American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-9, pp: 47-51
www.ajer.org
Research Paper Open Access

Effect of Rice Husk Ash on the Sorptivity of Concrete

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ABSTRACT : *This paper investigated the effect of rice husk ash on the sorptivity of concrete. Rice husk ash was used to partially replace the Portland cement contents of concrete at the replacement levels of 0-50%. Compressive strength at 28 days and Sorptivity at 28, 90, 120 and 180 days were obtained at the water/cement ratios of 0.35, 0.50 and 0.65 and examined at equal 28-day compressive strengths of 25-40 N/mm^2. Results revealed that, at equal water/cement ratios, sorptivity values increased with increasing content of rice husk ash and reduced with increasing curing age. Sorptivity increased by an average of 0.98 and 0.49% at 28 and 180 days, respectively, for a unit replacement of Portland cement with rice husk ash. At equal strengths, sorptivity reduced with increasing content of rice husk ash and all the blended cement concretes have better resistance to sorption than Portland cement concrete. Hence, rice husk ash has the propensity to improve the permeation resistance of concrete.*

KEYWORDS *absorption, concrete, permeation resistance, rice husk ash, sorptivity.*

Date of Submission: 21-08-2021 Date of acceptance: 05-09-2021

I. INTRODUCTION

The use of by-products of industrial wastes such as fly ash, silica fume and ground granulated blast furnace slag (GGBS), as partial replacement for Portland cement in concrete, is recognised, among others, by BS EN 197-1 [1], BS EN 206-1 [2], BS 8500-1 [3] and BS 8500-2 [4]. This is due to their ability to produce cheaper and more environmentally friendly concrete than the conventional Portland cement concrete [5-7]. Rice husk ash, a by-product of agricultural waste, has high silica content and could be used at up to 50% content as partial replacement for Portland cement in concrete [8]. Also, the use of rice husk ash would result in blended cement concrete with better compressive strength, microstructure and permeation resistance than the conventional Portland cement concrete at equal water/cement ratios at later ages and at equal 28-day compressive strengths [8]. However, like the other by-products of agricultural wastes, the use of rice husk ash (RHA) has not been recognised by relevant cement and concrete standards.

A permeable concrete would permit the entry of water and deleterious substances in aggressive environments and make concrete structures less durable. BS 8500-1 [3] presenting the minimum requirements for concrete in various exposure conditions for working lives of at least 50 and 100 years shows that the service life of concrete structures depends on the durability of concrete. Hence, the permeation resistance of concrete has an important role to play in the durability of concrete. Permeation could be investigated with the aid of initial surface absorption, air and water permeability and sorptivity among others [9]. Sorptivity measures the rate of absorption of water [10] and could be used to assess the capillary rise of water in porous concrete when no pressure is applied [9]. Hence, sorptivity could be used to assess the microstructure and the resistance of concrete to water movement through sorption that could result in rising dampness or permit the ingress of deleterious substances that could impair concrete quality or cause problems in structural concrete. In order to provide more information on the suitability of RHA, this paper investigates its effect on the sorptivity of concrete at equal water/cement ratios and 28-day strengths.

II. MATERIALS AND METHODS

The experimental materials were Portland cement (PC, 42.5 Class), rice husk ash (RHA) obtained by calcining rice husk at 600^{o}C and fine and coarse aggregates. In line with Folagbade [8], Portland cement was partially replaced with RHA at 0, 10, 20, 30, 40 and 50% contents. The mix proportions, at the water/content of 210 kg/m^3 and water/cement ratios of 0.35, 0.50 and 0.65, were obtained using the Building Research and

Establishment (BRE) guide [11]. Concrete was mixed, placed, demoulded and cured in water until the test dates. Mapefluid N200 was used as superplasticiser to achieve a consistence level of S2 defined by a nominal slump of 50-90 mm in BS EN 206-1 [2]. The properties of the cements and the preparation of the concrete mixes are as detailed in Folagbade [8]. Tests were performed to determine the compressive strength at 28 days and sorptivity at 28, 90, 120 and 180 days. Compressive strength was determined in accordance with BS EN 12390-3 [12].

Sorptivity was determined in accordance with ASTM C 1585 [10] using 100 mm diameter and 50 mm thick concrete discs cut from 100 mm diameter and 300 mm thick water-cured concrete cylinders. Specimen was oven dried to constant mass at 105 ± 5 °C, cooled in a desiccator containing silica gel and the side was waxed with molten candle. One end was covered with loose plastic sheet fastened with masking tape to prevent water loss through evaporation and accommodate the air in the pores of the specimen displaced by water. The mass of the specimen was measured and recorded as the initial mass for water absorption calculation. After this, the other end of the specimen was placed on the support device positioned in a pan containing water and a level of about 3 mm above the top of the support device was maintained throughout the test (Figure 1).

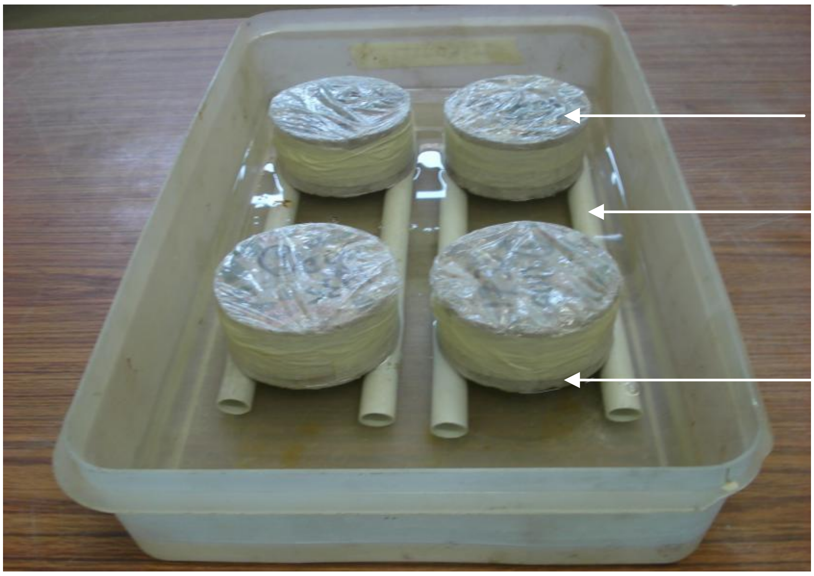

Fig. 1: Sorptivity test specimens

Sorptivity test was conducted over 6 hours after the first contact of the specimen with water and the cumulative change in mass at each test age was determined. At each test age, the specimen was removed from water, cleaned with dampened paper towel to remove water droplets from the surface, weighed to obtain the mass and immediately replaced on the support device to continue the test. The tests were conducted, continuously, at 1, 5, 10, 20 and 30 minutes and at 1, 2, 3, 4, 5 and 6 hours. The cumulative absorption, at each test age, was obtained by dividing the cumulative change in mass by the product of the cross-sectional area of the test specimen and the density of water. Sorptivity was obtained as the slope of the line that best fits the plot of the cumulative absorption values against the square root of test times (test times measured in seconds).

III. RESULTS AND DISCUSSION

Sorptivity of concrete at different water/cement ratios

Figure 2 compares the sorptivity of PC and RHA blended cement concretes at the water/cement ratios of 0.35, 0.50 and 0.65. Sorptivity decreased with increasing curing age and increased with increasing water/cement ratio and content of RHA. The decrease in the sorptivity with increasing curing age would be attributed to increasing content of the performance enhancing hydration products arising from the hydration reaction of Portland cement and the pozzolanic reaction of RHA. Sorptivity increased with increasing water/cement ratio due to decreasing content of the cements (PC and RHA) with increasing water/cement leading to reduction in the hydration products required for improved performance of the PC and blended cement concretes. Sorptivity of concrete also increased with increasing content of RHA. This is probably, on one hand, due to reduction in the Portland cement content and reduction in the content of calcium hydroxide ($Ca(OH)_2$) available for pozzolanic reaction of RHA. On the other hand, the pozzolanic reaction is a delayed reaction as it will have to wait for $Ca(OH)_2$ to be produced by the hydration reaction of PC. These results agree with previous results on other supplementary cementitious materials by Bai et al. [13] and Folagbade and Newlands [14].

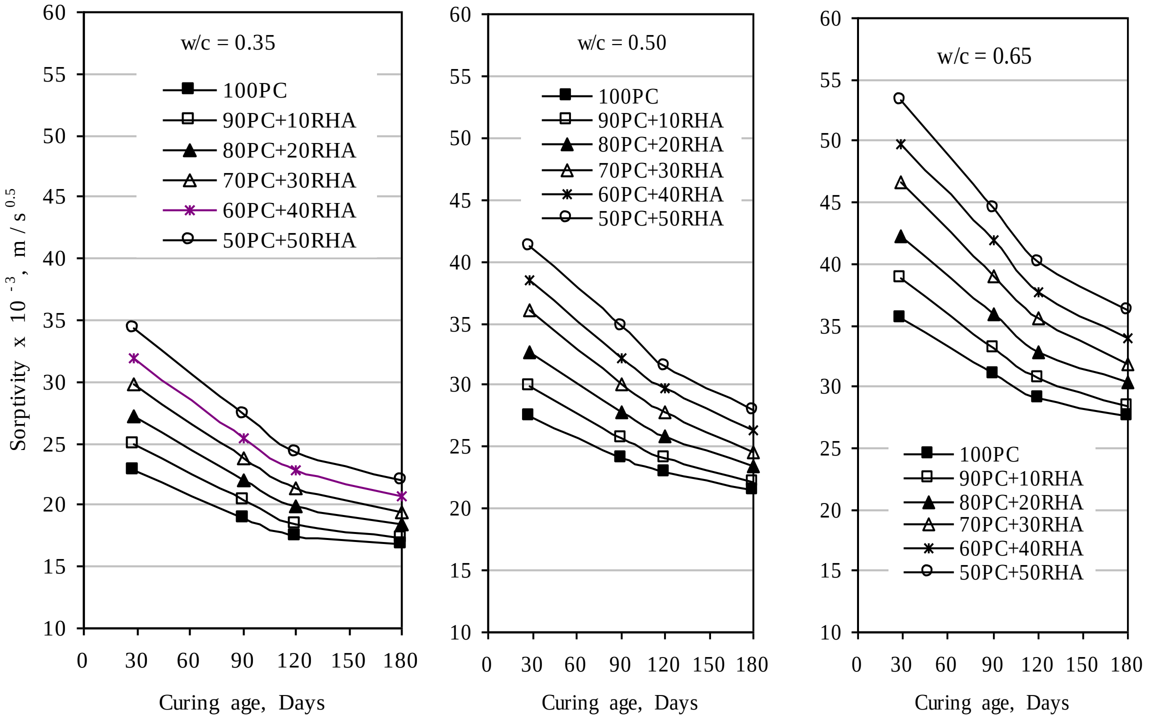

Fig. 2: Sorptivity of concretes at different water/cement ratios

Table 1 presents the sorptivity factors of the concretes. The sorptivity factors measure the ratios of the sorptivity values of the blended cement concretes to the sorptivity values of the Portland cement concrete over the curing ages and water/cement ratios. The sorptivity factors reduced with increasing curing age. The reduction in the disparity between the sorptivity factors of the PC and the blended cement concretes also confirms the contribution of the pozzolanic reaction of RHA to improved performance of the blended cement concrete with increasing curing age.

Table 1: Compressive strength and sorptivity factors of concretes

Mix combination	w/c	28-Day strength, N/mm^2	Sorptivity factors, %					
			Day 28	Day 90	Day 120	Day 180	Day 28 Average,	Day 180 Average,
100PC	0.35	67.5	100	100	100	100	100	100
	0.50	49.5	100	100	100	100		
	0.65	38.0	100	100	100	100		
90PC+10RHA	0.35	60.5	108.99	107.79	105.71	103.04	109.00	103.02
	0.50	44.5	109.02	107.00	105.06	103.02		
	0.65	34.0	109.00	107.17	105.93	103.01		
80PC+20RHA	0.35	54.5	118.98	116.86	114.06	110.00	119.00	109.64
	0.50	40.0	119.02	116.08	112.78	109.07		
	0.65	30.0	119.01	116.19	113.38	109.86		
70PC+30RHA	0.35	47.0	131.00	126.35	122.17	115.42	131.00	114.99
	0.50	35.0	131.02	125.33	121.47	114.37		
	0.65	26.5	130.99	126.17	122.55	115.18		
60PC+40RHA	0.35	39.5	139.98	134.89	130.57	123.33	139.96	122.82
	0.50	29.0	140.00	133.96	129.80	122.23		
	0.65	22.5	139.90	135.22	130.14	122.90		
50PC+50RHA	0.35	32.5	150.46	144.80	138.46	130.83	150.15	130.74
	0.50	23.0	150.07	144.63	137.78	130.37		
	0.65	18.0	149.92	143.94	138.14	131.01		

At 28 days, the average increases in sorptivity factors were respectively 9.00, 19.00, 31.00, 39.96 and 50.15% at 10, 20, 30, 40 and 50% contents of RHA. This results, respectively, in sorptivity increases of 0.90, 0.95, 1.03, 1.00 and 1.00% (with an average of 0.98%) per unit increase in the content of RHA. At 180 days, the average increases in sorptivity factors were respectively 3.02, 9.64, 14.99, 22.82 and 30.74% at 10, 20, 30, 40 and 50% contents of RHA resulting respectively in sorptivity increases of 0.30, 0.48, 0.50, 0.57 and 0.62% (with an average of 0.49%) per unit increase in the content of RHA. This result is also in line with previous studies by Folagbade [8], Bai et al. [13] and Folagbade and Newlands [14] which show that pozzolanic reactivity increasing with increasing curing age would result in improved performance of concrete. Hence, with increasing pozzolanic reaction the sorptivity resistance of RHA blended cement concrete could become comparable or better than that of Portland cement concrete at later ages.

Sorptivity of concrete at different 28-day compressive strengths

Table 2 presents the sorptivity values of concretes at equal 28-day compressive strengths of 25-40 N/mm^2. The values were obtained by interpolating the 28-day compressve strengths (Table 1) and the 28-day sorptivity values of the concretes. The Table shows that sorptivity reduced with increasing compressive strength and with increasing content of RHA. The Table also shows that the blended cement concretes at up to 50% contents of RHA performed better than the PC concrete at these strengths. This result is in line with previous study by Folagbade [8] which supports an RHA content of up to 50% as partial replacement for PC content of concrete. In addition to the high silica content resulting in higher reactivity [8], the higher permeation resistance of the blended cement concrete could be due to the spherical shape of RHA [15, 16] resulting in better particle packing and denser microstructure. Hence, if appropriate designed, RHA blended cement would produce concrete with higher permeation resistance than the conventional Portland cement concrete.

Table 2: Sorptivity of concretes at different 28-day compressive strengths

Mix combination	25 N/mm^2		30 N/mm^2		35 N/mm^2		40 N/mm^2	
	w/c	Sorptivity x 10^{-3}, m/√s	w/c	Sorptivity x 10^{-3}, m/√s	w/c	Sorptivity x 10^{-3}, m/√s	w/c	Sorptivity x 10^{-3}, m/√s
100PC	-	-	-	-	-	-	0.61	33.08
90PC+10RHA	-	-	-	-	0.63	37.38	0.55	32.50
80PC+20RHA	-	-	0.64	41.56	0.56	36.09	0.49	32.23
70PC+30RHA	-	-	0.58	41.11	0.50	36.03	0.43	32.61
60PC+40RHA	0.58	43.92	0.48	37.35	0.40	33.6	<0.32	< 31.93
50PC+50RHA	0.46	38.92	0.38	35.30	-	-	-	-

IV. CONCLUSION

Based on the investigation carried out on the sorptivity of RHA blended cement concrete, the following conclusions have been drawn.

- Sorptivity increased with increasing water/cement ratio and increasing content of RHA and reduced with increasing curing age.
- Due to continuous pozzolanic reaction, the disparity between the blended cement concrete and the conventional PC concrete reduced with increasing curing age.
- At equal strengths, all the RHA blended cement concrete at up to 50% content have higher sorptivity resistance than the conventional PC concrete.

Hence, in practice, RHA blended cement concrete would have better resistance to water movement by sorption than the conventional PC concrete.

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FOLAGBADE Samuel Olufemi. "Effect of Rice Husk Ash on the Sorptivity of Concrete."*American Journal of Engineering Research (AJER)*, vol. 10(9), 2021, pp. 47-51.