DOI: 10.2478/v10077-011-0001-0

Badorul Hisham Abu Bakar, Ramadhansyah Putra Jaya, Megat Azmi Megat Johari, Mohd Haziman Wan Ibrahim
School of Civil Engineering, Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Pulau Pinang, Malaysia
cebad@eng.usm.my

ENGINEERING PROPERTIES OF NORMAL CONCRETE GRADE 40 CONTAINING RICE HUSK ASH AT DIFFERENT GRINDING TIME

ABSTRACT

The effect of rice husk ash with different grinding time on the engineering properties of concrete was studied. Eight rice husk ashes with different grinding were used in this investigation. Rice husk ash was used to partially replace Portland cement Type I at 15% by weight of cementitious material. The 100-mm concrete cube specimens were cast and cured in water for 7 and 28 days. The compressive strength of concrete was designed to achieve of grade 40 N/mm^2 at 28 days. A superplasticizer was added to all mixes to provide workability in the range of 110 – 120 mm. However, the water to cement ratio (w/c) of the concrete was maintained at 0.49. Based on the results, the morphology of the rice husk ashes were changed by grinding. These appear to be an optimum grinding time of approximate 90 minutes which the compressive strength increased significantly. Generally, incorporation of RHA at varies grinding time can be decrease or increased the engineering properties of concrete extremely.

Key words: *grinding, compressive strength, superplasticizer, concrete, rice husk ash*

INTRODUCTION

Mineral admixtures have been used successfully to partially replace energy and resources dependent Portland cement. The technical advantage of using these mineral admixtures is the enhancement of many properties in the fresh and hardened states, including lower heat of hydration, improved durability, and higher ultimate strengths [1]. Current technology points to the fact that the ash produced by burning rice husk, can be used as a supplementary cementitious material in concrete [2]. Under controlled burning and after grinding to a specified fineness, the ash produced by increasing rice husk is pozzolanic. Being a pozzolan, it will contribute to higher long term strength and improve the durability of concrete. On the other hand, Rukzon and Chindaprasirt [3] reported that fly ash has a high potential to develop into a good pozzolanic material if it is improved to have high fineness.

Many researchers had been modifying the concrete properties such as from normal to higher concrete by adding some mineral admixtures; RHA, SF, metakaolin, fly ash, etc. Hewlett [4] stated that when cementitious is added to a concrete mix, it will increase the strength significantly. Coutinho [5] also reported that the concrete incorporated with RHA improved the compressive strength drastically. Several researchers have studied the durability variation of the concrete with pozzolanic materials [6, 7]. According to Temiz et al [8] noted that used of the pozzolanic materials can improve the permeability of concrete. SiO_2 present in pozzolanic material which is used in cement and concrete production, can react with $Ca(OH)_2$ to form C-S-H gel. This C-S-H gel reduces the permeability of the concrete by filling the cavities in the matrix.

Most of the previous works have been carried out on the effect of the fly ash fineness of cement paste, concrete, or mortar. But in this investigation, the results of the effects of grinding on the engineering properties of eight rice husk ash finenesses are presented. Optimum ground RHA with regards of concrete it to be determined. Ordinary Portland cement (OPC) and ground rice husk ash are used as the base materials for studying the blended cement. The beneficial effects of inclusion of RHA at various grinding in concrete properties are clearly shown in this paper.

MATERIALS AND METHODS

Materials

The Ordinary Portland cement (OPC) Type I from a local manufacturer was used. It has a specific gravity and specific surface of 3.12 g/cm^3 and 359 m^2/kg conducted by using Blaine test. Rice husk used was obtained from a typical local rice milling factory. This rice husk was burned to ash at 700°C for 6 hours in gas furnace with the heating rate of 10°C/min. After a cooling down period, which may take 24 hours, the ash was ground using the laboratory ball mill with porcelain balls to achieve the required fineness standard of BS 3892 [9]. The grading analysis, X-ray diffraction (XRD), and SEM photograph were performed on the rice husk ash. The fineness test was determined in accordance with ASTM C204 [10]. The coarse aggregate used was crushed granite with 20 mm maximum size. The fine aggregate was natural river sand, having a fineness modulus of 3.11. The coarse and fine aggregates had a specific gravity of 2.66 and 2.70, and water absorption of 0.48% and 0.62%, respectively and conformed to Zone 1 of BS 882 [11].

Superplasticizer

The GLENIUM C380 superplasticizer was used throughout the investigation. The specific gravity is 1.07-1.16 while the pH in the range of 6 to 7.5. Though, the colour of the superplasticizer is Light brown.

Grinding of rice husk ash

Grinding tests were carried out using a laboratory ball mill with porcelain balls. A grinding mill, 140 mm in length and 235 mm in diameter was used. In experiments, 150 gram of rice husk ash was put into the mill and ground with the grinding media as presented in Table 1. The rice husk ash was ground separately for up to 5 hours. The rice husk ash was taken after 30, 60, 90, 120, 180, 240, and 300 minutes of grinding and was ground into eight lots. The unground rice husk ash, having an average particle size of about 17.96µm, was identified as RHA0; further explanation is exhibited in Table 2.

***Table 1**. Summary of mill characteristics and grinding conditions used in this study*

<table>
<tr><th>Parameters</th><th colspan="2">Value</th><th>Remark</th></tr>
<tr><td>Mill</td><td colspan="2">14 x 23.5 cm</td><td>Ceramic (porcelain)</td></tr>
<tr><td rowspan="4">Porcelain ball</td><td>Size (mm)</td><td>Amount</td><td rowspan="4">Ceramic (porcelain)</td></tr>
<tr><td>30</td><td>20</td></tr>
<tr><td>20</td><td>40</td></tr>
<tr><td>10</td><td>300</td></tr>
<tr><td>Milling Speed</td><td colspan="2">76 rev/min</td><td></td></tr>
</table>

***Table 2**. Designation of rice husk ash with different grinding*

Time of grinding (minute)	0	30	60	90	120	180	240	300
Description	RHA0	RHA30	RHA60	RHA90	RHA120	RHA180	RHA240	RHA300
Particles size (μm)	17.96	10.93	9.74	9.52	9.34	8.70	6.85	6.65

Mix proportions

All mix proportions had the same replaced of rice husk ash at rate of 15% by weight of binder. The water to cementitious materials ratio (w/b) was 0.49 and superplasticizer was employed in all concrete mixtures in order to maintain the slump of fresh concrete between 110 and 120 mm. The mixes were designed to achieve concrete of grade 40 N/mm^2 at 28 days. Two mix proportions of concrete were used in the current study. The first mix was the control concrete (control) containing only Portland cement type I as cementitious materials, and the second mix contained the replacement of Portland cement type I by rice husk ash at different grinding. The concrete mix proportions were presented in Table 3. The size of the cylindrical mold used to cast all the concrete samples was 100 mm in diameter and 100 mm in height. After 24 hours, the concrete samples were removed from the molds and cured in water at room temperature. They were tested to determine their compressive strengths at the ages of 7 and 28 days.

***Table 3.** Concrete mix proportions*

Symbol	Sp (%)	Slump (mm)	Water (kg/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
OPC	0	120	205	420	950	805
RHA 0	1.55	120	205	357	950	805
RHA 1	1.38	118	205	357	950	805
RHA 2	1.30	118	205	357	950	805
RHA 3	1.15	121	205	357	950	805
RHA 4	0.90	119	205	357	950	805
RHA 5	0.90	120	205	357	950	805
RHA 6	0.85	118	205	357	950	805
RHA 7	0.80	120	205	357	950	805

Compressive strength

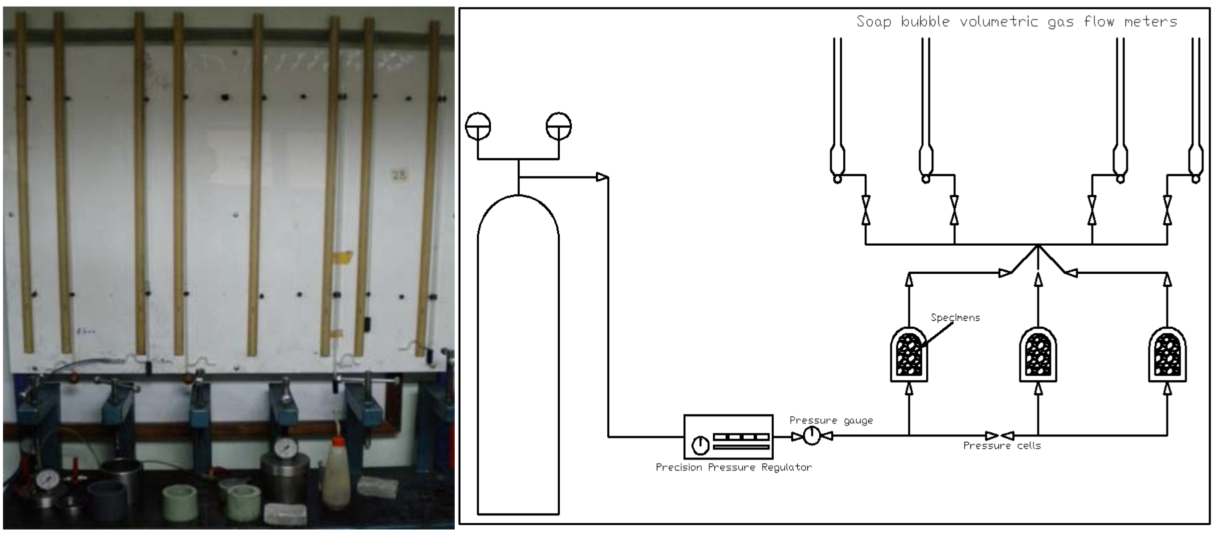
Cubes of 100x100x100 mm size were cast and compacted in two layers on a vibrating table. The test was carried out according to the BS EN 12390 [12]. Each layer was vibrated for 10s. After that, the moulds were covered after cast with polyethylene sheets and moistened burlap for 24h. Thereupon, the specimens were demoulded and cured in water at a temperature of 20°C until the day of testing. Compressive strength of the concrete was determined at 7 and 28 days, with three specimens per test age.

Gas Permeability

The cylinder of 50 mm diameter with 40 mm thick were cored and cut from prisms 100x100x500 mm to obtain the specified dimension. Prior to the permeability test, cylinder specimens would be dried at 105°C in oven for 24 hours. When the dried process finished, the samples were applied with a thin layer of silicon rubber to the curved surface and stored in a dessicator for 24 hours. Then, they were placed in the permeability cell and gas pressure was applied of 2 bars for 10 minutes to get fitting steady state. The time of gas flow was measured using the appropriate bubble meter within 100 mm length of flow meter with 3 mm diameter. This method had been developed by RILEM [13] and Abbas et al [14]. Schematic layout of the apparatus is illustrated in Fig. 1. Gas permeability coefficient *K* is calculated using the following equation:

$$\mathrm{K} = 2\mathrm{P}_2 \frac{VL\, x 1.76 x 10^{-16}}{A\left(P_1^2 - P_2^2\right)} \qquad (1)$$

Where K is permeability coefficient, m^2; P_1 is absolute applied pressure, bar; P_2 is pressure at which the flow rate is measured, bar; A is measured cross-sectional area, m^2; L is length of specimen, m; and V is flow rate, cm^3/sec.



(a) (b)

Fig. 1. (a), (b). Experimental setup for gas permeability test

Schmidt hammer test methods

The rebound number, a NR-type Schmidt hammer was used in this investigation and depicted in Fig. 2. The test was carried out according to BS EN 12504 [15]. A uniform compressive stress of 2.5 Mpa was provided to the test specimen of 100mm height, 100mm width and 100mm length along the vertical direction-the same direction with casting direction, before striking it with the hammer to prevent the dissipation of hammer striking energy due to the lateral movement of the specimen. Striking points were uniformly distributed to reduce the influence of local aggregates distribution, and the rebound number of the specimen was obtained by averaging the results. The test procedure used in current technique was similar to that original established by Kim et al [16].

Fig. 2. Schematic view for measurement of rebound number

Ultrasonic equipment and measuring technique

The ultrasonic equipment used in this study was the portable ultrasonic non-destructive digital indicating tester (PUNDIT) which carried out according to BS EN 12504 [17]. The PUNDIT can be used with piezo electric transducers over a frequency range from 20 to 500 kHz. According to Gaydecki et al [18] recommended to use the low frequencies in the range of 40–80 kHz in evaluating the concrete. All prepared concrete specimens were evaluated using UPV at different curing times: 7 and 28 days curing in a water bath at 20^{o}C. Before each UPV measurement, the concrete were removed from the water bath and its surface was dried before placing the transducer and performing the measurement. In order to ensure uniform and constant pressure between transducers and concrete surfaces, the transducers were pressed by hand to apply about 10 N of constant force. Also, Vaseline was used as a coupling between the transducer and concrete surface. The PUNDIT device was used to read the time required for ultrasonic waves to transfer across the specimen. This procedure was similar to Qudais [19].

RESULTS AND DISCUSSION

Characterization of the ash

A graphical presentation of the particle size data at various grinding time is shown in Fig. 3. It can be seen that the expected reduction in particle size of RHA with the increased in grinding time is evident. At grinding time up to 300 minutes, the particle size of 6.65μm was achieved. Particle morphology was characterized qualitatively with the aid of scanning electron microscope (SEM) images, obtained using a Zeiss Supra 55VP. Fig. 4 shows a comparison between OPC and RHA produced before and after grinding. Fig. 4(b) shows that RHA unground presented a coarser quartz particle. After grinding, RHA also presented some coarser quartz particles; however, the cellular grains were totally broken down (Fig. 4(c) by the mechanical action of the grinding media. It reveals that the RHA and Portland cement type I have irregular and crushed shaped particles, whereas the original rice husk ash has spherically shaped particles. Particle size distribution curves of the materia.ls were obtained by using HELOS Particle Size Analyses and the results were illustrated in Fig. 5. It should be noted that, after coarse rice husk ash had been ground, the median particle size was reduced from about 17.96μm to 6.65μm. This is due to the hollow or porous particles of coarse fly ash have been crushed to be fine particles [20]. The particle size of the RHA decreased with increasing grinding time. The particle size decrease was most significant during the first 30 minutes of grinding. After 30 minutes of grinding, most of the large particles had been crushed so that all the particles were less than 10μm, and more than 50% of the particles were less than 9μm. Further increase in the grinding time was less effective in increasing the particle fineness [21].

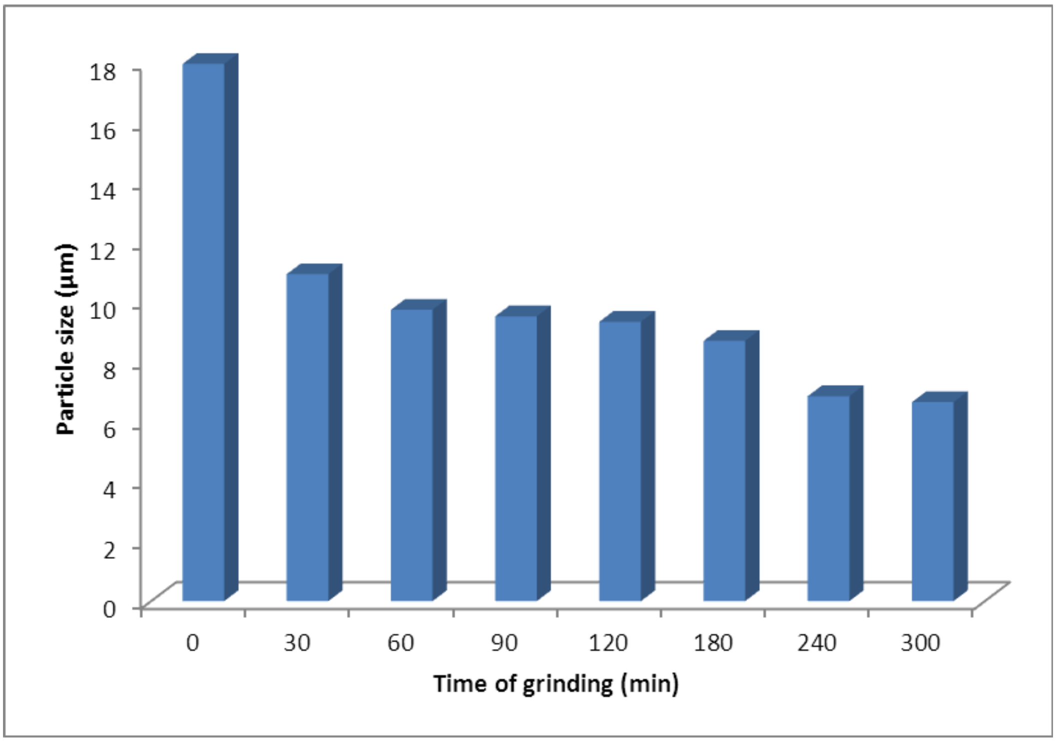


Fig. 3. Particles size of the RHA at different grinding time

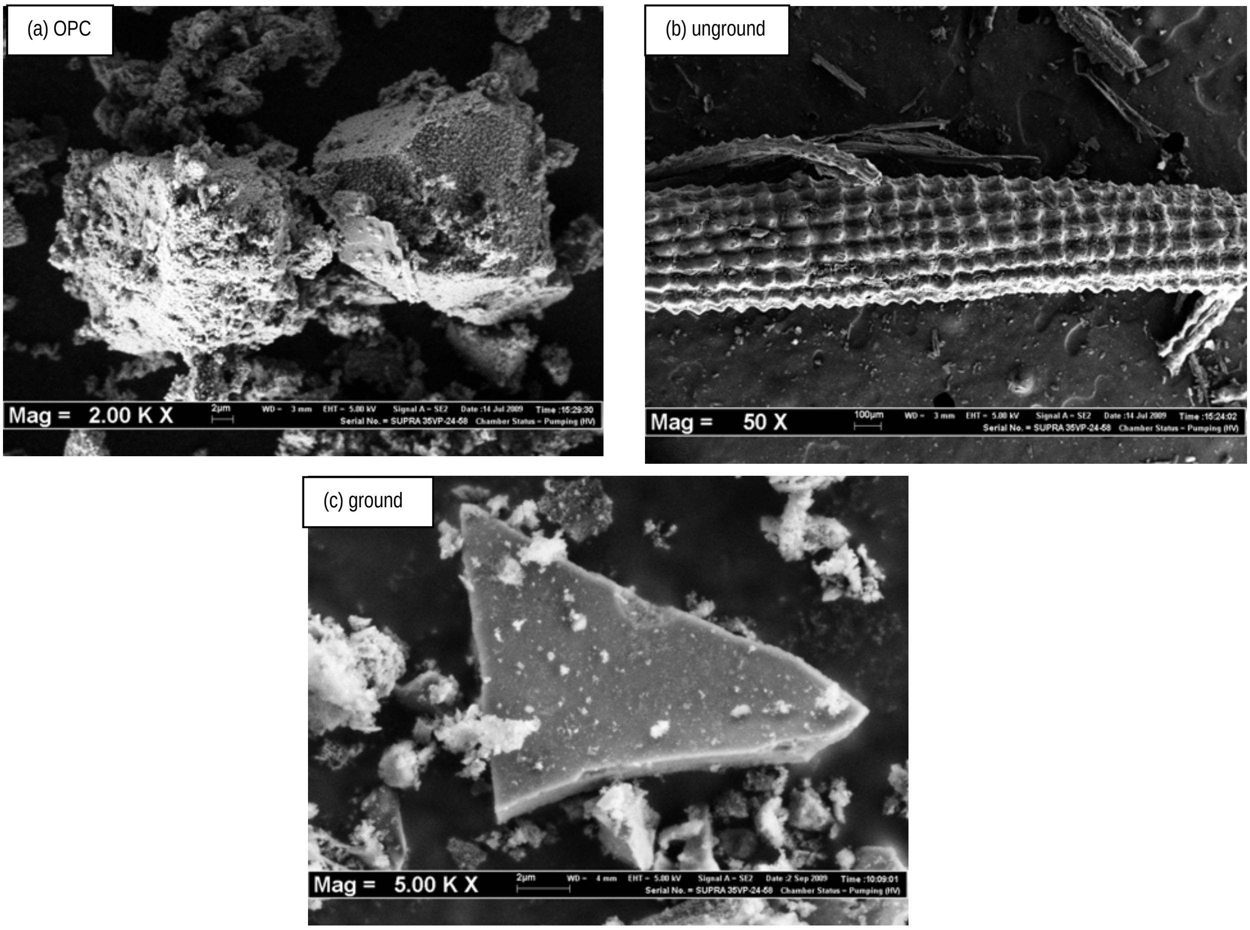


Fig. 4. Scanning electron microscope of materials; (a) OPC; (b) unground; (c) grounded

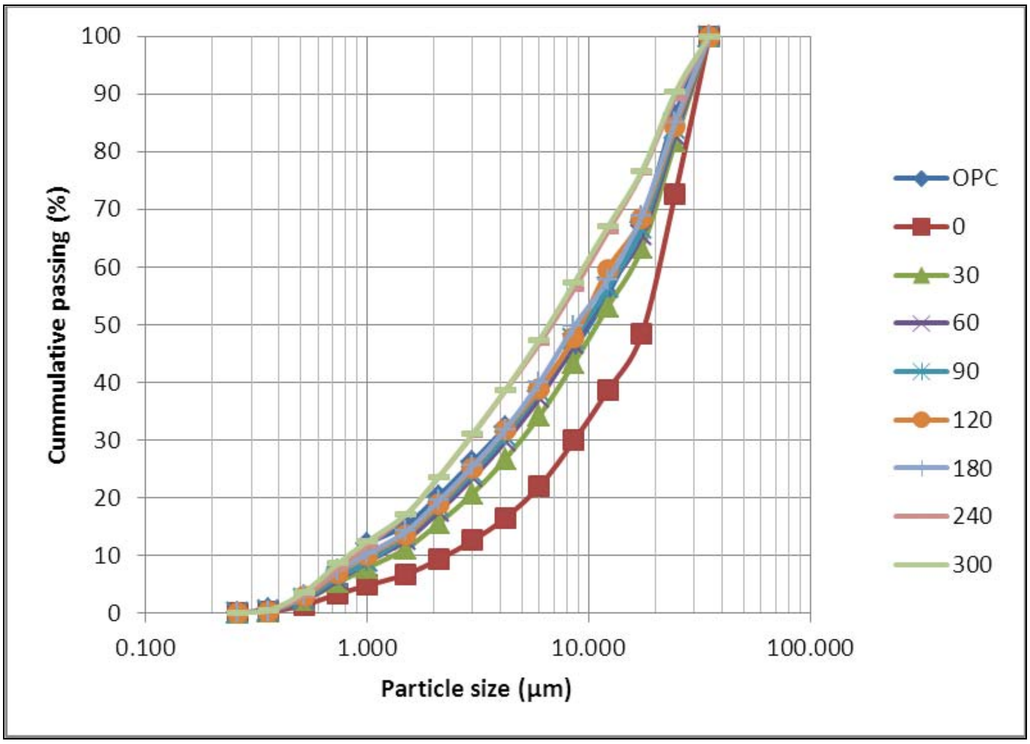


Fig. 5. Particle size distributions of cementitious materials

Chemical compositions of materials

Chemical compositions of Portland cement type I, original rice husk ash, and grinding RHA are given in Table 4. It shows that RHA consists in the range of 90 to 93.7 % SiO_2. The total sum of the components SiO_2, Al_2O_3, and Fe_2O_3 is 90% and hence RHA can be classified as Class N as prescribed in ASTM C618, and the loss on ignition (LOI) is not higher than 6% and 5%, respectively. It was found that the grinding process did not have much effect on the chemical composition of rice husk ash and the result conformed to the previous research [22].

Table 4. *Chemical compositions of cementitious materials*

Oxides	OPC	Rice husk ash at various time of grinding (min)							
		0	30	60	90	120	180	240	300
SiO_2	17	93	90	91	90.99	90.87	90.7	93.7	92.9
Al_2O_3	3.90	0.20	0.39	0.10	0.23	0.14	0.40	0.30	0.18
Fe_2O_3	3.20	0.13	0.37	0.10	0.26	0.95	0.40	0.20	0.43
CaO	70.0	0.49	0.46	0.40	0.41	0.49	0.40	0.60	0.41
MgO	1.50	0.73	0.88	0.90	0.73	0.65	0.50	0.40	0.35
Na_2O	0.02	0.02	0.02	0.15	0.02	0.25	0.10	0.20	0.02
K_2O	0.53	1.30	3.10	3.30	2.19	2.16	2.20	1.40	0.72
SO_3	3.60	0.15	0.15	0.50	0.08	0.09	0.10	0.10	0.10
LOI	0.25	3.98	4.63	3.55	5.09	4.40	5.20	3.10	4.89

Compressive strength

The compressive strength of RHA mixed at various grinding time are presented in Fig. 6. The curves indicate that the strength of concrete mixes increases as the grinding time of RHA increases and then decline after the peak value. The higher strength was achieved at 90 minute grind. Further increase in the grinding time of the RHA did not affect its strength. On the other hand, the strengths of rice husk ash concrete are reasonably higher than those of the OPC concrete. For the normal strength of concrete, the 28 day strength of the OPC concrete was 40.98 N/mm^2, while with the RHA at 90 min grinding was 42.64 N/mm^2. At the ages of 7 and 28 day, compressive strength of the RHA at 90 min (9.52µm) grind is 8.64% and 4.05% of that of the OPC concrete. This is due to the extreme fineness of rice husk ash that exhibits pozzolanic properties and packing effect. These characteristics tend to improve concrete strength [23]. The results also confirm those of Isaia et al [24] that the fine fineness of pozzolans had a greater pozzolanic reaction and the small particles could also fill in the voids of the concrete mixture, thus increasing the compressive strength of the concrete.

Coefficient of permeability

The result of gas permeability values calculated at five pressures reading for 7 and 28 day concrete mixed at different grinding time is demonstrated in Fig. 7. These individual permeabilities were calculated by application of formula (1) for all specimens between 7 and 28 days. From Fig. 7 it can be clearly seen that permeability decreases with time. All specimens undergo a significantly drop in permeability after 7 days. The original rice husk ash (unground) concrete shows the greatest permeability at all age while the other mixes have achieved the lowest permeability. For instance, at 28 days of curing, the permeability of original rice husk ash (RHA0), RHA30, RHA60, RHA90, RHA120, RHA180, RHA240, and RHA300 mixes were $1.53x10^{-17}$, $1.27x10^{-17}$, 1.28 $x10^{-17}$, 0.92 $x10^{-17}$, 0.85 $x10^{-17}$, 0.71 $x10^{-17}$, 0.75 $x10^{-17}$, and 0.70 $x10^{-17}$ m^2 compared with 1.28 $x10^{-17}$ m^2 of the OPC concrete at the same age. In general, the coefficient of permeability decreases with increasing grinding time. However, specimen associated with 300 minute grinding has shown lower permeability in comparison with normal concrete and other mixes. This may be related to grinding time variation in these mixes which produced fewer pores.

Rebound number

The graphical illustration as presented in Fig. 8 shows that the rebound values of the Schmidt hammer were obtained using the rice husk ashes that had been subjected to 90-min of grinding, and these indices were 100% and 75.82% higher than those of the unground rice husk ash, respectively for 7 and 28 days of curing. After subjecting to grinding for 90 minute, the rebound value of the RHA concrete decreased. An increased in the grinding time from 0 to 60 minutes did not affect the rebound value substantially. Further increasing the grinding time from 90 to 300 minute increased the rebound value because of the increased in the irregular-shaped particles.

Relationship between compressive strength versus rebound number

Schmidt Hammer was used to estimate the strength of concrete between rebound readings and compressive strength of concrete. In this study, lines depicting the compressive strength as related to the Schmidt number are illustrated in Fig. 9. Each coordinate on the curves is an average reading of three samples tested. The tabulation of the coefficient of the correlation for the relationship between strength and Schmidt number is presented in Table 5. The test results have shown a very good correlation between two tested properties with correlation coefficient (R^2) of 0.92 and 0.81, respectively for 7 and 28 days. A previous study by Fowell and Johnson [25] had shown that good correlations exist between cementation coefficient and compressive strength. Schmidt hammer rebound a value was reflected the interrelated combination of materials properties such as the strength of the cementation between grains, hardness and strength [26]. In addition, the ratios of the increased in strength to the increased in the rebound number after 7 and 28 days of concrete.

Table 5. *Correlation between compressive strength versus rebound number*

curing time	Independent variable, x	Dependent variable, y	Constant		R^2
			c	m	
7 days	Schmidt Number	compressive strength	0.8495	-7.3707	0.92
28 days			1.2644	13.362	0.90

Ultrasonic waves

The influence of rice husk ash at different grinding time on the ultrasonic wave of concrete is presented in Fig. 10. The results show that the grinding time of RHA increases when the wave velocities decreased. The results also indicated that the ultrasound wave velocity increase with the increasing of curing time. However, this increase was rapid in the first 7 days and continued at a slower rate until it reaches the 28 days. For instance, at 7 day of curing, the ultrasound wave velocities of concrete specimens, prepared using OPC (control) was 4.41 km/s, while for specimens at 28 day of curing it was 4.63 km/s. The increasing by 4.98% when the curing time increased from 7-d to 28-d. This effect can be explained by the fact that, there was an inverse relationship between the volume of pores and ultrasound wave's velocity [19]. The volume of capillary pores in the hydraulic cement paste decrease with time, since the degree of hydration of cement depends on duration of hydration in addition to other curing conditions like temperature and humidity which was kept constant in this study. The influence of rice husk ash with different particle size on ultrasonic wave of concrete is summarized in Fig. 10. Indicate that, as the particle size increases the wave velocity decrease. For instance, at 7-d of curing, ultrasound wave velocities at particle size of 17.96µm (RHA-unground) were 4.25 km/s. While it was 4.05 km/s for concrete with 6.65µm (RHA-300 min) of size.

Relationship between compressive strength versus wave velocity

The relationship between compressive strength and wave velocity of concrete containing RHA at various grinding time is graphically presented in Fig. 11. Every coordinate on the plot area is representation of the average of three specimens tested. Based on the Figure 8 clearly show that by increasing compressive strength, the velocities of concrete proportionally increases. Moreover, the concrete strength increases as the particle size of RHA decreases from 17.96µm to 6.65µm. The correlation coefficient between strength versus wave of velocity was R^2 = 0.91 (7-d) and R^2 = 0.94 (28-d). Indicate that the amount of rice husk ash in concrete is a very important factor that affects the strength and velocities relationship. It can be noted that the strengths of transition zone and cement paste matrix the concrete strength [19]. As the grinding time of RHA increases, a progressive weakening of the cement paste and the transition zone will occur due to the increase in their capillary voids.

CONCLUSION

The following conclusion can be drawn based on results of the current study:

a. Strength of 40 N/mm2 can be achieved with the incorporation of RHA. The optimum grinding time of RHA to produce optimum strength is 90 minute.
b. Irrespective of the method of scanning electron microscope, the morphology of the rice husk ashes was changed by grinding. However, the particles size of the rice husk ash decreases when increasing grinding time.
c. The compressive strength of concrete mixes increases as the grinding time of RHA increases and then decline after the peak value.
d. The coefficient of permeability decreases with increasing grinding time, with 300 minute grinding has shown lower permeability in comparison with normal concrete and other mixes.
e. The rebound values of the Schmidt hammer were obtained using the rice husk ashes that had been subjected to 90-min of grinding
f. The grinding time of RHA increases when the wave velocities decrease. The results also indicated that the ultrasound wave velocity increase with the increasing of curing time

ACKNOWLEDGEMENTS

The support provided by Universiti Sains Malaysia in the form of a research grant for this study is very much appreciated.

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