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An Experimental Study on Synergic Effect of Sugar Cane Bagasse Ash with Rice Husk Ash on Self Compaction Concrete

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Abstract - Self-compacting concrete, also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight and is de-aerated almost completely while flowing in the formwork. It is cohesive enough to fill the spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily-reinforced concrete members or in complicated work forms. The objectives of this research were to make a synergic effect of Rice husk Ash (RHA) and Sugar cane bagasse ash(SCBA) incorporated in self compaction concrete in order to increase in strength and a better bonding between aggregate and cement paste, . The mix design used for making the concrete specimens was based on previous research work from literature. The water – cement ratios varied from 0.3 to 0.75 while the rest of the components were kept the same, except the chemical admixtures, which were adjusted for obtaining the self-compactability of the concrete. All SCC mixtures exhibited greater vaules in compressive strength after being tested, the compressive strength was around 40% greater. In addition, the SCC had a good rheological properties as per the requirements from European standards from economical point of view the pozzolanic replacements were cheap and sustainable. In the experiments cement was replaced with 0%, 2.5%, 5% of both blended mixture of rice husk ash and sugar cane bagasse ash. This was possible due to the use of mineral and chemical admixtures, which usually improve the bonding between aggregate and cement paste, thus increasing the strength of concrete.

Keywords - Self-Compaction Concrete (SCC); Rise Husk Ash (RHA); Sugar cane bagasse ash (SCBA); Viscosity Modifying Agent (VMA); supplementary cementing material (SCM)

I. INTRODUCTION

Advancements in concrete technology have resulted in the development of a new type of concrete, which is known as self-compaction concrete (SCC). The merits of SCC are based on the concept of self-compaction, Self-compaction concrete (SCC) is a flowing concrete that spreads through congested reinforcement, fills every corner of the formwork, and is consolidated under its self-weight (Khayat 1999). SCC requires excellent filling ability, good passing ability, and adequate segregation resistance. But it does include high strength and good durability as essential performance criteria. An SCC is that concrete, which offers excellent performance with respect to filling ability, passing ability, segregation resistance, strength, transport properties and durability.

SCC is produced by exploiting the benefits of super plasticizers, viscous modifying agent and supplementary cementing material (SCM). The use of SP and VMA is essential to produce SCC. The admixtures contribute to achieve excellent filling ability and passing ability. In addition, SCMs are incorporated in SCC mostly to enhance the strength and durability of concrete. It may also contribute to attain good segregation resistance. In most countries, several well-known SCMs such as Rice husk ash, sugar cane bagasse ash, ground granulated blast-furnace slag, and fly ash has been used to produce SCC (Bouzoubaâ and Lachemi 2001, Khayat 2000, Okamura and Ozawa 1994, Persson 2001). In comparison, the use of rice husk ash (RHA) in SCC is very limited. RHA is obtained by controlled burning of rice husks; RHA provides dramatic improvements in hardened properties and durability of concrete (Mehta and Folliard 1995, Maeda et al. 2001). Similarly the use of SCBA can also be used as a partial replacement of cement since it exhibits same chemical compositions as the alternative pozzolanic materials .Similar effects might be observed when RHA is used in SCC. SCMs are also essential for high strength and high durability of SCC. Moreover, the expense of some SCMs such as silica fume and high reactivity metakaolin increases the overall material cost of SCC. Therefore, the use of less-expensive RHA and SCBA is more desirable to decrease the overall production cost of SCHPC. The usage of RHA and SCBA also minimizes the environmental burden resolving vast waste disposal problems caused by rice milling industries.

II. OBJECTIVES OF THE RESEARCH

The main objectives set for this research were to incorporate different percentage of pozzalonic materials such as rice husk ash and sugar cane ash to increase on the Strength bond and Compressive Strength of self-compacting and to examine the bonding between the coarse aggregate and the cement paste in self compaction concrete.

III. CHARACTERISTICS OF MATERIALS

A. Portland cement:

Portland cement is general-purpose cement suitable for all uses where the special properties of other types are not required. Its uses in concrete include pavements, floors, reinforced concrete buildings, etc. and it has a relative density of 3.15.

B. Water:

The water used in the mix design was potable water from the water-supply network system; so, it was free from suspended solids and organic materials, which might have affected the properties of the fresh and hardened concrete.

C. Coarse Aggregate:

The coarse aggregate used in the concrete mixtures was river gravel, having the maximum size of 19.5 mm. Its absorption value was 1.9% and was determined according to IS Code "Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate". Also, sieve analysis was performed on the coarse aggregate according to IS383-1970 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate". The results presented in Table I

TABLE I
SIEVE ANALYSIS OF COARSE AGGREGATE

Passing through IS sieve (mm)	**Retained on IS sieve** (mm)	**Cumulative % retained**	**%Passing**
20	12.5	100	100
12.5	10	7.5	92.5
10	4.75	30.01	69.99
4.75	Pan	90.45	9.55

D. Fine Aggregate:

The natural sand that has been used to cast the concrete cylinders was very clean and had the maximum size of 1 mm. It was also brought from the south part of Louisiana, which has quite big deposits of different types of sand. Its absorption value was 1.12% and was determined according to IS Code "Standard Test Method for Specific Gravity and Absorption of Fine Aggregate. The results presented in Table II

TABLE II
SIEVE ANALYSIS OF FINE AGGREGATE

Passing through IS sieve (mm)	**Retained on IS seive** (mm)	**Cumulative % retained**	**%Passing**
4.75	2.36	2.00	98.00
2.36	1.18	21.20	78.88
1.18	0.6	46.40	53.60
0.6	0.3	63.14	36.68
0.3	0.15	88.14	11.86

E. Rice Husk Ash (RHA):

Rice husk ash is produced by incinerating the husks of rice paddy. Rice husk is a by-product of rice milling industry. Controlled incineration of rice husks between $500^{0}C$ and $800^{0}C$ produces non-crystalline amorphous RHA (Mehta and Monteiro 1993, Malhotra 1993). RHA is whitish or gray in color. The particles of RHA occur in cellular structure with a very high surface fineness. They have 90% to 95% amorphous silica (Mehta 1992). Due to high silica content, RHA possesses excellent pozzolanic activity. Specific Gravity of RHA is 1.2.

F. Sugar Cane Bagasse Ash (SCBA)

The physical effect (or the so-called filler effect) is concerned with the packing characteristics of the mixture, which in turn depends on the size, shape, and texture of the SCBA particles. The chemical effect relates to the ability of the SCBA to provide reactive siliceous and aluminous compounds to participate in the pozzolanic reaction with calcium hydroxide (an unfavorable product from cement hydration) and water. The product of such reaction is called calcium silicate hydrate, a compound known to be responsible for compressive strength in cement-based materials. Cordeiro (2006) found that the pozzolanic reactivity of SCBA depended strongly on the incinerating temperature; a maximum reactivity occurred at around 500°C. Specific Gravity of SCBA is 1.63. Also under goes the same reaction as RHA since having the same chemical constituent's high silica and alumina compositions.

TABLE III
CHEMICAL COMPOSITIONS OF RAW MATERIAL

Materials	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI
RHA	91.2	0.94	0.37	2.15	0.88	-	-
SCBA	78.34	8.55	3.61	2.15	1.65	-	-
Cement	18.1	5.58	2.43	62	2.43	3.1	4.4

G. Admixtures:

A complex retarding super-plasticizer poly carboxylic in nature was used. Its water reduction rate 30% and the dosage of the admixture is 1% + justify amount. The VMA used was polyethylene glycol with high viscous affinity.

IV. MICROFILLING EFFECT OF RHA AND SCBA

The role of both RHA and SCBA in SCC is the same as that in any other concretes. In concrete, the RHA mainly serves as a micro filler, pozzolanic, and viscosity modifier. The RHA and SCBA particles can fill the voids between the larger cement grains because of their smaller size, as shown in Figure 2. However, the micro filling ability of RHA is not as effective as silica fume and SCBA is finer too than it. This is because the RHA particles are much larger than the silica fume particles. The typical median particle size of RHA is about 7 μm, while that of the cement and silica fume is 13 μm and 0.1 μm, respectively (Mehta 1994, Zhang and Malhotra 1996). Although RHA is not very fine in particle size, it behaves as a very reactive pozzolanic material because of its extreme surface fineness and high silica content (Mehta 1992, Mehta 1994). In the presence of water, the RHA actively reacts with $Ca(OH)_2$ liberated during cement hydration (pozzolanic reaction) and produces additional calcium silicate hydrate (CSH),

Hydration reaction:

$$C_2S \text{ or } C_3S + H_2O \rightarrow \text{primary CSH} + Ca(OH)_2 \quad \text{Equation 2.1}$$

Pozzolanic reaction: $Ca(OH)_2 + RHA\ (SiO_2) + H_2O \rightarrow$ secondary CSH

The pozzolanic reaction product fills the pores existing between cement grains and results in dense calcium silicate hydrate, as shown in Figure 1. Both microfilling and pozzolanic effects of RHA and SCBA play an important role to refine the pore structure in bulk paste matrix and interfacial transition zone of concrete. The pore refinement occurring due to the secondary reaction between RHA and $Ca(OH)_2$ makes the microstructure of concrete denser and improves the interfacial bond between aggregates and binder paste. As a result, the strength, transport properties and durability of concrete are improved.

Hydration in the absence of RHA and SCBA Hydration in the presence of RHA and SCBA

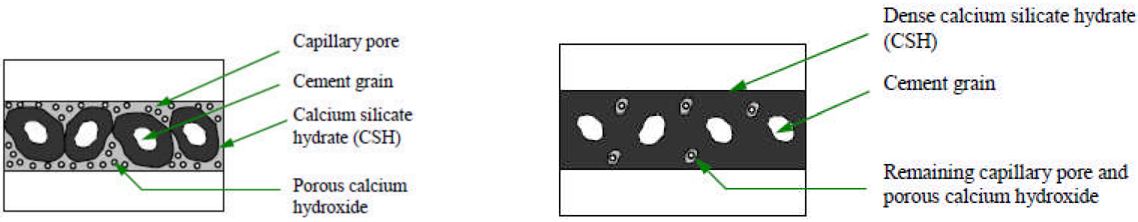

Fig. 1: Pozzolanic Effect of both RHA and SCBA

V. TESTING METHODS OF SCC

Different methods have been developed to characterize the properties of SCC. No single method has been examined till date, which characterizes all the relevant workability aspects. Each mix has been tested by more than one test method for the different workability parameters. Following are the tests recommended by European guidelines.

A. *Slump flow Test*

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. The test also indicates resistance to segregation. On lifting the slump cone, filled with concrete the average diameter of spread of the concrete is measured. It indicates the filling ability of the concrete.

Fig. 1: Slump Flow Test

B. *V-Funnel Test*

The flowability of the fresh concrete can be tested with the V-funnel test, whereby the flow time is measured. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Shorter flow time indicate greater flowability.

Fig. 3: V-Funnel Test

C. *L-Box Test*

This is a widely used test, suitable for laboratory and site use. It assesses filling and passing ability of SCC and serious lack of stability (segregation) can be detected visually. The vertical section of the L-Box is filled with concrete, and then the gate is lifted to let the concrete flow into the horizontal section. Blocking ratio (i.e. is ratio of the height of the concrete at the end of the horizontal section (h2) to height of concrete at beginning of horizontal section (h1)) is determined It indicates passing ability of concrete or the degree to which the passage of concrete through the bars is restricted.

D. *U-Box Test*

The test is used to measure the filling and passing ability of self-compacting concrete. The apparatus consists of a U shape vessel that is divided by a middle wall into two compartments. The U-box test indicates degree of compactability in terms of filling height i.e. (h1-h2), difference of height of concrete attained in two compartment of U-box.

E. *Orimet Test*

Orimet test is able to simulate the flow of fresh concrete during actual placing on sites. The Orimet apparatus is filled with about 8 liters of concrete and the time taken for it to flow through the apparatus is measured.

F. GTM Screen Stability Test

GTM screen stability test is a very effective way of assessing the stability of SCC. It consists of taking a sample of 10 liter of concrete, allowing it to stand for a period to allow any internal segregation to occur, then pouring it on to a 5mm sieve of 350mm diameter. After two minutes, the mortar which passed through the sieve is weighed and expressed as a percentage of the weight of the original sample on the sieve (i.e. Segregation Ratio).

TABLE IV
RECOMMENDED LIMITS FOR DIFFERENT PROPERTIES

S.No	Property	Range
1.	Slump flow diameter	500-700mm
2.	T_{50cm}	2-5sec
3.	V-funnel	6-12sec
4.	L-box H_2/H_1	0.8

VI. MIX DESIGNS AND PROPERTIES

The self-compacting concrete mix design used in the study was based on previous work done in Japan, US, Canada. All the mixes were prepared in concrete pan using an electrical mixer. The mix proportions for concrete specimens are given in Table V.

The type I Portland cement was replaced by rice husk ash (2.5%, 5%), sugar cane bagasse ash (2.5%, 5%). The water-cement ratios have been varied from 0.3 to 0.75 while the rest of the components were kept the same, except the chemical admixtures, which were adjusted for obtaining the self-compactability of the concrete.

Mixing Procedure the mixing process for all batches was as follows

- The coarse and fine aggregates were initially dry mixed for about 30 seconds
- This was followed by the addition of cement, fly ash and 1/3 of total mixing water.
- After 1.5 minutes of mixing, the rest of the mixing water together with the high-range water-reducing admixture was added.
- All batches were mixed for a total mixing time of 4 minutes in a pan type mixer of 60-litre capacity. In case of a mix with fibers, the further mixing time at this stage was increased for 2-3 minutes. Thus, non-fibrous concrete mixture was mixed for approximately 4 minutes while fibrous concrete mixtures were mixed for 6-7 minutes.
- For both the series, workability tests were performed on fresh concrete mixes namely, Slump flow, J-ring flow, V funnel, L-box and U-box.
- The self-compactability of the mixed was examined according to EFNARC.

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TABLE V
MIX PROPORTIONS OF SCC

S.No.	Mix	Cement (Kg/m^3)	RHA (Kg/m^3)	SCBA (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	Water (Kg/m^3)	S.P. (%)	V.M.A (%)	W/P ratio
1	TR1	398.69	49.84 (10%)	49.84 (10%)	514.37	1195.97	300	1.1	0.3	0.6
2	TR2	414.02	23.01 (5%)	23.01 (5%)	969.88	769.88	276.02	1.1	0.4	0.6
3	TR3	450.13	25 (5%)	25 (5%)	753.77	1019.26	300	1.1	0.3	0.6
4	TR4	500	12.35 (2.5%)	12.35 (2.5%)	874.57	750	309.57	1.1	0.3	0.59
5	TR5	500	12.35 (2.5%)	12.35 (2.5%)	874.57	750	335.80	1.1	0.4	0.64
6	TR6	500	12.35 (2.5%)	12.35 (2.5%)	874.57	750	393.52	1.1	0.4	0.75
7	SCC	498.37	0	0	514.37	1195.97	300	1.1	0.3	0.6
8	2.5R SCC 2.5 S	500	12.35 (2.5%)	12.35 (2.5%)	874.57	750	359.42	1.2	0.7	0.685
9	5R SCC 5S	500	24.69 (5%)	24.69 (5%)	874.57	750	340.74	1.2	0.7	0.62

VII. RESULTS AND DISCUSSIONS

The RHA significantly increased the compressive strength of concretes at the ages of 3, 7, 14 and 28 days, as evident from Table 6 and Figure 4. The improvement of compressive strength is mostly due to the microfilling ability and pozzolanic activity of RHA and SCBA. With a smaller particle size, the RHA blended with SCBA can fill the micro-voids within the cement particles. Also, the RHA readily reacts with water and calcium hydroxide, a by-product of cement hydration and produces additional calcium silicate hydrate or CSH (Yu et al. 1999). The additional CSH increases the compressive strength of concrete since it is a major strength-contributing compound. Also, the additional CSH reduces the porosity of concrete by filling the capillary pores, and thus improves the microstructure of concrete in bulk paste matrix and transition zone leading to increased compressive strength.

The increase in both SCBA and RHA increases the demand in water so this causes limited percentage of replacement since it's difficult to maintain the adequate amount of proportions

It has been verified, by using the slump flow and L-box tests, that self-compacting concrete (SCC) achieved consistency and self-compactability under its own weight, without any external vibration or compaction. Also, because of the special admixtures used, SCC has achieved a density between 2400 and 2500 kg/m^3.The observations show a low strength at early stage of 3days, 7days but with an increase of the strength parameter in later stages after 60 days of curing thus having good bond strength between cement, pozzolona materials and coarse aggregates.

The compressive strength increases gradually with the SCC incorporated with RHA and SCBA than the one without pozzolona materials incorporated with it. Since at early age the introduction of RHA and SCBA reduces the early strength of SCC mixes.

TABLE VI

Workability and Compressive Strength ResultsS.No	Mix	Fresh Concrete Properties				Hardened Concrete Properties			
		Slump flow (mm)	V-funnel (sec)	L- Box (H_2/H_1)	U- Box (H_2/H_1)	3 – Days (MPa)	7-days (MPa)	14 – Days (MPa)	28-days (MPa)
1	TR1	540	-	-	-	4.44	8.88	15.11	17.78
2	TR2	540	2.2	-	-	-	8.58	15.05	17.78

3	TR3	550	2.02	-	-	-	14.67	17.88	31.11
4	TR4	550	2.02	-	-	-	21.33	29.70	33.33
5	TR5	580	3.4	0.8	0.8	-	13.33	22.22	30.56
6	TR6	570	2.2	-	-	-	20	24.44	39.56
7	SCC	650	5	0.8	0.8	-	12.88	21.33	22.22
8	2.5R SCC 2.5 S	680	2.1	0.82	0.8	-	16	27.66	31.56
9	5R SCC 5S	670	3.15	0.84	0.81	-	7.74	12.33	14.22

From above table and discussions some SCC did not fulfill the rheological properties of SCC as per European standards. But as the increase of RHA and SCBA the concrete had some good passing and filling ability because of good blending capabilities of both the supplementary materials.

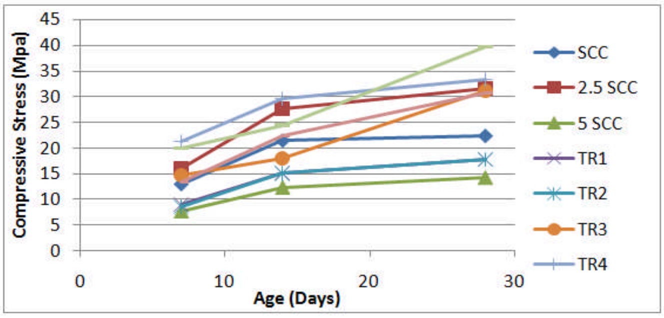

Fig.4: Average Copressive Strength Result

VIII. CONCLUSIONS

The compressive strength tends to be less at the early stage but increases at later stage meaning the usage of RHA and SCBA can be used into practice.

- The RHA and SCBA content is suggested to use in the range of 0 to 15% in this mixture design to achieve the SCC mixtures with the desired level of properties and durability.
- A coarse aggregate content less than 35% of concrete volume is suggested to use in this design method to enhance the flowing ability and segregation resistance of concrete.
- The design method suggests that a paste volume greater than the minimum amount of paste must be used in SCC to enhance the flowing ability of concrete.
- Due to the use of chemical and mineral admixtures, self-compacting concrete has shown smaller interface micro cracks than normal concrete, fact which led to a better bonding between aggregate and cement paste and to an increase in compressive strength.
- Economic point of view the percentage of cement replaced saves money.

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