Mechanical Performance and Acid Resistance of Self Compacting Concrete with Fly Ash and Rice Husk Ash as Cementitious Materials

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ABSTRACT. Self-compacting concrete (SCC) is an extremely flowable, non-segregating concrete that fills every corner of formwork evenly and completely by its own mass and encapsulates reinforcement without vibrating, all while retaining homogeneity. SSC’s mechanical efficiency can be enhanced by using byproducts or waste materials as cement replacements. Rice husk ash (RHA) & fly ash stay very reactive byproducts. Because of its high silica content, Fly ash and RHA have strong pozzolanic properties, used as complementary cementations material in SCC. The automatic properties and Self-compacting concrete has a high acid resistance determined. Mainly the cement is replace by fly ash & rice husk ash with three different percentages variations (10%, 20%, and 30%). In each percentage of replacement, the fly ash and RHA has equal percentages. For example, in 10% of replacement 5% of fly ash and 5% of RHA is replaced. In frequently fly ash is industrial by-product and having the pozzolanic properties. And the RHA (rice husk ash) is also a pozzolanic reactive material. Compared to the adhesive, fly ash & RHA has more silica ingredient. The self-compacting concrete was calculated for M30, and specimens are cast. Compressive strength and split tensile strength, flexural strength, and durability (acid resistance) tests are performed for 7 days, 14 days, and 28 days.

Keywords: Self Compacting Concrete (SCC); Fly Ash; Rice Husk Ash (RHA); Mechanical Properties; Acid Resistance.

1. INTRODUCTION

Construction Industry of 21°C fronting plenty of criticism as of the Conservationists throughout the Globe to the diminution of natural resources and contamination which is causing the Environmental Impact. According to the research conducted by Construction blog BIM how, the construction sector contributes to 23% of Air pollution, 50% of the Climate change, 40% of Drinking water pollution, and 50% of Landfill wastes. Construction Industry alone accounts for 25% to 40% of world’s total carbon emissions [1]. So, to reduce the carbon footprint of Construction Industry, we are trying to implement the utilize Fly Ash & Rice Husk as a replacement for the binder in the mix of Self Compacting Concrete [2]. As per EFNARC, May 2005, Guidelines for SCC defines it as “Concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction”.

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The extreme size for coarse aggregate was 20 mm, but in case of a structure with dense reinforcement, the aggregate dimension container be as small as 10 to 12 mm. For the superlative product, make use of well-graded round or cubical aggregates [3]. Fine aggregates may be natural or produced with a consistent grade, with dimension of under 0.125 mm in most cases. Self-compacting concrete is resistant to segregation, as a result of using mineral fillers and unique admixtures [4]. As discussed earlier, this type of concrete must have high fluidity and be able to fill special forms due to its own weight with no mechanical vibration. It must also be flexible sufficient to move through dense reinforcement while avoiding any segregation [5]. Owing to the lack of friction, concrete that self-compact in a similar manner water-cement ratio as conventional vibrated concrete would have a slightly higher strength. The boundary among the aggregate and the hard-bitten paste is strengthened as a result [6]. It is worth noting that self-compacting concrete could be placed more quickly than standard concrete.

Rice Husk Ash (RHA) contain reactive alumina - silicate content is generated by properly burning rice husk resultant after rice mills at temperatures less than 700°C. RHA has silica gratified of about 90%, making it suitable to use as pozzolan in SCC to strengthen the microstructure of the cement's interfacial transition zone (ITZ)slurry and aggregate [7]. The usage of RHA in concrete decreases the CO2 emission in environment. And the RHA acts like supplementary cementitious material. As it possesses high SiO2 content, RHA was used as a concrete when RHA was admixture properly burnt. It also has a high pozzolanic contented and contribute to concrete’s high strength and impermeability [8]. The mix cannister increase 15% increase in power up to 15% by increasing in the amount of substitute of RHA by15%. By performing this replacement, we can experience Compressive Strength & Split Tensile Strength both increased.

Fly ash was recognized as ‘Pulverized Fuel Ash’ was by-product of thermal power plants. It is pozzolanic material of fine particles. Usage of Fly Ash is rising not only to reduce the carbon footprint but similarly profits the drop in rate of raw materials [9]. The fly ash is initially used in large extent in the construction of the Hungry Horse Dam in U.S. They used Fly Ash nearly 30% by heaviness of cement. If 30% Fly Ash replacement of PPC had resulted the highest Compressive Strength of 100Mpa, Splitting Tensile Strength & Elastic Modulus. It also reduced the chloride permeation, with 30% replacement resulting the greatest resistance to chloride penetration [10]. As a result, the finest Fly Ash percentage was 30%. Later Fly Ash was used in canyon and ferry dams. In India it be used in Rihand Dam construction replacing cement to 15%. Fly Ash has become a common substitute for cement in concrete, for getting great presentation and great strength concrete. The usage of fly ash not only varies the possession of concrete other than also helps in controlling pollution of environment [11]. The ASTM categorize fly ash as two classes, individuals are class C, and class F. The class F has only pozzolanic properties, class C has mutually pozzolanic & cementitious properties. Class C: It normally produced by burning lignite or sub-bituminous coal. It has CaO content more than 10%. Class F: this type is produced by burning anthracite or bituminous coal. It has>5%CaO.

The main intention of the study was to determine mechanical properties of SCC through Fly Ash & RHA & Acid Resistance. The designed row portion of the concrete mix is compared with the standard concrete mix. The fly ash and RHA is taking as equal weight of percentage to the cement (10%,20%, and 30%).
2. MATERIALS PROPERTIES AND MIX PROPORTIONS

2.1 Materials and Properties

2.1.1 Cement

Ordinary Portland cement Grade 53 (OPC Grade 53) was adapted from IS: 12269–2013 & applied to the Chemical constituents of ordinary Portland cement in this article, as shown in Table 1.

2.1.2 Fine Aggregate

Fine aggregate is acts as the filler material in concrete. The sand is used which is locally available from river Krishna. And it can be cast-off in concrete which is passing concluded the 4.36mm sieve.

2.1.3 Coarse Aggregate

The coarse aggregate is used which is angular and 20mm in size.

2.1.4 Fly Ash

This is fine granular material, which was taken as three different percentages of 5%, 10%, 15%. Physical & chemical properties of fly ash was shown in Table 1.

Figure 1. Fly Ash

2.1.5 Rice Husk Ash

Figure 2. Rice Husk Ash
RHA having high silica content in it. This material was occupied in three different volume fractions (5%, 10%, 15%) with replacement of cement. The properties of RHA was shown in Table 1.

2.1.6 Water

The water is added to concrete when alkali free and pure water.

2.1.7 Super Plasticizer

The water reduction agent of HIBOND with base of polycarboxylate ether chemical added to water as 1.3% and it is named as HI-FORZA705.

Table 1. Chemical Composition of OPC, RHA and Fly Ash.

| Composition (%) | OPC  | RHA | Fly Ash |
|-----------------|------|-----|---------|
| SiO₂            | 21.24| 94.0| 62.5    |
| Al₂O₃           | 5.98 | 1.2 | 26.2    |
| Fe₂O₃           | 4.10 | 0.37| 4.2     |
| MgO             | 0.96 | 0.60| 0.8     |
| CAO             | 60.78| 2.93| 1.7     |
| Na₂O            | 0.86 | -   | 0.12    |
| K₂O             | 2.20 | 0.50| 1.14    |
| SO₃             | 3.98 | 0.30| 0.2     |

3. MIX PROPORTIONS AND MIX DESIGN

3.1 Mix Proportions

This study the self-compacted concrete (SCC) is designed and taking the partial replacements in cement with fly ash & RHA with different percentages are taken. The fly ash and RHA replacement percentages was shown in the mix design. The mixed of mix proportions is shown in below table 3. And before going to design mix proportions the material properties tests were performed; those results was shown in Table 2.
### Table 2. Material Properties

| Material     | Specific Gravity | Water Absorption (%) |
|--------------|------------------|-----------------------|
| Cement       | 2.53             | -                     |
| Fly Ash      | 1.7              | -                     |
| RHA          | 1.77             | -                     |
| Fine Aggregate | 2.5          | 3.6                   |
| Coarse Aggregate | 2.78      | 0.46                  |

### Table 3. Details of Mix Proportion

| Mix ID | Mix Details               |
|--------|---------------------------|
| Mix0   | SCC                       |
| Mix1   | 5%flyash+5%RHA            |
| Mix2   | 10%flyash+10%RHA          |
| Mix3   | 15%flyash+15%RHA          |

3.2 Mix Design

The mix design of Normal SCC and three replacements of fly ash & RHA in SCC are shown in Table 4.

### Table 4. Details of Mix Design

| Material               | Normal SCC | Mix1     | Mix2     | Mix3     |
|------------------------|------------|----------|----------|----------|
| Water                  | 186.00     | 186.00   | 186.00   | 186.00   |
| Cement                 | 395.74     | 391.79   | 348.26   | 304.72   |
| Fly ash                | 0          | 33.49    | 66.97    | 100.46   |
| RHA                    | 0          | 33.49    | 66.97    | 100.46   |
| Fine Aggregate         | 877.23     | 880.37   | 880.37   | 880.37   |
| Fine Aggregate (0.125mm)| 124.26     | 84.68    | 84.68    | 84.68    |
| Coarse Aggregate       | 940.16     | 943.52   | 943.52   | 943.52   |

**Note:** All the material quantities are shown in kg/m³.
4. EXPERIMENTAL INVESTIGATION

4.1 Fresh Properties

In slump slow test, the slump flow is measured and compared for SCC and self-compact concrete with RHA and fly ash. For normal SCC mix, mix 1(5%fly ash+5%RHA), mix 2(10%fly ash+10%RHA), mix 3(15%fly ash+15%RHA) of measured values was shown in table 5. This test is done from code ISO 1920-13:2018. The v-funnel test is similarly a workability test. In this test determine the ability of self-compact concrete and can find resistance of segregation. Firstly, the SCC is filled in V-funnel and allowed to sit for 5-minutes. And the allowable range is 0 to 10mm. This test was taken done code ISO 1920-13:2018. The L-box test is also one of workability test to SCC. In this test the concrete was discharge to L-Box upper section and then open the gate after 1min, and when the flow is stopped measure the H1 & H2 values. This test was taken from code ISO 1920-13:2018.

Four different mixes were used in the trials, as shown in Table 1. Table 5 summarizes the results for new properties. The flowability of all the mixes was excellent. Importantly, all the mixes met the minimum requirement criteria. The addition of fly ash and RHA had a minor impact on the workability. The addition of fly ash and RH resulted in a slight increase in water demand. The super plasticizer dosage was consistent across all RHA and fly ash mixes. This might be due to the small size of the fly ash and RHA particles that replace the cement, resulting in higher surface areas. Furthermore, the round shape and fine size of RHA particles reasons a growth in water demand. Many researchers have previously reported an increase in water demand as a result for the use of fly ash & RHA Slump flow and other fresh properties for concrete decreased with increasing percentages of fly ash & RHA, affording to Memon et al., Chopra et al., and Kannan and Ganesan. This was attributed to the improved surface zone provided by fly ash & RHA particles. According to them, an increase in fly ash and RHA content increases flowability and V-funnel flow times.

| Mix Proportion          | Slump Flow(mm) | V-Funnel(sec) | L-Box Range |
|-------------------------|----------------|--------------|-------------|
|                         | Range(650-800) | Range(6-12s) | (0.8-1)     |
| Normal Mix (SCC)        | 680            | 10           | 0.97        |
| 5%fly ash+5%RHA         | 700            | 9.5          | 0.92        |
| 10%fly ash+10%RHA       | 720            | 9.2          | 0.9         |
| 15%fly ash+15%RHA       | 730            | 9            | 0.85        |
4.2 Hardened Properties

4.2.1 Compressive Strength:

The compressive strength test was one of the hardened properties test to the concrete. For this test concrete cube specimens are used having a dimension of 150x150x150 mm³. The cube specimens remained cast for each four mix proportions, for separately mix proportion 3 cubes casted each curing period. The specimens was cured for 7 days, 14 days, 28 days and after completing the curing period the test are conducted & the result values are noted and shown in below table 8. This test was taken from code IS: 516-1959. The load shall be applied gradually at a rate of 140 kg/cm² per minute until failure occurs Fig- 3. The load obtained as a result of failure is separated by the area of the specimen, yielding the precise compressive strength of concrete.

![Figure 3. Photograph of Compressive Strength Test](image_url)

The difference for compressive strength outcomes between different replacement percentages of RHA and fly ash was observed in Fig- 4. Extreme compressive strength existed realized for 20% RHA and fly ash. According to results, it is observed that compressive strength increases with increases in percentage of the RHA and fly ash ahead to 20% replacement after which compressive strength starts to decrease. Increase in compressive strength seen in this work is mostly attributable to RHA's micro filing volume & pozzolanic activity. RHA was too very reactive, reacting by calcium hydroxide (byproduct of cement hydration) to form more C-S-H.
4.2.2 Split Tensile Strength:

The split tensile test is for obtain the tensile strength of concrete. It was an indirect method to know the tensile strength. Split tensile test the cylindrical specimens are used having of 150x 300 mm² are casted for 7days, 14days, and 28days curing period for all mix proportions. And after completing curing period the test is performed. The result values was shown in the table 9. In this test, the load shall be applied gradually at a rate of 140kg/cm² per minute until failure occurs.

Splitting strength exhibited a consistent pattern to compressive strength results. A tall curing ages, the 20% replacement for fly ash & RHA mix attain highest strength. A tall curing ages, the 20% replacement of RHA & fly ash mix attain highest strength. Fig- 6 indicates the split tensile strength improves as proportion of RHA, and fly ash replacement rises to 20%, and that strength improves as the curing age rises. There was decrease in strength for replacement more than 20%, and the values were even lower than control mix at all ages.
Figure 5. Photograph of Split Tensile Strength Test

Figure 6. Bar Chart for the Results to Split Tensile Strength Results
4.2.3 Bending Strength

The bending/flexure test were conducted for concrete beam specimens without reinforcement with a dimension of 100x100x500 mm$^3$. Specimens are casted for designed four mix proportions and cured for 7 days, 14 days and 28 days. And then completing the curing time test is performed. The result are shown in under table 10. This test is taken from code IS 516-1959. In this test, the load should be applied gradually at a rate of 7 kg/cm$^2$ per minute until failure occurs.

![Figure 7. Photograph of Bending Strength Test](image)

Fig- 8 shows the results of bending strength test of concrete specimens that have been water cured for 7, 28, and 90 days. When compare to the normal mixture, 10% & 20% replacement of RHA and fly ash modified cement concrete mixes showed considerable strength improvements compared to control mix. The improvement in the flexural strength resulted from the replacement with RHA & fly ash was completely attributable for addition C-S-H formed by the reaction between the CH & RHA. It seems that adding various amounts of fly ash and RHA has densified the microstructure and better for attaching intensity to the blended cement concretes and led to flexural strength increase.
4.3 Durability

4.3.1 Acid Resistance Test.

Acid resistance is one of the durability tests to know the functioning of concrete when the concrete is under chemical attack (sulphuric acid). The test is performed for 150x150x150mm³ concrete specimens later treating period for 28 days. The cube specimens are cast for regular mix, 5% and 10% mix percentages. The concrete cube samples were measured and submerged to 28 days in water diluted by 10% sulphuric acid by volume. After that, the specimens were separated to the acid water and the cubes' surfaces were washed. The samples' mass and compressive strength stood then determined, and the avg percentage of mass loss & compressive strength were estimated.
After acid resistance test, the percentage weight reduction 20% have high weight reduction occurred and the compressive strength reduction 6.30% has for the 20% mix proportion is shown in figure 10.

![Acid Resistance Test](image)

**Figure 10. Bar Chart for Results of Acid Resistance Test**

### 5. Conclusion

The investigational study was done for the self-compacting concrete & various mix proportions with various replacements of fly ash and RHA are compare with normal self-compacting concrete. After performing the tests and resulting, the following conclusions are made.

1. The adding of fly ash and RHA to mix proportions indicates the improve performance when compared to the normal self-compacting concrete.
2. The 20% mix proportion (10% fly ash+10% RHA) gives the best compressive strength performance when compared to the plain mix proportion specimens.
3. For split tensile strength test also the 20% mix proportion (10% fly ash+10% RHA) is shows the better performance compared to the other mix proportions.
4. In bending test performance, the mix proportions of three mixes show the equal performances.
5. After acid resistance test, the percentage weight reduction 20% have high weight reduction occurred and the compressive strength reduction 6.30% has for the 20% mix proportion.
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