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 concrete fresh generation. The demand for building products has risen tremendously in latest years, so that 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. 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 m2/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 tests 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 Table 2.

Table 2 Typical range of fresh state properties of SCC

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

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 3 Fresh state Properties

| MIX ID | Slump flow | J-ring | L-Box | V-Funnel |
|--------|------------|--------|-------|----------|
|        | D (mm)     | T500 (Sec) | (mm) | (Sec)    |
| NSCC   | 720        | 2       | 7.3   | 1.0      |
| RC1    | 678        | 2.19    | 7.7   | 0.97     |
| RC2    | 653        | 2.94    | 7.9   | 0.95     |
| RC3    | 648        | 3.25    | 8.1   | 0.87     |
| RC4    | 637        | 3.65    | 8.9   | 0.85     |
| RC5    | 620        | 3.92    | 9.7   | 0.82     |

1. 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.
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 90 days 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.

| 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
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.

Table 6 Acid attack Results

| Mix Type | 30 days | 90 days |
|----------|---------|---------|
|          | Weight loss (%) | Loss Compressive strength (%) | Weight loss (%) | Loss 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  |

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.
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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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