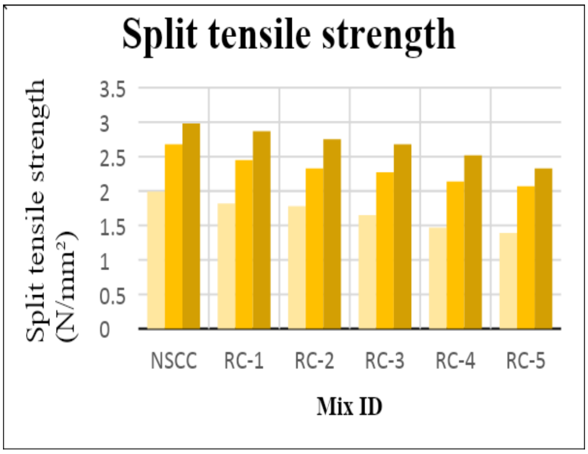

Figure 3 Split Tensile strength of Specimens

From the figures it is evident that the addition of recycled concrete waste aggregate significantly reduced the mechanical properties.

VI. DURABILITY PROPERTIES OF SCC

Durability of SCC is defined as the ability to withstand in strongest weathering conditions, abrasion, chemical attacks and deterioration and hence it retain its original dimension, shape, quality and service life during its estimated service life. The concrete structures durability properties are strongly associated with permeability of the concrete surface and the ingress of substances such as chloride, sulphate, water, oxygen, acids and alkalis which initiated the deleterious actions. Several tests are conducted to evaluate the durability characteristics under aggressive environments. Preamble voids, water absorption, acid attack, chloride attack and alkalinity were investigated.

A. Preamble Voids and Water absorption

In this investigation, ratio of preamble voids and percentage of water absorption determined by following the guide lines given in ASTM 642-82. 100 mm cube moulds are used to produce cube specimens with 30%, 40% and 50% of RCA contained SCC. These specimens are dried and kept in a hot air oven at 1050°C and this setup was kept until a constant weight was attained. Preamble voids are calculated using the following formula.

Permeable Voids = [(W1 – W2) / V] x 100

B. Acid attack

Acid attack of the SCC specimens were investigated by immersing SCC specimens in 5% sulphuric acid solution. The solution pH value was properly kept constant throughout the time period of the test. The specimens are taken after 28 days of curing from the acidic solution. The loss in their weights and the compressive strength values are measure after 28 days and 90 days.

C. Chloride Ingress

The most important aspect of durability study is chloride attack. Chloride attack is primarily considered because which estimated the corrosion in reinforcement. The test specimens are immersed in 5% NaCl solution. After 28 days and 90days the fractured specimens are spurted with 0.1 N silver nitrate aqueous solution and this method was used to accurately mention the chloride penetration depth using white precipitation.

VII. DURABILITY TEST RESULTS

A. Water Absorption Test Results

Water absorption is strongly associated with the permeability of concrete. Test results indicated that the level of water absorption in modified SCC have linear relation with to amount of RCA replaced in SCC. When the amount of recycled aggregate rises then the water absorption level also gets increased this is due to the higher initial water absorption levels of recycled coarse aggregate. The percentage rise in water absorption level of RCA is recorded as 4.44%, 11.71%, 13.08 %, 22.85% and 27.92% respectively. Water absorption levels are tabulated in Table 5.

Table 5 Water absorption levels of modified SCC

Specimen	Water absorption level (%)
NSCC	5.12
RC-1	5.35
RC-2	5.72
RC-3	5.79
RC-4	6.02
RC-5	6.55

B. Resistance to Acid Attack

The dried specimens are immersed in sulphuric acid solution and the weight loss percentage is calculated. The results indicated that the loss in weight of SCC mixes increases with increase in RCA content. The highest amount of weight loss was observed in RC-5 specimens and their weight loss percentage is 2.45. The loss in compressive strength also increased with increase in RCA content in SCC mix. The acceptable level of acid attack is observed below 20% of replacement level. Further increase in RCA content leads

Table 6 Acid attack Results

Mix Type	30 days		90 days	
	Weight loss (%)	**Loss in Compressive strength (%)**	**Weight loss (%)**	**Loss in Compressive strength (%)**
NSCC	0.89	2.15	1.57	7.59
RC-1	0.95	2.54	2.92	8.23
RC-2	1.25	2.78	3.15	9.68
RC-3	1.57	3.17	3.98	12.46
RC-4	1.89	3.59	4.05	16.55
RC-5	2.45	4.79	4.79	20.65

to severe reduction in compressive strength which changes the cement as alkaline. This alkaline state of cement is not resistant to attack by strong acids. From the figure 4 it is evident that the substitution of RCA in the place of NCA reduced the weight of SCC specimens.

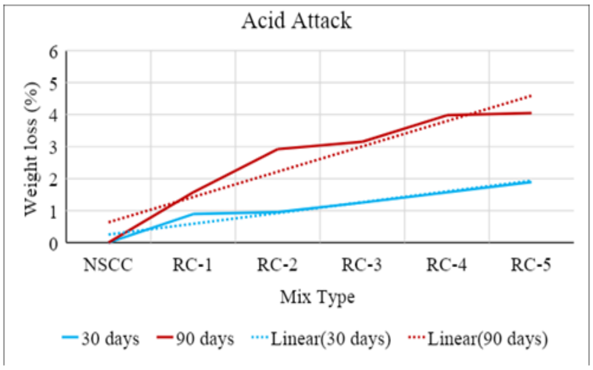

Figure 4 Loss in Weight (%)

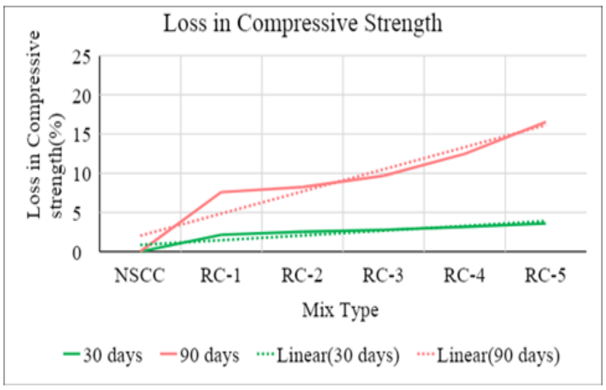

Figure 5 Loss in Compressive strength

Compressive strength values are reduced with increase in RCA content. From the figure 5 the reduction of compressive strength is illustrated.

C. Chloride Ingress

Chloride penetration depths of concrete is calculated by immersing the SCC specimens in 5% NaCl solution for the period of 30 and 90 days. From the results tabulated in table 7 it is evident that the percentage of RCA increase in SCC mix resulted increased chloride penetration depths. The maximum chloride penetration depth was observed as 28.95 mm for RC-4 mix at 90 days duration.

Table 7 Chloride Penetration Results

Mix Type	Chloride Penetration Depth (mm)	
	30 days	90 days
NSCC	6.25	11.23
RC-1	10.15	17.54
RC-2	14.33	19.65
RC-3	15.25	26.26
RC-4	19.25	27.32
RC-5	20.51	28.25

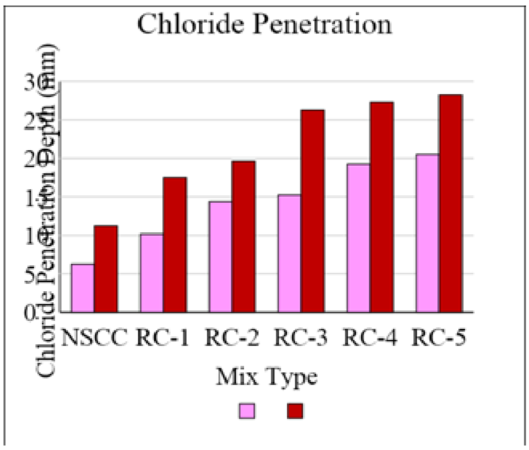

Figure 6 Chloride Penetration Depth

Chloride penetration results are shown in figure 6. From the outcomes it was understood that the presence of RCA in SCC suggestively increased the chloride penetration depth.

VIII. CONCLUSION

In construction industry, sustainable development is the main concern. Using RCA in the place of NCA is considered as sustainable method in building constructions. SCC modified with RCA have attained the required strength in all mixes. The strength properties such as compressive, split tensile and flexural values has inverse relationship with amount of RCA in SCC.

This is due to the weaker interfacial zone in between adhered mortar and recycled aggregate. It was concluded that the mixes contain recycled
aggregate exhibited better strength properties at the early stages of SCC mixture.
The mixes with high amount of RCA have exhibited high initial water absorption level which increased the permeability values of SCC mix.
SCC mixes contains 40% of RCA exhibited better resistance to chloride penetration and acid attack.

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