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MECHANICAL AND DURABILITY PROPERTIES OF SELF COMPACTING CONCRETE USING RICE HUSK ASH AND MARBLE POWDER

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ABSTRACT

Self Compacting Concrete (SCC) is the new category of High Performance Concrete (HPC) characterized by its ability to spread and self consolidate in the form work exhibiting any significant separation of constituents. In this study, the benefits of Fly Ash (FA) & Marble stone powder (MP) and Rice husk ash (RHA) as partial replacement of Portland cement are established. Furthermore, MP and FA are used directly without attempting any additional processing in the production of Self Compacting Concrete (SCC). The water binder ratio is maintained between 0.3 and 0.35 depending upon the mix. The fresh and hardened properties were examined. Workability of the fresh concrete is determined by using the slump-flow test, L-box test, U-box test and V-funnel test. For all mix the constant replacement of fly ash is 25% by weight of cement. The remaining 15% is replaced by RHA and MP with different proportions. The Hardened Properties like compressive strength, splitting tensile strength, Flexural strength were evaluated at 7, 14 and 28 days. In addition to that the durability properties were examined by saturated water absorption and acid resistance test.

Based on the above tests result equal percentage replacement of RHA and MP produce comparatively better results.

Key words: Self Compacting Concrete (SCC), Marble stone Powder (MP), Fly Ash (FA), Rice Husk Ash (RHA), Fresh Concrete Properties, Hardened Concrete Properties.

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1. INTRODUCTION

The construction of concrete structures needs thorough placement and proper consolidation of fresh concrete to obtain good hardened properties and durability. However, the appropriate placement and consolidation were not always achievable with ordinary concretes, even though placed by skilled laborers. To resolve these problems, the concept of self-compacting concrete (SSC) first emerged in 1986.

However, the first prototype of SCC was developed in Japan in 1988. Later Japan tailored and optimized the technology of SCC, and used it commercially in large construction of buildings and infrastructure. The use of SCC in civil engineering structures has spread to other countries during the last two decades. SSC is a highly flowable concrete that spreads through packed reinforcing bars, fills all corners of the formwork, and achieves the compacted condition under self-weight. It differs from ordinary concrete with respect to its performance in fresh and hardened states that are mainly driven by exceptional material components and mixture proportions.

The use of SCC concrete has been increasing in the United States also during the last 5 years. Currently the technology is being primarily applied to the precast industry. Other segments being targeted are flatwork, columns and wall construction.

The applications of SCC are many, limited only by the industry's knowledge of it, ability to produce it and acceptance of it.

The usual self-compacting concretes have compressive strengths in the range of 60-100N/mm². However Ultra High Performance Self-Compacting Concrete (UHPSCC) with strength about 150 N/mm² have also been successfully developed.

The principal benefits of SCC are advantages derived from the properties of fresh mix itself, namely:

- Ability to completely fill complex formwork and encapsulate areas of congested steel reinforcement without any compaction and yet with reduced risks of voids and honeycombing.
- Ability to develop higher early and ultimate strengths and enhanced durability properties compared with conventional vibrated concretes.
- Potential for improved surface finishes with reduced making good costs related to poorly compacted surfaces.

2. RESEARCH SIGNIFICANCE

The filling ability, passing ability, and segregation resistance are three essential properties of SCC. These three properties must be carefully maintained to achieve self compacting capacity of concrete.

These properties are also interrelated and must be maintained for a required period of time after mixing. To achieve these properties, the material selection, proportioning and quality control including production control are critical.

Filling Ability: - The concrete must have the ability to flow and completely fill all parts within the formwork under its own weight without leaving voids. As it is highly fluid it has the ability to flow considerable distances both horizontally and upwards and fill vertical elements from the bottom.

Passing Ability: - The concrete containing the required aggregate size must have the ability to flow through and around restricted spaces between steel reinforcing bars and other embedded objects under its own weight and without blocking or segregation.

Segregation Resistance: - The concrete must be able to satisfy both the filling ability and passing ability requirements while it still remains homogeneous both during transport and placing and after placing.

3. MATERIALS AND METHODS

3.1. Materials Used

Effect of marble stone powder and ice husk ash as filler on fresh and harden properties of self compacting concrete (SCC) was done in various percentages as 5%MP+10%RHA, 10%MP+5%RHA,7.5%MP+7.5%RHA respectively cubes, cylinder and prism.

The materials used and their significance is given below:

Cement-Portland cement can be found in both concrete and mortar. Portland cement is a hydraulic material, which requires the addition of water in order to form exothermic bonds, and is not soluble in water.

Coarse aggregate-Crushed angular granite metal of 12.5 mm size from a local source was used as coarse aggregate.

Fine aggregate-River sand was used as fine aggregate in the investigation.

Superplasticizer-GLENIUM B233 Super plasticizers is used in project. GLENIUM B233 is an admixture of a new generation based on modified polycarboxylic ether. GLENIUM B233 is free of chloride and low alkali.

Fly ash-Fly ash is one of the residues generated in burning, and comprises the fine particles that rise with the flue gases. In an industrial field, fly ash usually refers to ash produced during burning of coal.

Marble powder-Marble, formed from limestone with heat and pressure over years in the earth's crust. These pressure or forces cause the limestone to change in texture and makeup. The process is called recrystallization.

Rice husk ash-Rice plant is one of the plants that absorbs silica from the soil. Rice husk is the outer covering of the grain of rice plant with a high concentration of silica, generally more than 80-85%.

The physical and chemical properties of the above materials are given below:

Table 1 Physical Properties of Ordinary Portland Cement (53 Grade)

S. No.	Property Of Cement	Values
1	Fineness Of Cement	7.5%
2	Grade Of Cement	53
3	Specific Gravity	3.15
4	Initial Setting time	28 min
5	Final Setting Time	600 min

Table 2 Physical Property of Materials

S NO	Specific Gravity					
	Fly Ash	RHA	MP	LM	Coarse Aggregate	Fine Aggregate
1	2.12	2.06	2.7	2.51	2.806	2.78

Table 3 Chemical properties of fillers

S.No	Constituents	% By Weight Of Sample				
		Cement	Fly Ash	Rice Husk Ash	Marble Powder	Lime Stone Powder
1	SiO_2	20.67	42.54	62.96	2.08	4.32
2	Al_2O_3	6.21	23.59	5.10	-	1.47
3	Fe_2O_3	2.06	12.36	3.21	0.74	1.16
4	MgO	0.82	2.62	1.25	0.86	0.8
5	CaO	64.89	13.78	2.06	41.48	41.65
6	Na_2O	0.06	1.44	1.87	-	-
7	K_2O	0.55	2.49	5.65	-	-
8	SO_3	2.71	0.55	-	-	-

4. MIX COMPOSITION:

The mix composition shall satisfy all performance criteria for the concrete in both the fresh and hardened states. the requirements of EN 206 shall be fulfilled. In designing the mix it is most useful to consider the relative proportion of the components by volume rather than by mass.

Indicative typical ranges of proportions and quantities in order to obtain self- Compact ability are given below. Further modification will be necessary to meet strength and other performance requirements.

- Water/powder ratio by volume of 0.80 to 1.10
- Total powder content- 160 to 240 liters (400-600kg) per cubic meter
- Coarse aggregate content normally 28 to 35 % by volume of the mix.
- Water : Cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 liters/m^3.
- The sand content balances the volume of the other constituents.

5. TEST METHODS OF FRESH CONCRETE PROPERTIES:

5.1. Slump Flow Test

This is a test method for evaluating the flow ability of SCC, where the slump flow of SCC with coarse aggregates having the maximum size of less than 40 mm is measured . The basic equipment is the same as for the conventional slump test. However, the concrete placed into the mold is not rodded. When the slump cone has been lifted and the sample has collapsed, the diameter of the spread is measured rather than the vertical distance of the collapse.Slump flows for an SCC mix can range from 18 to more than 30 inches. Observations of the flow should look for no separation of grout from the mix, no fringe of water at the edge or on the surface, and an even distribution of aggregate in the patty . The greater the slump flow, the higher the level of "flow ability" of the concrete.

5.2. VFunnel Test

A test method for evaluating the material segregation resistance of SCC, using a funnel where the efflux time of SCC with coarse aggregates having the maximum size of less than 25 mm is measured. Funnel test of concrete equivalent to the Marsh Funnel for grout testing. A V-shaped box is made with a narrow opening at the bottom. A gate is fixed, at the bottom of the box. The box is filled with concrete. The gate is opened and the time for the concrete to flow out of the box is measured. Low flow times indicate a lower plastic viscosity of the mix. This test provides a qualitative assessment of the SCC mix viscosity.

5.3. U-box Type

A U-Box is a U-shaped box divided into two sections that are separated by a door. One side is filled with concrete with the door in place. The other side has rebar placed in it of a given size and spacing. The door is removed and the concrete flows through the rebar, reaching an equilibrium height on the other side of the U-box. The height of the concrete is measured. This test measures the ability of the concrete to flow through rebar and fill a form. The higher the concrete flows on the other side of the U-box, the greater the ability of the concrete to flow through dense rebar and around corners in a form.This test measures the ability of the concrete to flow through rebar and fill a form. The higher the concrete flows on the other side of the U-box, the greater the ability of the concrete to flow through dense rebar and around corners in a form.

5.4. L-Box Type

The method aims at investigating the passing ability of SCC. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. With this reached height, the passing or blocking behavior of SCC can be estimated.

6. TESTS METHODS FOR HARDENED PROPRTIES OF CONCRETE

6.1. Compressive Strength

Compression test develops a rather more complex system of stresses. Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson’s ratio effect. The steel plates do not undergo lateral expansion to the some extent that of concrete, with the result that steel restrains the expansion tendency of concrete in the lateral direction. This induces a tangential force between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine. It has been found that the lateral strain in the steel plates is only 0.4 of the lateral strain in the concrete.

6.2. Split Tensile Test

Tensile strengths are based on the indirect splitting test on cylinders. This is also sometimes referred as, “Brazilian Test”. This test was developed in Brazil in 1943. At about the same time this was also independently developed in Japan.

The test is carried out by placing a cylindrical specimen horizontally between the loading specimen of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. The loading condition produces a high compressive stresses immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. It is estimated that the compressive stress is acting for about 1/6 depth and the remaining 5/6 depth is subjected to tension.

6.3. Flexural Strength

The mould should be of metal, preferably steel or cast iron and the metal should be constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the molded specimens without damage. The tamping bar should be steel bar weighing 2 kg, 40 cm long and should have a ramming face 25 mm square.The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate specified. The permissible errors should not be greater than ± 0.5% of the applied load where a high degree of accuracy is required and not greater than ± 1.5% of the applied load for commercial type of use.

7. TEST RESULTS OF FRESH PROPERTIES CONCRETE

Table 4 Standard Values

Methods	Standard values
Slump Flow	650-680 mm
V-funnel test	8-12 sec
U-box	H2-H1= 30mm (max)
L-box	H2/H1=0.8 to1.0
T50 slump	5 sec max

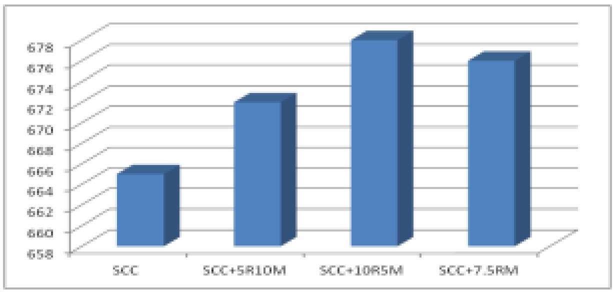


Figure 1 Slump Flow Test Results(mm)

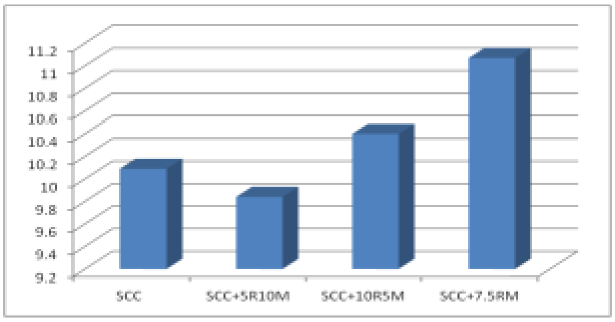


Figure 2 V Funnel Test Results(sec)

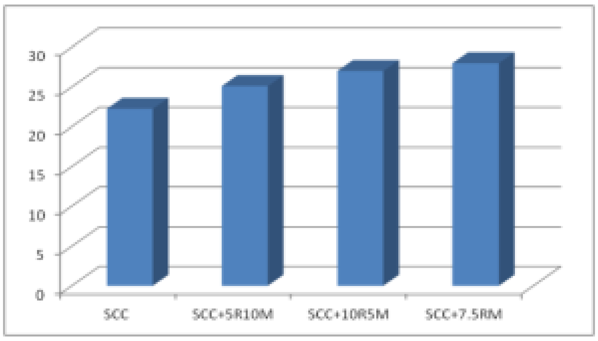


Figure 3 U Box Test Results(mm)

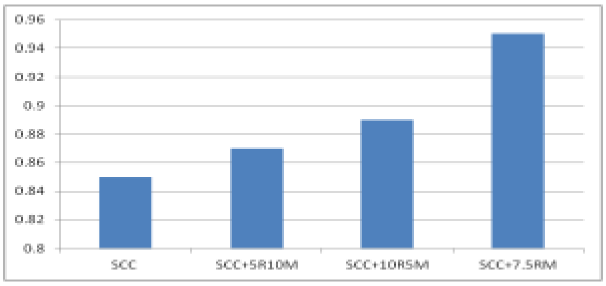


Figure 4 L Box Test Results

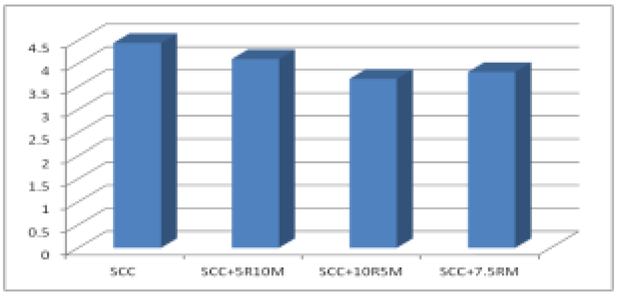


Figure 5 T_{50} Test Results (sec)

Inference- SCC with equal replacement of Rice Husk Ash and Marble Powder is better than other proportions.

8. TEST RESULTS FOR HARDENED PROPERTIES OF CONCRETE

8.1. Compressive Strength Results

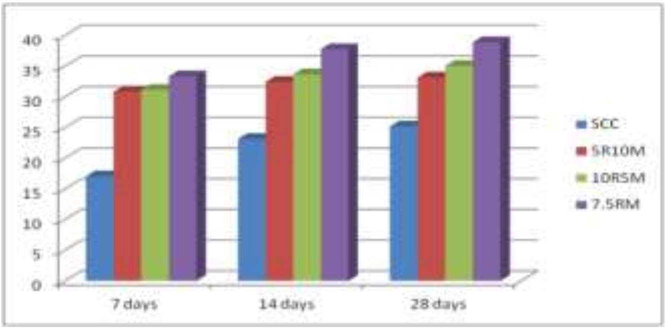


Figure 6 Compressive Strength

Inference - The 7.5% replacement of Marble Stone Powder and Rice Husk Ash with cement produced better hardened properties results when compared to the other percentage of replacements.

8.2. Split Tensile Test

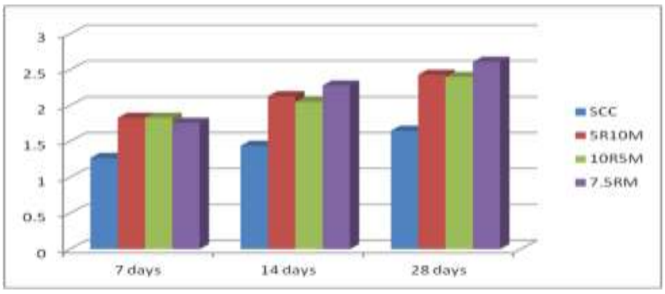


Figure 7 Split Tensile Strength

Inference - The 7.5% replacement of Marble Stone Powder and Rice Husk Ash with cement produced better hardened properties results when compared to the other percentage of replacements.

8.3. Flexural Strength

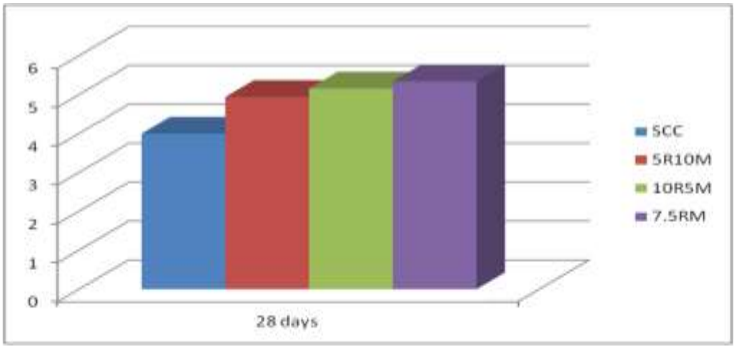


Figure 8 Flexural Strength

Inference -The 7.5% replacement of Marble Stone Powder and Rice Husk Ash with cement produced better hardened properties results when compared to the other percentage of replacements.

9. TEST METHODS FOR DURABILITY PROPERTIES OF CONCRETE

9.1. Durability Property

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration. Durable concrete will remain its original form, quality and serviceability when exposed to its environment. Tests to be conducted on durability:

- Saturated Water absorption test
- Sulphate Resistance test
- Acid Resistance test

9.2. Saturated Water Absorption Test

Water absorption tests were carried out on 150mm cube specimens at the age of 28 days curing. The specimens were weighed before drying. The drying was carried out in a hot air oven at a temperature of 115oC . The drying process was continued, until the difference in mass between two successive measurements at 24 hours interval agreed closely. The dried specimens were cooled at room temperature and then immersed in water. The specimens were taken out and the surface dried using a clean cloth and weighed. The difference between the measured water saturated mass and oven dried mass expressed as a percentage of oven dry mass gives the Saturated water absorption.

Water absorption was calculated as

Percentage water absorption = (Ws-Wd)/Wd

Ws- Weight of specimen at fully saturated condition

Wd- Weight of oven dried specimen

9.3. Sulphate Resistance Test

The term sulphate attack denote an increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates.

The cubes were cast at the size of 100x100x100 mm and kept at a room temperature. After 24 hours the cubes were removed from the mould and immersed in clean fresh water until 28 days after curing the cubes were immersed in a 5% sodium sulphate solution, after 28 days of curing, measurement of the weight and the compressive strength of cubes and calculation of durability factors were completed.

9.4. Acid Resistance Test

Sulphuric acid (H2SO4)

Chloride attack is particularly important because it primarily causes corrosion of reinforcement. The cubes were cast at the size of 100x100x100 mm and kept at a room temperature. After 24 hours the cubes were removed from the mould and immersed in clean fresh water until 28 days. After 28 days of curing, each cube is tested for weight. The cubes are subjected to 5% solutions of Sulphuric Acid (H2SO4). Cubes are continuously immersed in solution for 30days and 60days.The specimens are arranged in the plastic baths in such a way that the clearance around and above the specimen is not less than 30mm. After 30 and 60 days of curing, weight loss, compressive strength loss and acid durability factor will be determined.

Hydrochloric acid (HCl)

Chloride attack is particularly important because it primarily causes corrosion of reinforcement. The cubes were cast at the size of 100x100x100 mm and kept at a room temperature. After 24 hours the cubes were removed from the mould and immersed in clean fresh water until 28 days. After 28 days of curing, each cube is tested for weight. The cubes are subjected to 5% solutions of Hydrochloric Acid (HCl). Cubes are continuously immersed in solution for 30days and 60days.The specimens are arranged in the plastic baths in such a way that the clearance around and above the specimen is not less than 30mm. After 30 and 60 days of curing, weight loss, compressive strength loss and acid durability factor will be determined.

9.5. Acid Durability Factor

For determining the resistance of concrete specimens to aggressive environment such as acid attack, the durability factors as proposed by the philosophy of ASTM (666-1997).The standard test method for resistance of concrete to rapid freezing and thawing and the durability factors are defined in terms of relative dynamic modulus of elasticity. In the present investigation, the “Acid Durability Factors” are derived directly in terms of relative strengths. The relative strengths are always compared with respect to the 28 days value (i.e. at the start of the test)

The “Acid Durability Factors” (ADF) can be calculated as follows.

$$\mathbf{ADF = Sr\ N / M}$$

Where, Sr - Relative Strength at N days, (%)

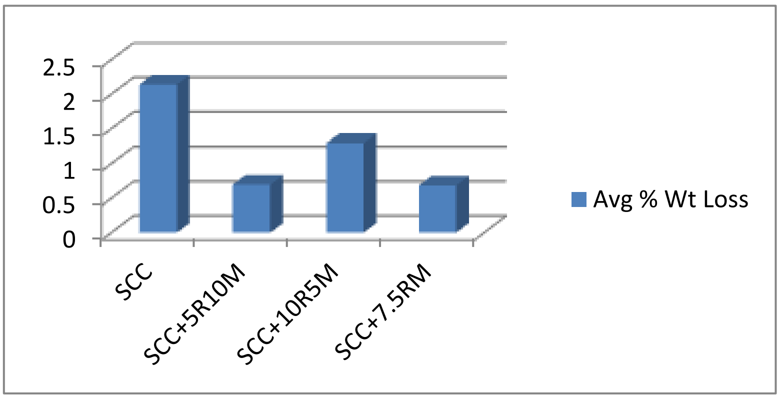
N - Number of days at which the durability factor is needed.

M - Number of days at which the exposure is to be terminated.

So M is 60 in this case.

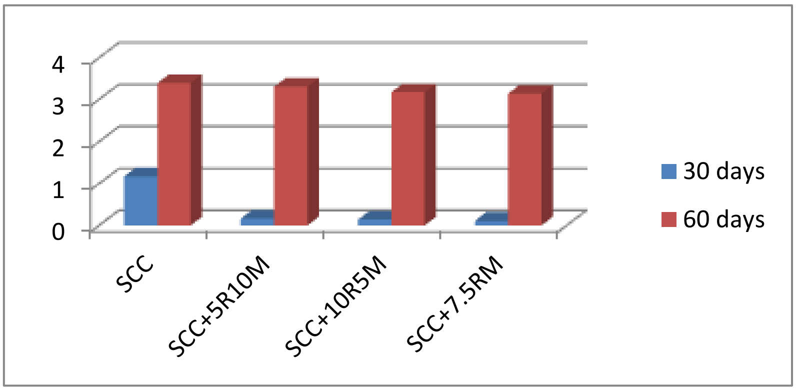
10. TEST RESULTS FOR DURABILITY PROPERTIES OF CONCRETE

10.1. Saturated Water Absorption Test

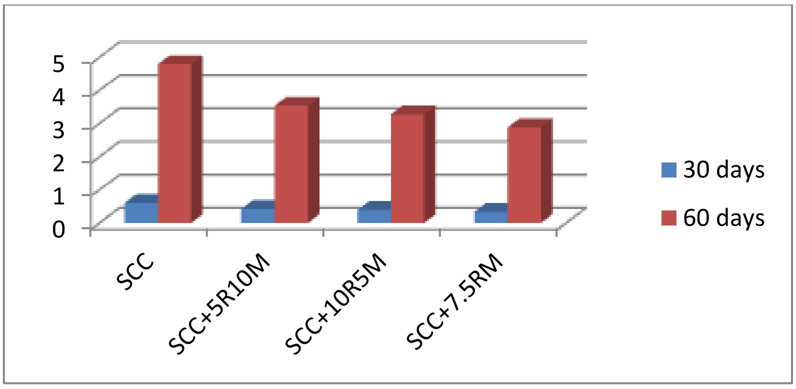


SCC with equal replacement of Rice Husk Ash and Marble Powder gives better performance than other mix proportions

10.2. Sulphate Resistance Test



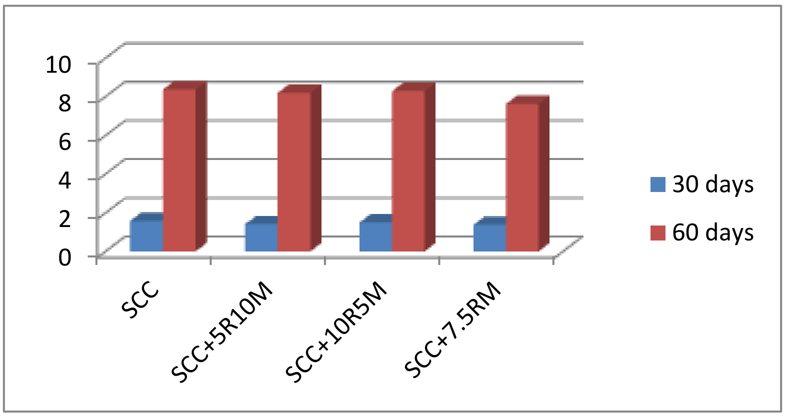
Average % Weight Loss in Sodium Sulphate



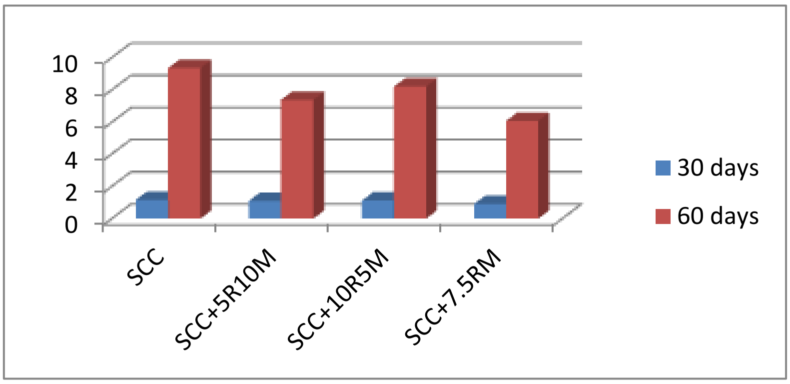
Average % Compressive Strength Loss in Sodium Sulphate

SCC with equal replacement of Rice Husk Ash and Marble Powder gives better performance than other mix proportions

10.3. Acid Resistance Test

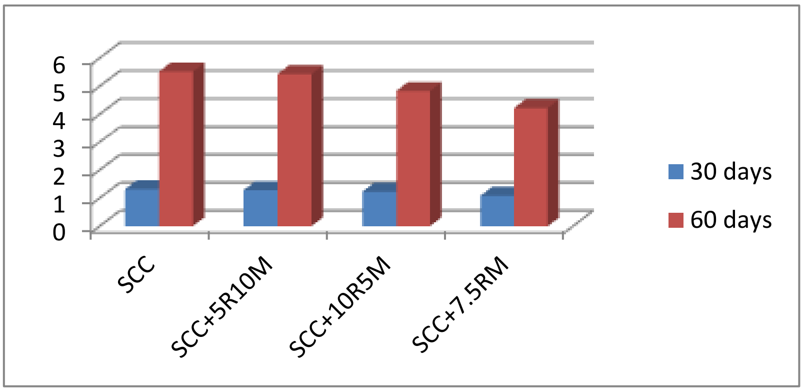


Average % Weight Loss in Sulphuric Acid

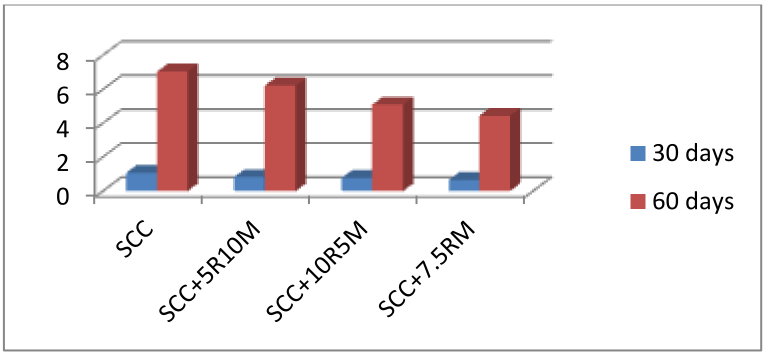


Average % Compressive Strength loss in Sulphuric Acid

SCC with equal replacement of Rice Husk Ash and Marble Powder gives better performance than other mix proportions



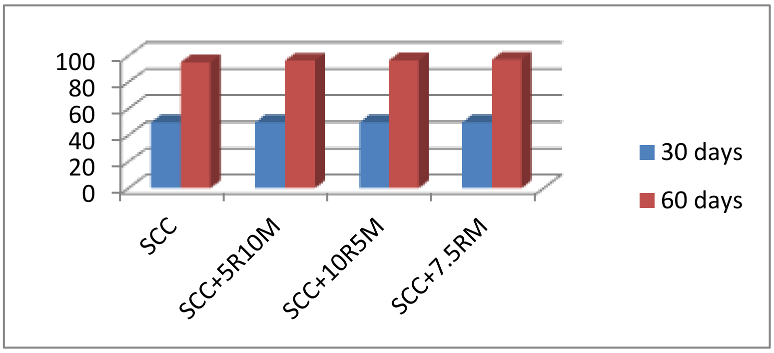
Average % Weight Loss in Hydrochloric Acid



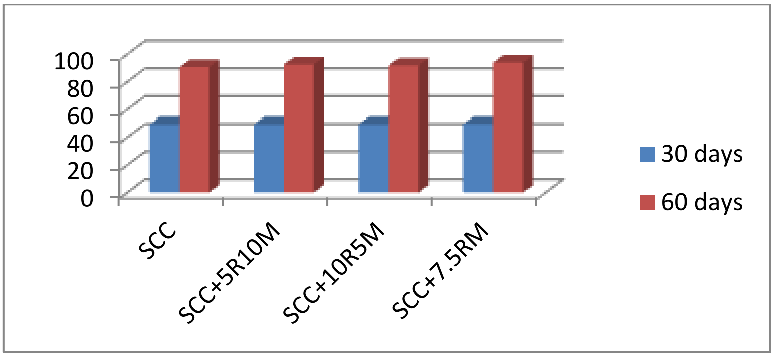
Average % Compressive Strength Loss in Hydrochloric Acid

SCC with equal replacement of Rice Husk Ash and Marble Powder gives better performance than other mix proportions

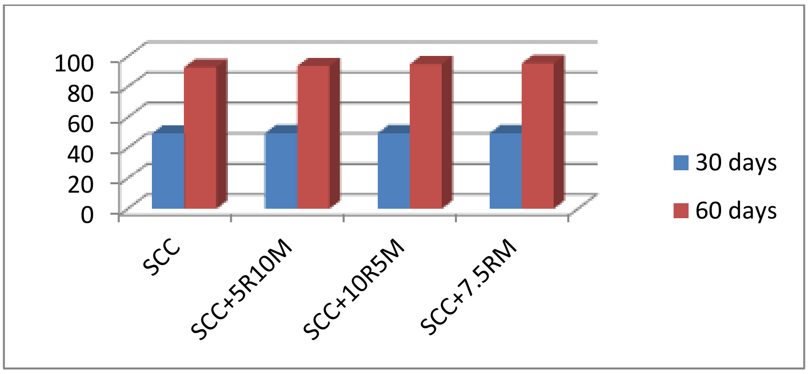
10.4. Relative Strength and Acid Durability Factor



Acid Durability Factor for Sodium Sulphate



Acid Durability Factor for Sulphuric Acid



Acid Durability Factor for Hydrochloric Acid

SCC with equal replacement of Rice Husk Ash and Marble Powder gives better performance than other mix proportions

11. CONCLUSIONS

- **SCC** helps in creating durable and reliable concrete structures requiring very little maintenance work. SCC is becoming so widely used that it will be soon seen as the "standard concrete" rather than as a "special concrete".
- This project has studied the feasibility of using RHA and MP in SCC. The mechanical and durability properties of various mixture proportions were studied and results were compared.
- Test results show that SCC with equal replacement of RHA and MP gives better performance than other mix proportions.
- SCC with equal replacement of RHA and MP increases Compressive Strength by 35%, Split Tensile Strength by 37% and Flexural Strength by 25%.
- The results also show that SCC with equal replacement of RHA and MP gives better acid resistance.
- Substitution of RHA and MP in cement also reduces cost.

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