International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Investigation on the Hardened Properties of Ternary Blended Concrete using Agricultural and Industrial Substitutes

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Abstract - *Cement is the most widely used material in the world after water. It finds its major use in concrete. Cement usage is not very environmentally beneficial .To make it sustainable we have to make use of the waste materials without compromising its strength and durability. Hence we have in this paper an experimental study was made on the effects of using Rice Straw Ash (RSA) & (GGBS) as a partial replacement of cement in mortar. Cement replaced with GGBS not only increase the compressive strength but also its tensile, splitting and flexural strength properties. Locally available rice straw being waste product was burnt to ash in uncontrolled manner. There is enhancement of strength of mortar due to excess amount of SiO2 in RSA and CaO in GGBS. Replacement of cement with RSA& GGBS will also lead to reduction of construction cost. Control specimens with ordinary portland cement was made, and in other hand specimens with cement which is replaced with (5% and 10% of RSA) and (10% and 20% of GGBS) by weight of cement. All the specimens are cured in normal room temperature and it can be tested for 7, 14 and 28th days. The compressive strength tests were conducted on specimens. The addition of these SCM's boosted the results and they can be further used.The results are tabulated. Based on the results obtained, conclusion and suggestion are made.*

Keywords: Rice Straw Ash, GGBS , Compressive and tensile strength tests

1. INTRODUCTION

Concrete is the second most used material used my man after water. Although concrete is modelled as a homogenous material for our convenience, it is actually a heterogenous composite material made various substances largely classified as binder and aggregates which harden over time. Most concrete used are lime based materials such as portland cement concrete or concrete made with other hydraulic cements The conventional concrete is not a very sustainable material and hence it produces a very large carbon footprint. We have already gone in the search of alternate materials for cement and we are in the verge of finding many alternatives. This paper discusses the use of GGBS and Rice straw ash as alternatives.

In Portland cement concrete, when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which blinds all the materials together into a durable stone like material that has many uses.

Iron & steel plants generate waste in form of slag from blast furnace while reducing iron ore to iron. This waste in form of blast furnace slag usually collected in dumping grounds of the industries and they cause harmful effects to the environment. Annual production of steel in India is about 89.58 million according to 2015 figures, and world production 1622.8 million. In addition, generation of waste slag according to figures of 2013-14 in India is larger than 13.5 (106 MT/annum**). [JyotiMali and PiyushBagul (2014)]** There is a cost reduction of up to 50% when used GGBS. [**Kamran MuzaffarKhan (2004**)]. The compressive and tensile splitting strengths, flexure and modulus of elasticity increases with increasing GGBS content. The drying shrinkage shows a slight increment with GGBS. GGBS fails the initial surface absorption test confirming that the surfaces of their concrete mixes were practically impermeable. Based on the results, the optimum mix is the one with 50% OPC 50% GGBS. [**ReshmaRughooputh and JaylinaRana (2014**)]. Setting times are delayed with increased amount of cement replacement and there is enhancement of strength of mortar with certain quantity of replacement of cement with RSA which will lead to reduction of construction cost.Thus as a result the compressive strength of concrete increased by using an optimum mix of replacement with cement. [**Surajattmunshi and GopinathanDey** (2015)]

2. PHYSICAL PROPERTIES OF MATERIALS

The properties of individual materials has to be found out in order to arrive at a good mix

2.1. GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to make iron. These

operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimises the cementitious properties and produces granules similar to coarse sand. Specific Gravity of GGBS according to IS 2720 – Part 3 = 2.75

TABLE 1 CHEMICAL PROPERTIES OF GGBS

Chemical Composition	PERCENTAGE %
Silica	51.25%
Calcium Oxide	22.45%
Magnesium Oxide	3.21%
Ferric Oxide	2.23%
Aluminium Oxide	11.89%

2.2 RICE STRAW ASH

The main byproduct comes from rice are (rice straw, rice bran, rice husk). To decrease the use of construction material and to raise the environmental concern natural materials are used. In the production of rice large amount of solid residue is produced, for which alternative utilization are scarce or are not commonly used. Among various materials rice straw has a very high potential for production use. Rice straw is a waste product of rice harvest that is generated in equal or greater quantities than rice itself. Rice straw have 15% ash after burn of every 1000kg i.e.150kg.In search of possible use of rice straw it should be noted that its ash (RSA) is particularly rich in silica is used in fabrication of ceramic material for the construction industry. The burnt rice straw contains high content of SiO2, alkaline oxides and alkaline earth oxides which can be also used as partial replacement of cement and used in constructions.

Average Specific Gravity of RSA as per IS 2720- Part 3 = 0.651

Standard consistency = 30 % (as per IS 4031 Part -IV)

TABLE 2 CHEMICAL COMPOSITION OF RICE STRAW ASH

Chemical Composition	PERCENTAGE %
Silica	62.24%
Calcium Oxide	0.60%
Magnesium Oxide	4.21%
Ferric Oxide	0.75%
Aluminium Oxide	1.14%

2.3 FINE AGGREGATE

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Fine aggregate is natural sand which has been washed and sieved to remove particles larger than 4.75 mm.

Average Specific Gravity of Fine aggregate = 2.46

2.4 COARSE AGGREGATE

Those particles that are predominantly retained on the 4.75 mm (No. 4) sieve, are called coarse aggregate. Coarse aggregates is broken from rocks using explosives & crushed into pieces using crushers. Coarse aggregate sizes range from 6mm,12mm,20mm,40mm,60mm are divided using big sieves in machines. Coarse aggregate like 6,12,20mm is used to mix in concrete for construction purposes & 40mm is used for railroads.

Average specific gravity of coarse aggregate = 3.01

2.5 MIXING AND CASTING

The mixing of concrete throughout the research was carried out in a laboratory at room temperature. The aggregate were used in an air dry condition, and the water content was checked and adjusted before mixing to obtain saturated and surface dry condition.

The coarse aggregate were first placed in the pan and approximately one third of the mixing water added. The aggregate and the water were then mixed for approximately one minute to allow the aggregate to absorb water the cement and fine aggregate were then added and mixed for another 40-30 seconds. Thus the casting process is carried out.

Casting was performed in three layers, each layer is been compacted thoroughly, without causing segregation, but ensuring the removal of any untrapped air. Totally we cast 18 number of cubes.

2.6 CURING

After demoulding the concrete specimens were exposed to curing. The specimens were in the steel mould during the first 24 hours after casting, after which time they were demoulded and left to continue curing in the same environment. Then the specimens are carefully immersed into the curing tank for 28 days wet curing.

2.7 MIX PROPORTIONS

Cement: Water : Coarse aggregate : Fine aggregate

372 : 186 : 1298.8 : 650.62

1: 0.5 : 3.49 : 1.748

TABLE 3 MIX PROPORTIONS

MIXES	0% (RSA) +0% (GGBS)	5% (RSA) +25% (GGBS)	10% (RSA) +20% (GGBS)
MIX ID	CC	A1	A2
CEMENT	372	260.4	260.4
GGBS	0	93	74.4
RSA	0	18.6	37.2
FINE AGGEGATE (KG)	650.62	650.62	650.62
COARSE AGGREGATE (Kg)	1298.8	1298.8	1298.8

2.8 CAST SPECIMENS

The specimens used for testing the mechanical properties were prepared as follows. After 28 days the specimens were taken out from curing tank and then it is allowed to dry for 24 hours. The specimen surface is cleanly wiped out using waste cloth. Then destructive test were conducted respectively.

3. TEST PROCEDURE

3.1. COMPRESSIVE STRENGTH TEST FOR CUBE (IS 516-1959)

Compressive test is the most common test on hardened concrete, because most of the desirable characteristic properties of concrete are quantitatively related to its compressive strength.

TABLE 4 COMPRESSIVE STRENGTH TEST

S.No	Mix Id	7th Day (N/mm²)	14th Day (N/mm²)	28th Day (N/mm²)
1	CC	15	27.68	29.25
2	A1	14.69	26.26	28.65
3	A2	16.23	28.36	31.23

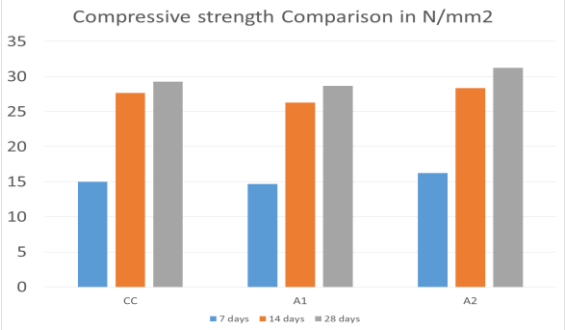

Figure 1: Compressive Strength Graph

The load is gradually applied without shock and continuously at the rate of 140 kg/cm2/minute till the specimen fails.

3.2 SPLIT TENSILE STRENGTH TEST FOR CYLINDER (IS 516-1959)

Split tensile is the most common test on hardened concrete, because it gives an idea of the tensile strength of the concrete .The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. Two bearings strips of nominal (1/8 in i.e 3.175 mm) thick plywood, free of imperfections, approximately (25 mm) wide, and of length equal to or slightly longer than that of the specimen should be provided for each specimen. The bearing strips are placed between the specimen and both upper and lower bearing blocks of the testing machine or between the specimen and the supplemental bars or plates.

TABLE 5 SPLIT TENSILE STRENGTH TEST

S.No	Mix Id	7th Day (N/mm²)	14th Day (N/mm²)	28th Day (N/mm²)
1	CC	2.7	3.1	3.3
2	A1	2.6	2.92	3.2
3	A2	2.9	3.12	3.35

The load is applied continuously and without shock, at a constant rate within, the range of 689 to 1380 kPa/min splitting tensile stress until failure of the specimen Note the type of failure and appearance of fracture.

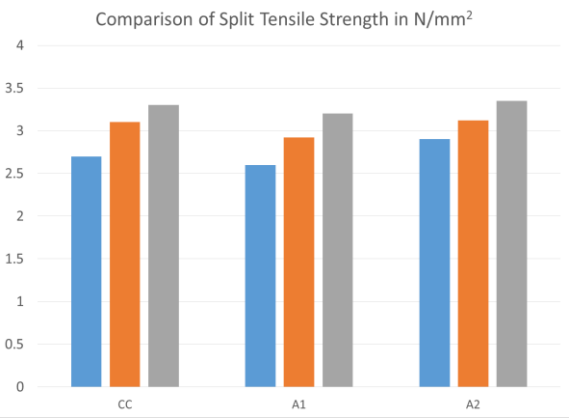

Figure 2: Split Tensile Strength Graph

3.3 FLEXURAL STRENGTH OF CONCRETE

The test specimen is prepared by filling the concrete into the mould in 3 layers of approximately equal thickness. Each layer is tamped 35 times using the tamping bar as specified above.

Tamping should be distributed uniformly over the entire crossection of the beam mould and throughout the depth of each layer. The bearing surfaces of the supporting and loading rollers are cleaned , and any loose sand or other material from the surfaces of the specimen are removed where they are to make contact with the rollers.

Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen.

A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes.

The distance between the outer rollers (i.e. span) shall be 3d and the distance between the inner rollers shall be d. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.

The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the roller.

TABLE 6 FLEXURAL STRENGTH TEST

S.No	Mix Id	7th Day (N/mm²)	14th Day (N/mm²)	28th Day (N/mm²)
1	CC	3.12	3.32	3.49
2	A1	3.03	3.35	3.89
3	A2	3.23	3.48	3.98

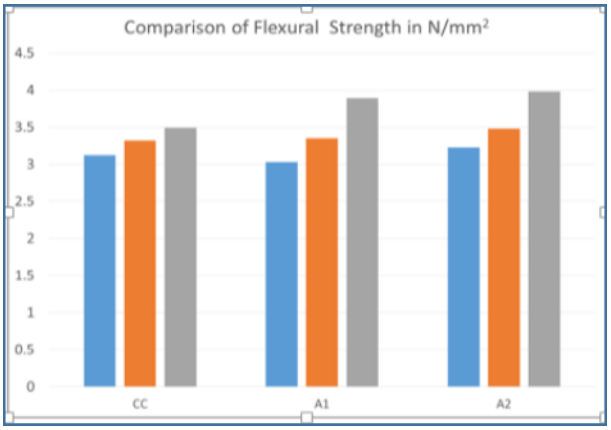

Figure 3: Flexural Strength Graph

4. CONCLUSIONS

- The results shows that the incorporation of rice straw ash and ground granulated blast furnace slag increased the compressive strength of concrete at the age of 7 days itself for mix A2.
- The same trend is followed for split tensile and flexural strength test.
- The increase in the strength may be attributed to the presence of silica and the silicate compounds formed.
- The crack pattern formed was ductile and did not show sudden failure. Hence it was found to be optimum.

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