Primljen / Received: 29.7.2014.
Ispravljen / Corrected: 4.12.2014.
Prihvaćen / Accepted: 30.12.2014.
Dostupno online / Available online: 10.2.2015.

Bagasse ash and rice husk ash as cement replacement in self-compacting concrete

Authors:

Thirumalai Raja Krishnasamy, M.Eng., CE
Department of Civil Engineering
Erode Builder Educational Trust's group of Institutions
kthirumalairaja@gmail.com

Prof. Murthi Palanisamy, PhD. CE
Vivekananda College of Engineering for Women
Department of Civil Engineering
drpmurthi@gmail.com

Subject review

Thirumalai Raja Krishnasamy, Murthi Palanisamy

Bagasse ash and rice husk ash as cement replacement in self-compacting concrete

In studies conducted to determine the workability of concrete, the bagasse ash and rice husk ash were added as a partial replacement for cement. Trial mixes with the varying water cement ratio, replacement percentage, quantity of super plasticizer and viscosity modifying agent, were prepared and tested. The results were used as the basis for defining three optimum cement replacement mix proportions, which comply with the self-compacting concrete requirements for several structural applications.

Key words:
self-compacting concrete, bagasse ash, rice husk ash, workability

Pregledni rad

Thirumalai Raja Krishnasamy, Murthi Palanisamy

Pepeo od šećerne trske i rižinih ljuski kao zamjena za cement u samozbijajućem betonu

Provedena su istraživanja kako bi se odredila svojstva obradljivosti betona u kojem su pepeo šećerne trske i rižinih ljuski korišteni kao djelomična zamjena za cement. Pripremljene su i ispitane probne mješavine s različitim vodocementnim omjerom, različitim udjelom zamjenskih materijala, različitom količinom superplastifikatora i stabilizatora mješavine. Na temelju dobivenih rezultata određeni su omjeri za tri optimalne betonske mješavine koje zadovoljavaju zahtjeve za samozbijajući beton koji se može koristiti za različite konstrukcijske namjene.

Ključne riječi:
samozbijajući beton, pepeo šećerne trske, pepeo rižinih ljuski, obradljivost

Übersichtsarbeit

Thirumalai Raja Krishnasamy, Murthi Palanisamy

Zuckerrohr- und Reisschalenasche als Ersatz für Zement in selbstverdichtendem Beton

Untersuchungen sind durchgeführt worden, um mit der Verarbeitbarkeit verbundene Eigenschaften von Beton, in dem Zuckerrohr- und Reisschalenasche als teilweiser Ersatz für Zement verwendet wird, zu bestimmen. Probemischungen mit unterschiedlichen Wasserzementwerten, Ersatzmaterialanteilen, Fließ- und Stabilisierungsmittelmengen wurden vorbereitet und getestet. Aufgrund der erhaltenen Ergebnisse sind die Anteile für drei optimale Betonmischungen, die den Anforderungen für selbstverdichtenden Beton zur Anwendung für verschiedene Konstruktionszwecke entsprechen, ermittelt worden.

Schlüsselwörter:
selbstverdichtender Beton, Zuckerrohrasche, Reisschalenasche, Verarbeitbarkeit

1. Introduction

The Self Compacting Concrete (SCC) was first made in the early 1980's in Japan. Due to its homogeneous nature and high workability, a relatively impervious concrete was thus formed. At present, the SCC is used in applications where requirements for High Performance Concrete (HPC) and High Strength Concrete (HSC) have to be met.
Concrete structures ranging from12m to 15m in height are termed as midrise structures. M25 & M30 concrete grades have been widely used for such midrise buildings [20, 21]. The present study therefore focuses on incorporating SCC characteristics in the normal strength concrete mix with possible addition of ash from agriculture waste such as the Bagasse Ash (BA) and Rice Husk Ash (RHA).
India is one of the world's largest producers of sugarcane, second only to Brazil, and its current production stands at around 380 million tons of sugarcane per year, which implies that large quantities of BA are also generated. Previous studies on the SCC suggest that the BA can be used in the SCC production, and that this practice enables safe disposal of BA, and keeps the environment free from pollution [1]. Due to its pozzolanic character, the extent of hydration is lower when compared to that of the conventional concrete [2-4]. A high early strength can be achieved if up to 20 percent of cement is replaced with the well burnt BA, without any adverse effect on the desirable properties of concrete [5]. The fly ash (FA) containing sieved BA has a beneficial effect on both the yield stress and viscosity, which results in lower consumption of Super Plasticizers (SP) when compared to simple mortar [6]. The fineness of BA contributes to a finer pore structure, and this fact is responsible for a reduced chloride permeation and diffusion [5]. The incorporation of FA and/or Silica Fume (SF) in SCC is very effective as a means to improve the chloride penetration resistance [29].
India also stands second in rice cultivation, next only to China, producing about 104 million tonnes per year. The production of rice husks is close to about 3.7 million tonnes per year. The addition of RHA enhances the viscosity of concrete, which improves the self-consolidating property [7]. The RHA with a high content of nano SiO_2 decreases the drying shrinkage value of SCC significantly [8]. However, a partial replacement of cement with the Fe_2O_3 nano phase, and with the TiO_2 nano phase, improves the compressive strength of concrete, but decreases its workability [9, 10]. The incorporation of 12 to 15 percent of RHA as a partial cement replacement may be sufficient to control the deleterious expansion due to alkali-silica reaction in concrete, depending on the nature of the aggregate [30].
The workability of concrete mix is proportionate to the quantum of chemical admixtures such as the SP and VMA in the conventional normal strength concrete. It can also be seen from the literature that there is no study involving supplementary addition of agro waste, such as BA and RHA, in the normal strength SCC. Akram et al [1] conclude that, to a certain extent, the BA and RHA could act as the VMA in the SCC. Since the VMA admixture is comparatively expensive, thus increasing the cost to production of the normal strength SCC, the BA and RHA are considered suitable for partial replacement of VMA in the SCC preparation. In view of the above, this paper is aimed at studying the workability of SCC by partial replacement of cement with the BA and RHA, in order to identify optimum replacement proportions.

2. Experimental program

2.1. Materials

Portland pozzolana cement based on Indian standard code IS: 1489-1991 is used as a binding material and it contains 22.5 percentage of Fly Ash (FA). The physical properties of the cement, BA, and RHA used in this study are given in Table 1. The consistency test and setting time tests are conducted for the mix proportions adopted in the present study, and the results are mentioned in Table 2, as per IS: 4031 (Part IV) – 1988 [22] and IS: 4031 (Part V) – 1988 [23].

Table 1. Physical properties of cement and other admixtures

Materials / Properties	Cement (PPC)	Bagasse ash (BA)	Rice husk ash (RHA)	IS Code
Bulk density [kg/m^3]	1480 [kg/m^3]	565 [kg/m^3]	280 [kg/m^3]	IS: 4031 (Part XI) - 1988.
Specific gravity	3.11	1.82	2.08	IS: 1727 - 1967
Percentage passing 45 µm	30	100	100	---
Specific surface area [m^2/kg]	335 [m^2/kg]	440 [m^2/kg]	550 [m^2/kg]	IS: 4031 (Part II) - 1988. IS: 3812 - 1981

In the present study, the RHA was collected from modern rice mills located in Kangayam (Tamilnadu, South India) which is popularly called the rice hub of Tamilnadu. The collected ashes were placed in the furnace for about 3 hours at the temperature of 800°C to reach the amorphous state. The air cooled sample was then sieved through the 45 µm sieve. The BA was collected from the nearby sugar factories where bagasse is used as fire wood. The BA samples were kept in furnace for 8 hours at the temperature of 800°C. The samples were then cooled, sieved at the 45µm sieve, and used in concrete mix.

Table 2. Standard consistency of paste prepared with cement or cement and ash mixture

Cement (PPC) [%]	Ash content [%]			Standard consistency			IST [min]			FST [min]		
	BA	RHA	BA+RHA	BA	RHA	BA+RHA	BA	RHA	BA+RHA	BA	RHA	BA+RHA
100	0	0	0+0=0	0.33	0.34	0.33	75	72	70	242	223	220
96	4	4	2+2=4	0.39	0.40	0.40	102	90	93	260	240	245
92	8	8	4+4=8	0.39	0.41	0.39	110	100	102	428	412	415
88	12	12	6+6=12	0.38	0.40	0.38	275	251	255	760	732	735
84	16	16	8+8=16	0.40	0.41	0.40	345	329	335	1010	932	965
80	20	20	10+10=20	0.43	0.44	0.43	402	391	390	1210	992	1130

IST – Initial Setting Time, FST – Final Setting Time

Table 3. Physical Properties of fine and course aggregate

Physical properties	Fine aggregate (river sand)	Coarse aggregate	IS Code
Specific gravity	2.497	2.79	IS: 2386 (III. Part) – 1963.
Bulk density	1928 kg/m³	1,604 kg/l	
Water absorption	23 %	4.75 %	
Moisture content	0,45 %	0 %	
Flakiness index	-	1.76 %	IS: 2386 (I. Part) – 1963.
Elongation index	-	43.63 %	
Impact value	-	16.85 %	IS: 2386 (V. Part) – 1963.

Table 4. Chemical composition of cement and BA and RHA ashes

Chemical composition / Materials	Cement (PPC)	Bagasse ash (BA)	Rice husk ash (RHA)
SiO_2 – silicon dioxide	36.4	51.47	87.76
Al_2O_3 – aluminium oxide	4.29	9.33	1.11
Fe_2O_3 – ferric oxide	2.53	-	-
CaO – calcium oxide	52.15	1.01	0.57
MgO – magnesium oxide	1.42	24.04	7.44
SO_3 – sulphur trioxide	2.16	6.70	0.51
Na_2O – sodium oxide	-	4.14	2.10
K_2O – potassium oxide	-	3.18	0.48
TiO_2 – – titanium oxide	-	0.13	0.03
Loss on ignition	1.05	-	-

The Master Glenium SKY 8760 high performance super plasticizer (Polycarboxylic ether), based on BASF, was used as SP. It is light brown in colour, its relative density is 1.09 ± 0.01 kg/l at 25°C, and its pH value is ≥ 6. The glenium stream 2 from BASF was used as VMA. It is a colourless, free flowing liquid with the relative density of 1.01 ± 0.01 at 25°C, while its pH value is ≥ 6.

2.2. Physical and chemical analysis of ashes

The Sscanning Electron Microscopy (SEM) was carried out to find the shape and size of ash particles in dry form. The scanning was done on the ash passing through the 45 µm sieve. The SEM image (Figure 1) shows the irregular shape of the BA. Just like the BA, the shape of RHA is also irregular (Figure 2). Sieving at the 45 µm sieve reduced the particle size of ashes and decreased the visible black colour of burnt carbon particles, and improved the quality of ashes [7]. The physical properties of cement and other ashes are as per IS code listed in Table 1. The chemical composition listed in Table 4 is in conformity with properties of cementitious materials as per IS: 4032 – 1985 [24].

2.3. Mix design

The mix design was made for the plain concrete grade M25. Water consistency values reported in Table 2 were adopted for SCC mixtures. Initially, a number of trial mixes were made and, finally, 1 percent of SP and 0.30 percent of VMA were selected so that the high workability without segregation or bleeding was achieved. The percentage of BA and RHA was varied and amounted to 4, 8,12,16, and 20 percent by weight with respect to cement, and an appropriate mix proportion was obtained to achieve the M25 concrete.

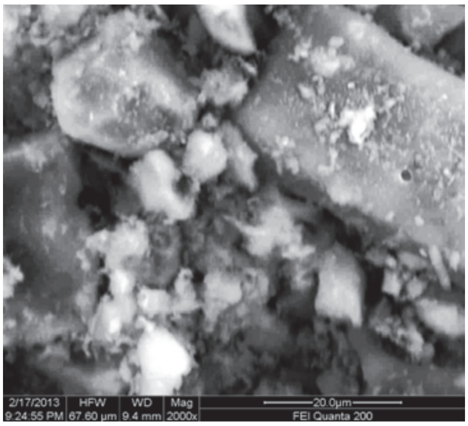

Figure 1. SEM image of BA after sieving (45µm sieve)

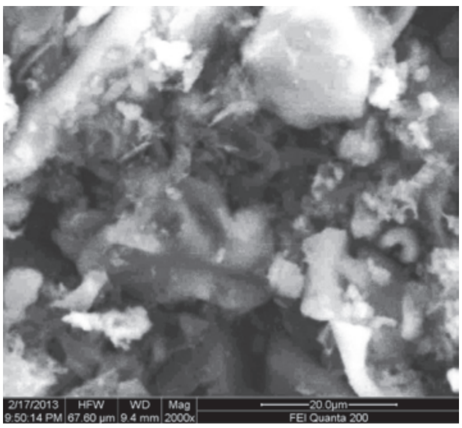

Figure 2. SEM image of RHA after sieving (45 µm sieve)

2.4. Testing of specimens

On the whole 18 different M25 mixes were tested to assess fresh concrete properties by means of the slump flow, J-ring, V-funnel, L-box, and U-box tests [11-13] as per the EFNARC specifications [16]. The tests were designed appropriately, depending on the replacement material and replacement percentage. For example, B4 refers to BA with 4 % replacement. Similarly, R8 refers to RHA with 8 % replacement, whereas B8R8 refers to BA with 8 % and RHA with 8 % replacement [1, 7].

3. Result and discussions

3.1. Physical and chemical analysis of materials

Physical properties of PPC and other cementitious ashes are given for comparison in Table 1. Density values of ashes were found to be two to four times lower than the PPC. The specific gravity, percentage passing 45 µm (Figure 3), and the specific surface areas of the cementitious ashes, were comparatively better than those of PPC. This is in conformity with the results reported by Ganesan et al [5]. It is clear that the water requirement to make the paste of standard consistency increased with an increase in the BA and RHA content, as mentioned by Memon et al [7].

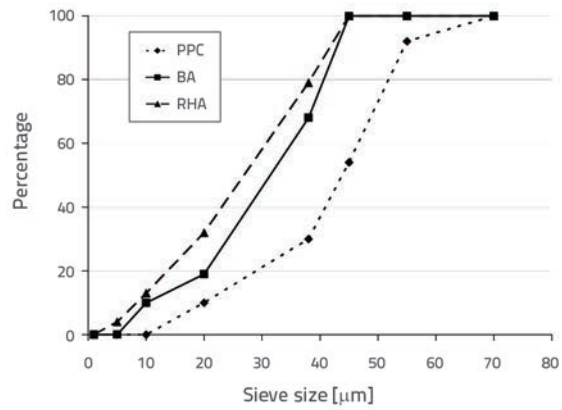

Figure 3. Particle size distribution curves of PPC, BA, and RHA

The chemical composition for PPC and the ashes is given in Table 4. As the PPC contains 22.5 percent of fly ash, the amount of SiO_2 in PPC was found to be 36.4 percent. The percentage of SiO_2 was about three times and 1.5 times of that of PPC, in the RHA and BA, respectively. This could lead to better later strength for SCC. A considerable amount of Al_2O_3 is present in BA which may increase the compressive strength of concrete during the C-S-H gel formation [14]. As the percentage of MgO is high, it increases the porosity and medium pores in the cement paste, and it decreases the large pores resulting in generally dense structures. The rate of expansion is also faster during the early curing, and it becomes stable after 150days [27].High percentage of MgO retards the initial hydration of cement and increases the setting time of cement. As the solubility product constant of $Mg(OH)_2$ is much smaller than the $Ca(OH)_2$, the $Mg(OH)_2$ precipitates earlier than the $Ca(OH)_2$. The formation of $Mg(OH)_2$ reduces the $Ca(OH)_2$ saturation ratio, thus delaying initiation of the maximum of the $Ca(OH)_2$ saturation ratio. When MgO hydrates in a high-alkali medium such as the liquid phase of hydrating cement, the $Mg(OH)_2$ with tiny crystals precipitates around the cement grains to form a protective layer, hence retarding further hydration of cement grains [25]. Na_2O and K_2O are the two oxides that are called alkali oxides. Drying shrinkage tests show that the low-alkali concrete shrinks a little more than the high-alkali one, although the two concretes lost the same amount of water. [28].

Standard consistency values of PPC with ash replacement were found to be greater than those for PPC (Table 2).This is because the specific surface area of the ashes is greater than that of PPC. The initial setting time (IST) and final setting time (FST) for all the mixes were found to be greater than those for PPC. This indicates that BA and RHA retard the setting actions. However, the final setting time is within acceptable limits of 600 min in case of up to 8 percentage replacement [26].

3.2. Properties of fresh SCC

Fresh SCC must be homogeneous and should have adequate workability. The results of tests such as the slump flow, V-Funnel, L-Box, J-Ring and U-Box, carried out to study these properties, are presented in Tables 5, 6, 7 and discussed below.

3.2.1. Slump flow test

The slump flow is a measure of the ability of concrete to flow under its own weight against friction without any external efforts [15]. The slump flow value should desirably be in the range of 650 mm to 800 mm at 0 minute [16]. However a few studies [15, 17] suggest that a slump flow of 600 mm would give acceptable workability. To examine how the fluidity of SCC changes with time taken for slump flow to reach 500 mm, the slump flow at 30 minutes after mixing was also observed [18]. The acceptable value for SCC to reach the 500 mm slump flow immediately after mixing is 2 to 5 seconds [16]. The slump flow values presented in Tables 5, 6 and 7 are also shown graphically in Figures 4 and 5, along with the target range. Figure 4 shows the slump flow value immediately after mixing for the various mixes tested. Figure 5 reflects the slump flow at 0 minute and after 30 minutes for the various mixes tested. These results (Figure 4) show that the replacement of up to B12, R16 and B6R6 satisfies the desirable target values.

Table 5. Fresh concrete properties of SCC (M25) with BA (Bagasse ash)

Mix	PPC (cement + fly ash)		BA		FA [kg/m³]	CA [kg/m³]	Standard consistency	Slump flow average [mm]			J - ring test [mm]			V - funnel [s]		L - box [mm]			U - box [mm]		
	[%]	Wt [kg/m³]	[%]	Wt [kg/m³]				0 min	30 min	T_{500} [s]	h_1	h_2	$h_1 - h_2$	T_0	T_5	h_1	h_2	h_2 / h_1	h_1	h_2	$h_2 - h_1$
B0	100	443.8	0	0	683.78	978.66	0.33	679	609	3.69	17	14	3	7.56	10.59	62	58	0.94	279	306	27
B4	96	426.04	4	17.75	683.78	978.66	0.39	691	611	3.62	20	18	2	9.12	11.11	61	58	0.88	279	303	24
B8	92	408.29	8	35.5	683.78	978.66	0.39	639.8	576	4.43	22	17	5	9.54	12.44	68	57	0.84	281	304	23
B12	88	390.54	12	53.25	683.78	978.66	0.38	610	539	5.11	25	19	6	8.89	12.31	71	58	0.82	273	306	33
B16	84	372.79	16	71.08	683.78	978.66	0.40	560.8	506.8	5.92	29	16	13	10.99	13.78	72	52	0.72	269	311	42
B20	80	355.04	20	88.76	683.78	978.66	0.43	541	485	6.4	32	16	16	11.66	15.02	75	50	0.67	263	314	51

Table 6. Fresh concrete properties of SCC (M25) with RHA (Rice husk ash)

Mix	PPC (cement + fly ash)		BA		FA [kg/m³]	CA [kg/m³]	Standard consistency	Slump flow average [mm]			J - ring test [mm]			V - funnel [s]		L - box [mm]			U - box [mm]		
	[%]	Wt [kg/m³]	[%]	Wt [kg/m³]				0 min	30 min	T_{500} [s]	h_1	h_2	$h_1 - h_2$	T_0	T_5	h_1	h_2	h_2 / h_1	h_1	h_2	$h_2 - h_1$
R0	100	443.8	0	0.0	683.8	978.7	0.34	679	609.0	3.69	17	14	3	7.56	10.59	62	58	0.94	279	306	27
R4	96	426.0	4	17.8	683.8	978.7	0.40	711	625.0	3.56	19	17	2	8.66	10.62	63	58	0.92	278	304	26
R8	92	408.3	8	35.5	683.8	978.7	0.41	688	600.5	3.96	20	16	4	9.08	11.95	64	57	0.89	280	305	25
R12	88	390.5	12	53.3	683.8	978.7	0.40	654	561.5	4.53	23	17	6	8.43	11.82	66	57	0.86	277	307	38
R16	84	372.8	16	71.1	683.8	978.7	0.41	603	533.5	5.03	28	19	9	10.53	13.29	67	54	0.81	279	308	39
R20	80	355.0	20	88.8	683.8	978.7	0.44	579	510.5	6.12	30	16	14	11.20	14.12	69	52	0.75	266	308	42

Table 7. Fresh concrete properties of SCC (M25) with BA & RHA

Mix	PPC (cement + fly ash)		BA		RHA		FA [kg/m³]	CA [kg/m³]	Standard consistency	Slump flow average [mm]			J - ring test [mm]			V - finnel [s]		L - box [mm]			U - box [mm]		
	[%]	Wt [kg/m³]	[%]	Wt [kg/m³]	[%]	Wt [kg/m³]				0 min	30 min	T_{500} [s]	h_1	h_2	$h_1 - h_2$	T_0	T_5	h_1	h_2	h_2 / h_1	h_1	h_2	$h_2 - h_1$
B0R0	100	443.80	0	0.00	0	0.00	683.78	978.66	0.33	679.0	609.0	3.69	17	14	3	7.56	10.59	62	58	0.94	279	306	27
B2R2	96	426.04	2	8.88	2	8.88	683.78	978.66	0.40	702.5	615.0	3.60	20	17	3	9.02	10.96	62	59	0.95	278	302	24
B4R4	92	408.29	4	17.75	4	17.75	683.78	978.66	0.39	651.5	592.0	4.22	22	18	4	9.46	11.98	66	56	0.85	280	303	23
B6R6	88	390.54	6	26.63	6	26.63	683.78	978.66	0.38	629.1	542.0	5.03	26	18	8	8.62	12.20	68	54	0.79	270	307	37
B8R8	84	372.79	8	35.54	8	35.54	683.78	978.66	0.40	581.0	520.0	5.66	28	16	12	10.80	12.98	72	52	0.72	266	310	44
B10R10	80	355.04	10	44.38	10	44.38	683.78	978.66	0.43	558.0	495.0	6.20	31	17	14	11.36	14.36	77	49	0.64	265	314	49

However, the slump flow value at 30 minutes shows that only the replacement of up to B4, R8, and B4R4 falls within the target values. T_{500} slump flow values tabulated in Tables 5, 6, and 7 show that the replacement of up to B8, R12 and B4R4 satisfies the EFNARC specifications [16].

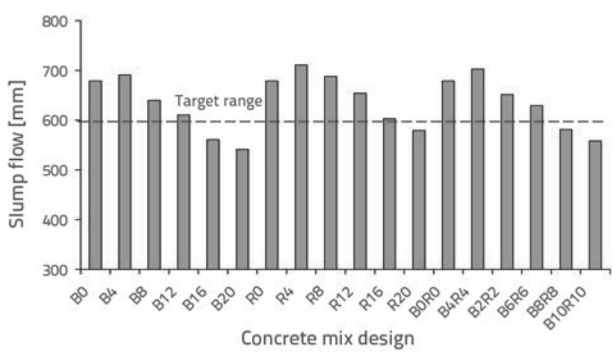

Figure 4. Slump flow of SCC for mixes tested

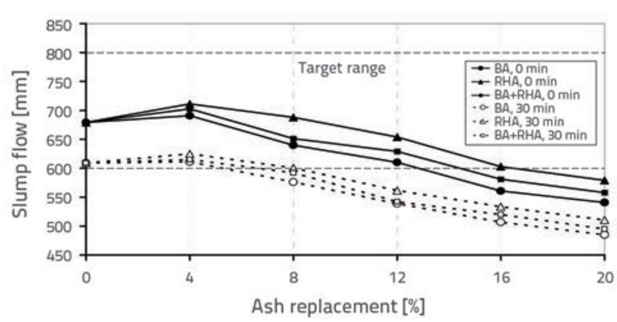

Figure 5. Slump flow at 0 min and 30 min after mixing

3.2.2. V-Funnel test

The V- Funnel test is a measure of the filling ability and segregation resistance of the SCC without any external force. The EFNARC [16] target time for the concrete to pass out of the funnel varies from 6 sec to 12 sec (V-time). If the concrete is poured into the funnel 5 min after mixing, the target V-time may be 15sec. Physically, a mixture with the V-time of 10 sec shows a certain degree of cohesiveness. Therefore, it is assumed that the V-time of more than 13 sec would be very cohesive and hard to handle [15]. It was projected that the V-funnel time ranging from 10 sec to 12 sec could be an appropriate range for the SCC mixture, while above 13 sec it would be hard to work with the SCC [17].

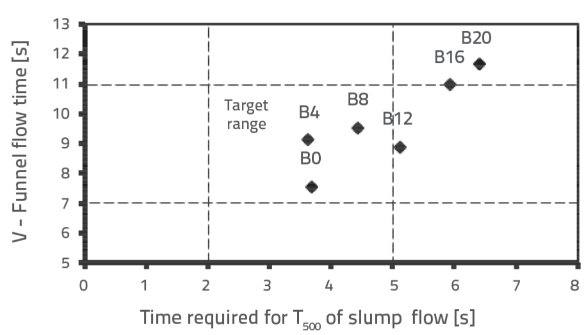

Figure 6. V-funnel timing and slump flow timing T_{500} for SCC with BA replacement

The V-funnel time values for the concrete to pass at 0 minute and 5 minutes after mixing are given in Tables 5, 6, and 7. The time required for the 500 mm slump flow (T_{500}), and V-funnel flow timings T_0 and T_{5min}, are shown in Figures 6, 7, and 8. These results show that the replacement of cement by up to 8 % of ash, either by BA or RHA, or by 4 % of BA + 4 % of RHA, produces the SCC mix that satisfies target values specified for the V-funnel flow and slump flow.

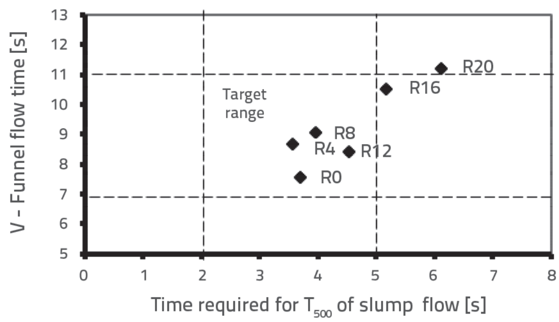

Figure 7. V-funnel timing and slump flow timing T_{500} for SCC with RHA replacement

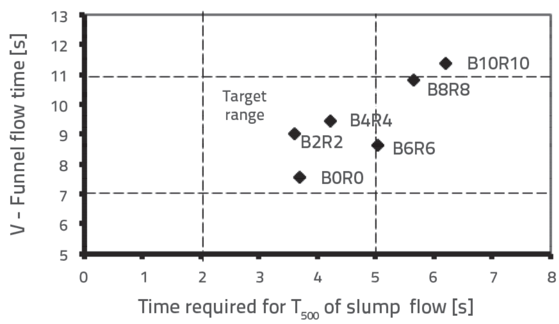

Figure 8. V-funnel timing and slump flow timing T_{500} for SCC with BA + RHA replacement

3.2.3. Results of J-Ring, L-Box, and U-Box tests

The passing ability of SCC is evaluated using the J-Ring test. For this test, the acceptable difference in height between the inside and outside should be between 0 and 10 mm. This difference in height values for the mixes is tabulated in Tables 5, 6, and 7. The L-box test evaluates the filling and passing ability of the SCC when subjected to blocking by reinforcement. The European Union research team suggested that the blocking ratio (h_2/h_1) must be no less than 0.8, and no more than 1. The U-Box test is another method to evaluate the passing and filling ability of the SCC. According to EFNARC [16], when the height difference of concrete (h_2-h_1) is less than 30mm in the U-box, the SCC is considered to have a good filling and passing ability [18]. The results of all these tests, as presented in Tables 5, 6, and 7, confirm that the replacement of cement by up to 8 % of ash produces satisfactory mixes.

As can be seen in Table 5, the BA as partial replacement for PPC, with fixed 1 percent of SP and 0.3 percent of VMA, exhibits encouraging fresh concrete properties for SCC, as revealed by Jimenez V. et al. [6]. It is clear that the BA and RHA, when added as a partial replacement for PPC in the proportion of up to 8 % AND 12 %, reveal an inherent viscosity property as mentioned by Akram T et al. As surface areas of the BA and RHA are much finer than that of the PPC, its pozzolanic character has extended the final setting for all trial mixtures of cement, as mentioned by Singh N et al and Cordeiro GC et al.

4. Conclusion

Based on the present experimental results, the physical and chemical composition of the Bagasse Ash and Rice Husk Ash is essentially responsible for the later hydration process. Their fineness and specific surface area coverage are highly suitable for the workability of concrete. The slump flow test has revealed encouraging values even after 30 minutes for the 8 % replacement with RHA, and for the BA + RHA combination. Similarly, the 8 % replacement in all three modes of mixing reveals a positive filling ability during the V-funnel test. The results obtained during the J - Ring test, L – Box test, and U – Box tests show a satisfactory level for the 8 % replacement with ashes, in all three mixing modes. Therefore, the grade M25 Self Compacting Concrete (SCC) can be produced with a partial replacement of PPC by Bagasse Ash or Rice Husk Ash, or with an up to 8 % combination of the two, without sacrificing workability requirements.

Positive results were obtained by subjecting these recommended concrete mixes to additional compressive strength tests, flexural strength tests, tensile strength tests, and durability tests.

The results obtained in the scope of the present study are expected to encourage the use of SCC with partial replacement of PPC with ash in building structures about 15m in height, where M25 concrete can adequately serve the purpose. In addition, a partial replacement of PPC with agricultural waste, such as the Bagasse Ash and Rice Husk Ash, contributes to useful disposal of these waste materials, and reduces consumption of cement, thus lowering adverse effects on the environment.

REFERENCES

[1] Akram, T., Memon, S., Obaid, H.: Production of low cost self compacting concrete using bagasse ash, Construction and Building Materials, 23 (2009), pp. 703-712, doi: http://dx.doi.org/10.1016/j.conbuildmat.2008.02.012

[2] Singh, N., Singh, V., Rai, S.: Hydration of bagasse ash-blended portland cement, Cement and Concrete Research, 30 (2000), pp. 1485-1488, doi: http://dx.doi.org/10.1016/S0008-8846(00)00324-0

[3] Cordeiro, G., Toledo, R., Tavares, L., Fairbairn, E.: Pozzolanic activity and filler effect of sugar cane bagasse ash in Portland cement and lime mortars, Cement and Concrete Composites, 30 (2008), pp. 410-418, doi: http://dx.doi.org/10.1016/j.cemconcomp.2008.01.001

[4] Cordeiro, G., Toledo, R., Tavares, L., Fairbairn, E.: Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete, Cement and Concrete Research, 39 (2009), pp. 110-115, doi: http://dx.doi.org/10.1016/j.cemconres.2008.11.005

[5] Ganesan, K., Rajagopal, K., Thangavel, K.: Evaluation of bagasse ash as supplementary cementitious material, Cement and concrete composites, 29 (2007), pp. 515-524, doi: http://dx.doi.org/10.1016/j.cemconcomp.2007.03.001

[6] Jiménez, V., León-Martínez, F., Montes-García, P., Gaona-Tiburcio, C., Chacon-Nava, J.: Influence of sugar-cane bagasse ash and fly ash on the rheological behavior of cement pastes and mortars, Construction and Building Materials, 40 (2013), pp. 691-701, doi: http://dx.doi.org/10.1016/j.conbuildmat.2012.11.023

[7] Memon, S., Shaikh, M., Akbar, H.: Utilization of rice husk ash as viscosity modifying agent in self compacting concrete, Construction and building materials, 25 (2011), pp. 1044-1048, doi: http://dx.doi.org/10.1016/j.conbuildmat.2010.06.074

[8] Sadrmomtazi, A., Barzegar, A.: Assessment of the effect of Nano-SiO_2 on physical and mechanical properties of self-compacting concrete containing rice husk ash, Second International Conference on Sustainable Construction Materials and Technologies, Universita Politecnica delle Marche, Ancona, 2010.

[9] Nazari, A., Sh, R., Sh, R., Shamekhi, S., Khademno, A.: Benefits of Fe_2O_3 nanoparticles in concrete mixing matrix, Journal of American Science, 6 (2010), pp. 102-106.

[10] Nazari, A., Sh, R., Sh, R., Shamekhi, S., Khademno, A.: Assessment of the effects of the cement paste composite in presence TiO_2 nanoparticles, Journal of American Science, 6 (2010), pp. 43-46.

[11] Ramanathan, P., Baskar, I., Muthupriya, P., Venkatasubramani, R.: Performance of self-compacting concrete containing different mineral admixtures, KSCE Journal of Civil Engineering, 17 (2013), pp. 465-472, doi: http://dx.doi.org/10.1007/s12205-013-1882-8

[12] Uysal, M., Sumer, M.: Performance of self-compacting concrete containing different mineral admixtures, Construction and Building materials, 25 (2011), pp. 4112-4120, doi: http://dx.doi.org/10.1016/j.conbuildmat.2011.04.032

[13] Felekoğlu, B., Türkel, S., Baradan, B.: Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete, Building and Environment, 42 (2007), pp. 1795-1802, doi: http://dx.doi.org/10.1016/j.buildenv.2006.01.012

[14] Nazari, A., Riahi, S.: The effect of aluminium oxide nanoparticles on the compressive strength and structure of self-compacting concrete, Magazine of concrete research, 64 (2012), pp. 71-82, doi: http://dx.doi.org/10.1680/macr.10.00106

[15] Topcu, I., Bilir, T., Uygunoğlu, T.: Effect of waste marble dust content as filler on properties of self-compacting concrete, Construction and Building Materials, 23 (2009), pp. 1947-1953, doi: http://dx.doi.org/10.1016/j.conbuildmat.2008.09.007

[16] EFNARC Specifications and guidelines for self-compacting concrete, UK, 2002., p. 32.

[17] Safawi, M., Iwaki, I., Miura, T.: A study on the applicability of vibration in fresh high fluidity concrete, Cement and concrete research, 35 (2005), pp. 1834-1845, doi: http://dx.doi.org/10.1016/j.cemconres.2004.10.031

[18] Wu, Z., Zhang, Y., Zheng, J., Ding, Y.: An experimental study on the workability of self-compacting lightweight concrete, Construction and Building Materials, 23 (2009), pp. 2087-2092, doi: http://dx.doi.org/10.1016/j.conbuildmat.2008.08.023

[19] IS: 2386-1963 Part I. to VIII. Indian Standard Methods of Test for Aggregate for concrete, *Bureau of Indian Standards*, New Delhi.

[20] IS: 10262-1982 and SP 23:1982., Recommended Guidelines for concrete Mix., *Bureau of Indian Standards*, New Delhi.

[21] IS: 516-1959., Indian Standard Methods of Test for Strength of concrete, *Bureau of Indian Standards*, New Delhi.

[22] IS: 4031(Part IV) - 1988., Indian Standard Methods of Physical Tests for Hydraulic Cement, *Bureau of Indian Standards*, New Delhi.

[23] IS: 4031(Part V) - 1988., Indian Standard Methods of Physical Tests for Hydraulic Cement, *Bureau of Indian Standards*, New Delhi.

[24] IS: 4032 - 1985., Indian Standard Method of Chemical Analysis of Hydraulic Cement, *Bureau of Indian Standards*, New Delhi.

[25] Zheng, L., Xuehua, C., Mingshu, T.: Hydration and setting time of MgO-type expansive cement, *Cement and concrete research*, 22 (1992), pp. 1-5, doi: http://dx.doi.org/10.1016/0008-8846(92)90129-J

[26] IS: 1489 (Part I) - 1991., Indian Standard Portland - Pozzolana cement specification, *Bureau of Indian Standards*, New Delhi.

[27] Li, F., Chen, Y., Long, S.: Influence of MGO Expansive Agent on Behavior of Cement Pastes and Concrete, *Arabian Journal for Science and Engineering*, 35 (2010), pp. 125-140.

[28] Smaoui, N., Bérubé, M., Fournier, B., Bissonnette, B., Durand, B.: Effects of alkali addition on the mechanical properties and durability of concrete, *Cement and Concrete Research*, 35 (2005), pp. 203-212, doi: http://dx.doi.org/10.1016/j.cemconres.2004.05.007

[29] Yazıcı, H.: The effect of silica fume and high-volume Class C fly ash on mechanical properties, chloride penetration and freeze–thaw resistance of self-compacting concrete, *Construction and building Materials*, 22 (2008), pp. 456-462, doi: http://dx.doi.org/10.1016/j.conbuildmat.2007.01.002

[30] Givi, A., Rashid, S., Aziz, F., Salleh, M.: Contribution of rice husk ash to the properties of mortar and concrete: a review, *Journal of American science*, 6 (2010), pp. 157-165.