International Journal of Technology (2011) 1: 10-19
ISSN 2086-9614 © IJTech 2011

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

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(Received: November 2010 / Revised: December 2010 / Accepted: January 2011)

## ABSTRACT

The effect of rice husk ash produced at different grinding times on the engineering properties of concrete was studied. Eight rice husk ashes representing different grinding times were used in this investigation. Rice husk ash (RHA) was used to partially replace Portland cement Type I at 15% by weight of cementitious material. The compressive strength of concrete was designed to achieve 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 was changed by grinding. Optimum grinding time appeared to be approximately 90 minutes, during which time the compressive strength increased significantly. Generally, incorporation of RHA at various grinding times can dramatically decrease or increase the engineering properties of concrete.

*Keywords*: Grinding; Compressive strength; Superplasticizer; Concrete; Rice husk ash

## 1. INTRODUCTION

Mineral admixtures have been used successfully to partially replace energy and resources dependent on 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 (Mehta, 1987). Current technology points to the fact that the ash produced by burning rice husk can be used as a supplementary cementitious material in concrete (Mehta & Folliard, 1994). Many researchers had been modifying concrete's properties by adding some mineral admixtures, such as RHA, SF, metakaolin, and fly ash. Hewlett (1998) stated that when cementitious material is added to a concrete mix, it will increase the strength significantly. Coutinho (2003) also reported that concrete incorporated with RHA improved the compressive strength drastically. 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 different levels of fineness of rice husk ash are presented. The beneficial effects of inclusion of RHA at various grinding times in concrete properties are clearly shown in this paper.

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## 2. MATERIALS AND METHODS

### 2.1. Materials

Ordinary Portland Cement (OPC) Type I from a local manufacturer was used. It has a specific gravity and specific surface of 3.12g/cm$^3$ and 359m$^2$/kg, respectively, measured by conducting the Blaine test. Rice husk was obtained from a local rice milling factory, and was burned to ash at 700°C for 6 hours in a gas furnace at a heating rate of 10°C/min. Then, the ash was ground using the laboratory ball mill with porcelain balls. The fineness test was determined in accordance with ASTM C204-07. 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 882:1992.

### 2.2. Grinding of Rice Husk Ash

Grinding tests were carried out using a laboratory ball mill with porcelain balls. In experiments, 150 grams of rice husk ash was ground with the grinding media as presented in Table 1. The rice husk ash was ground separately for up to 5 hours. The unground rice husk ash, having an average particle size of about 17.96µm, was identified as RHA0 (Table 2).

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

| Parameters | Value | | Remark |
|---|---|---|---|
| Mill | 14 x 23.5 cm | | Ceramic (porcelain) |
| Porcelain ball | Size (mm) | Amount | Ceramic (porcelain) |
| | 30 | 20 | |
| | 20 | 40 | |
| | 10 | 300 | |
| Milling Speed | 76 rev/min | | |

Table 2 Designation of rice husk ash with different grinding times

| Time of grinding (minute) | 0 | 30 | 60 | 90 | 120 | 180 | 240 | 300 |
|---|---|---|---|---|---|---|---|---|
| Description | RHA0 | RHA1 | RHA2 | RHA3 | RHA4 | RHA5 | RHA6 | RHA7 |
| Particles size (µm) | 17.96 | 10.93 | 9.74 | 9.52 | 9.34 | 8.70 | 6.85 | 6.65 |

### 2.3. Mix Proportions

All mix proportions had the same replaced value of rice husk ash at a 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 40N/mm$^2$ at 28 days. Concrete mix proportions are presented in Table 3.

### 2.4. Compressive Strength

The compressive strength test was carried out according to the BS EN 12390-3:2002. Each layer was vibrated for 10s. After that, the molds were covered after cast with polyethylene sheets and moistened burlap for 24h. The specimens were then demolded and cured in water at a temperature of 20$^{o}$C until the day of testing. Compressive strength of the concrete was determined at 7 and 28 days, with three specimens per test age.

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 |

## 2.5. Gas Permeability

The cylinder, 50 mm in diameter and 40 mm thick, was cored and cut from prisms 100x100x500 mm to obtain the specified dimensions. This method had been developed by RILEM (1999). The schematic layout of the apparatus is illustrated (Figure 1). Gas permeability coefficient $K$ is calculated using the following equation:

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

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.

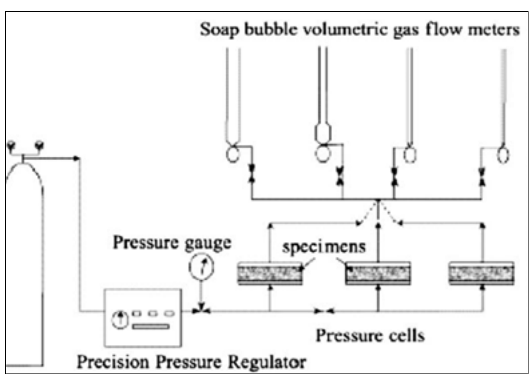


Figure 1 Experimental setup for gas permeability test (RILEM, 1999)

## 2.6. Schmidt Hammer Test Methods

A NR-type Schmidt hammer was used in this investigation to measure the rebound number (Figure 2). The test was carried out according to BS EN 12504-2:2001. A uniform compressive stress of 2.5MPa was provided to the test specimen of 100mm height, 100mm width and 100mm length along the vertical direction (same direction as the casting direction) before striking it with the hammer to prevent the dissipation of hammer-striking energy due to the lateral movement of the specimen. The test procedure used in this current technique was similar to the original established by Kim et al. (2009).

Figure 2 Schematic view for measurement of rebound number

### 2.7. Ultrasonic Equipment and Measuring Technique

The ultrasonic equipment used in this study was the portable ultrasonic non-destructive digital indicating tester (PUNDIT); tests were carried out according to BS EN 12504-4:2004. The PUNDIT can be used with piezo electric transducers over a frequency range from 20–500 kHz. Gaydecki et al. (1992) recommended using low frequencies in the range of 40–80 kHz in evaluating concrete. The PUNDIT device was used to read the time required for ultrasonic waves to transfer across the specimen. These procedures have been successfully used by Qudais (2005).

## 3. RESULTS AND DISCUSSION

### 3.1. Characterization of the Ash

From a graphical presentation of the particle size data at various grinding times (Figure 3), it is evident that the expected reduction in particle size of RHA occurs with an increase in grinding time. At a grinding time not exceeding 300 minutes, the particle size of 6.65µm was achieved. Particle morphology was characterized qualitatively with the aid of SEM images. Figure 4 shows a comparison between OPC and RHA produced before and after grinding. RHA unground presented a coarser quartz particle than OPC (Figure 4(b)). After grinding, RHA also presented some coarser quartz particles; however, the cellular grains were totally broken down (Figure 4(c)) by the mechanical action of the grinding media. 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 materials were obtained by using HELOS Particle Size Analyses, and the results were illustrated (Figure 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 due to crushing the hollow or porous particles of coarse fly ash into fine particles (Paya et al., 1995). The particle size of the RHA decreased with increasing grinding time, but the particle size decrease was most significant during the first 30 minutes of grinding. After 30 minutes, 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 particle fineness (Bouzoubaâ & Fournier, 2001).

### 3.2. Chemical Compositions of Materials

Chemical compositions of Portland cement type I, original rice husk ash, and grinding RHA (Table 4) show that RHA consists in the range of 90-93.7 % $SiO_2$. Since the total sum of the components $SiO_2$, $Al_2O_3$, and $Fe_2O_3$ is 90%, RHA can be classified as Class N as prescribed in ASTM C618-08, 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; results conformed to previous research.

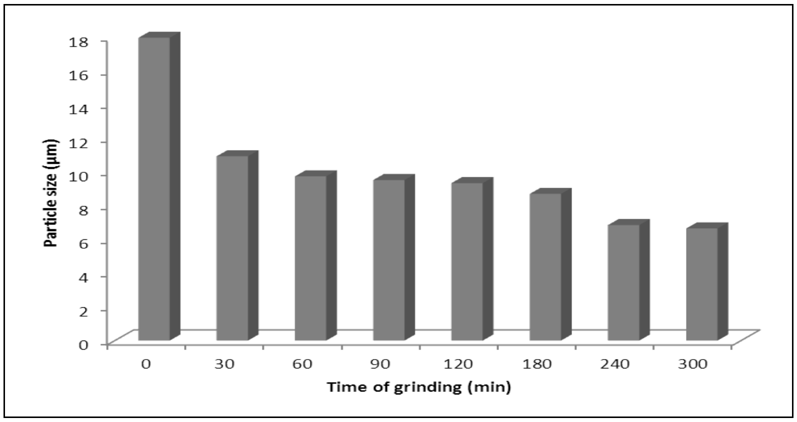


Figure 3 Particle size of RHA at different grinding times

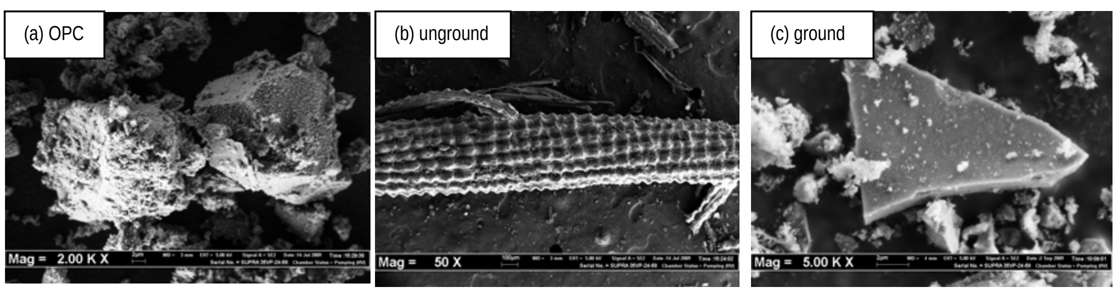


Figure 4 Scanning electron microscope (SEM) photography of cementitious materials; (a) OPC; (b) unground RHA(c) ground RHA

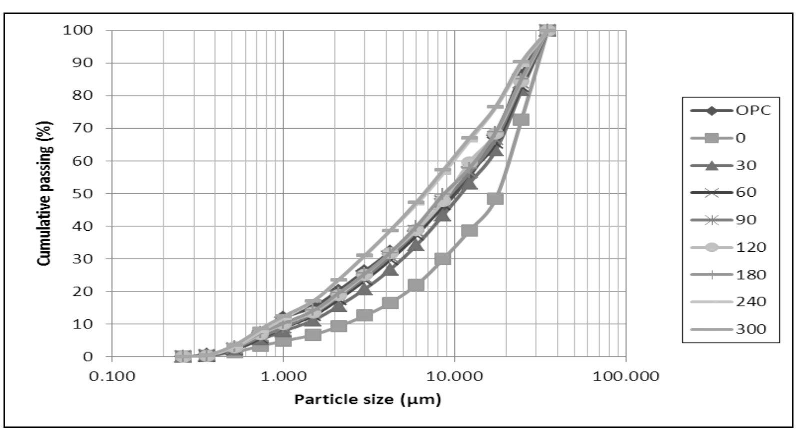


Figure 5 Particle size distribution of cementitious materials

### 3.3. Compressive Strength

The compressive strength of RHA mixed at various grinding times are presented (Figure 6), and the curves indicate that the strength of concrete mixes increases as the grinding time of RHA increases, and then declines after the peak value is reached. The higher strength was achieved at 90 min grind. Further increase in the grinding time of the RHA did not affect its strength. Next, the strengths of rice husk ash concrete were reasonably higher than those of the OPC concrete. For instance, the 28-day strength of OPC concrete was 40.98 N/mm$^2$, while RHA at 90 min grind was 42.64 N/mm$^2$. At 7 and 28 days, compressive strength of RHA at 90 min (9.52µm) grind was 8.64% and 4.05%, respectively, of that of OPC concrete. This is due to the packing effect and the extreme fineness of rice husk ash that exhibits pozzolanic properties (Isaia et al. 2003).

Table 4 Chemical compositions of cementitious materials

| Oxides | OPC | Rice husk ash at various grinding times (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 |

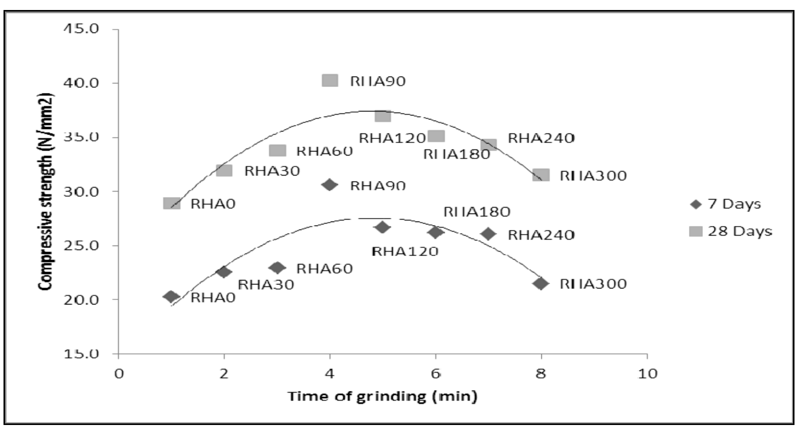


Figure 6 Compressive strength of RHA mixes at various grinding times

### 3.4. Coefficient of Permeability

The result of gas permeability values calculated at five pressure readings for concrete mixed at different grinding times at ages 7 and 28 days is demonstrated (Figure 7). It can be clearly seen that permeability decreases with time. All specimens demonstrated a significant drop in permeability after 7 days. The original rice husk ash (unground) concrete showed the greatest permeability at all ages. At 28 days of curing, the permeability of original rice husk ash (RHA0), RHA30, RHA60, RHA90, RHA120, RHA180, RHA240, and RHA300 mixes were $1.53x10^{-17}$, $1.27x10^{-17}$, $1.28x10^{-17}$, $0.92x10^{-17}$, $0.85x10^{-17}$, $0.71x10^{-17}$, $0.75x10^{-17}$, and $0.70x10^{-17}$ m$^2$ compared with $1.28x10^{-17}$ m$^2$ of the OPC concrete at the same age. In general, the coefficient of permeability decreases with increasing grinding time. However, specimens associated with 300 min grind showed lower permeability in comparison with normal concrete and other mixes. This may be related to grinding time variations which produced fewer pores.

### 3.5. Rebound Number

The graphical illustration (Figure 8) shows that rebound values of the Schmidt hammer were obtained using rice husk ashes that had been subjected to 90 min grind, 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 90 min grind, the rebound value of the RHA concrete decreased. An increase in grinding time from 0-60 min did not affect the rebound value substantially. Further increasing the grinding time from 90-300 min increased the rebound value because of the increase in irregular-shaped particles. In this study, lines depicting the compressive strength as related to the Schmidt number are illustrated (Figure 9).

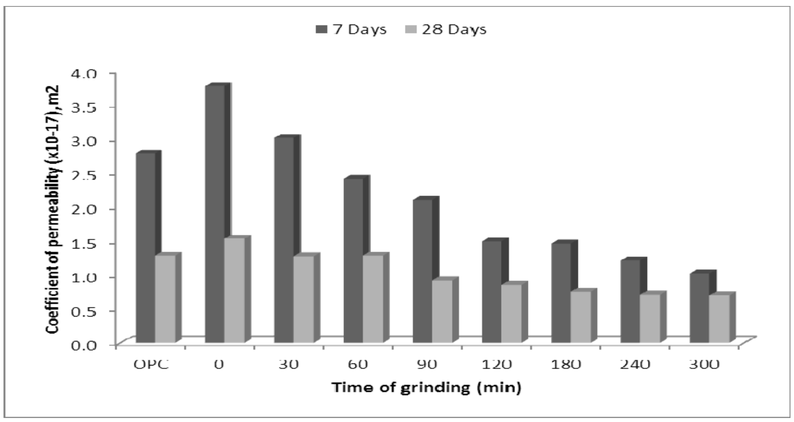


Figure 7 Coefficient of permeability of concrete containing OPC and RHA

The tabulation of the coefficient of the correlation for the relationship between strength and Schmidt number is presented (Table 5), and e test results revealed a very good correlation between two tested properties and the correlation coefficient ($R^2$) of 0.92 and 0.81, respectively, for 7 and 28 days. A previous study by Fowell & Johnson (1982) had shown that good correlations exist between cementation coefficient and compressive strength. Furthermore, the increase in strength: increase in rebound number after 7 and 28 days of curing.

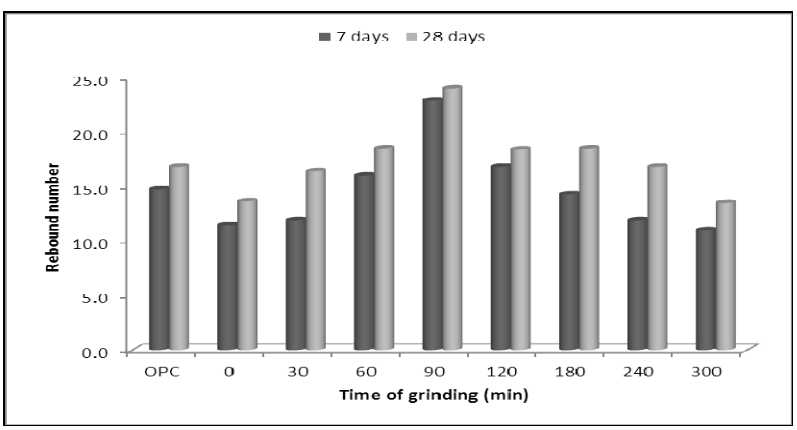


Figure 8 Rebound values of rice husk ash at various grinding times

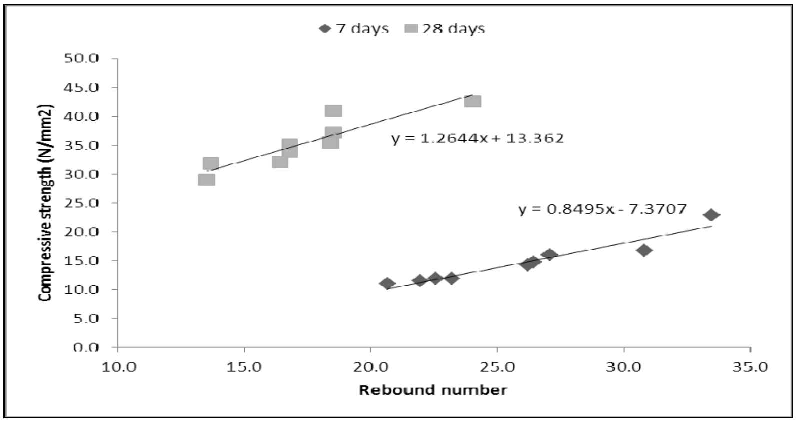


Figure 9 Relationship between compressive strength and rebound number

### 3.6. Ultrasonic Waves

The influence of rice husk ash at different grinding times on the ultrasonic wave of concrete is presented (Figure 10), and results show that as the grinding time of RHA increases, wave velocities decrease. The results also indicate that ultrasound wave velocity increases with increased curing time.

Table 5 Correlation between compressive strength versus rebound number

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

In our study, this increase was rapid in the first 7 days and continued at a slower rate until it reached 28 days. For instance, at 7 days of curing, the ultrasound wave velocity 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 increase by 4.98% associated with increasing curing time from 7 to 28 days can be explained by an inverse relationship between the volume of pores and ultrasound wave velocity (Qudais, 2005). The influence of rice husk ash with different particle sizes on the ultrasonic wave of concrete indicates that, as the particle size increases wave velocity decreases (Figure 10). For instance, at 7-d curing, ultrasound wave velocity at particle size of 17.96µm (RHA-unground) was 4.25 km/s, while it was 4.05 km/s for concrete measuring 6.65µm (RHA-300 min). The relationship between compressive strength and wave velocity of concrete containing RHA at various grinding times is graphically presented (Figure 11). It is clearly shown that by increasing compressive strength, wave velocities of concrete proportionally increase. Moreover, concrete strength increased as the particle size of RHA decreased 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), indicating that the amount of rice husk ash in concrete is a very important factor affecting the strength/velocity relationship.

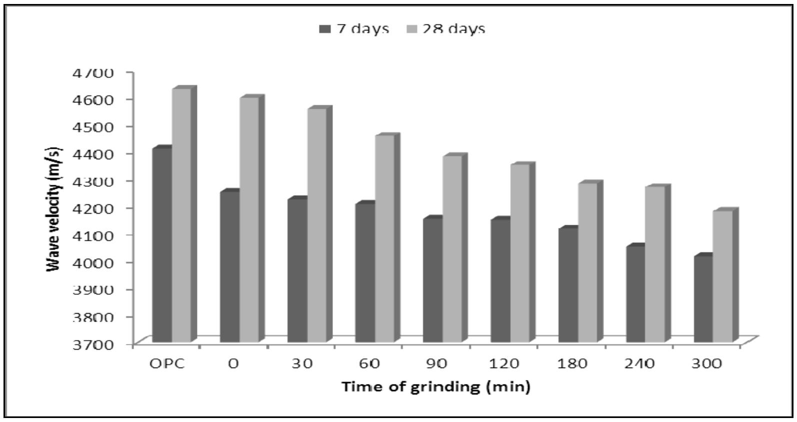


Figure 10 Ultrasonic wave of concrete at 7 and 28 days

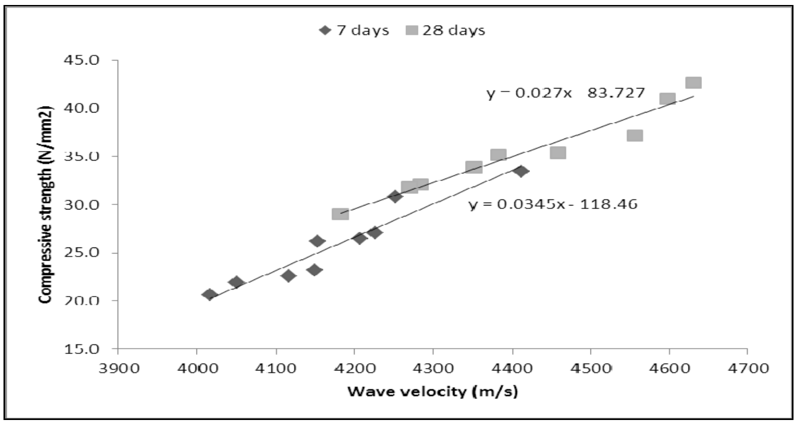


Figure 11 Relationship between compressive strength and wave velocity

## 4. CONCLUSIONS

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

a. Strength of 40 N/mm$^2$ can be achieved with the incorporation of RHA. The optimum grinding time of RHA to produce optimum strength is 90 minutes. Irrespective of the SEM method, the morphology of the rice husk ashes was changed by grinding. However, the particle size of the rice husk ash decreases when increasing grinding time.

b. The compressive strength of concrete mixes increases as the grinding time of RHA increases, and then declines after the peak value is reached. The coefficient of permeability decreases with increased grinding time, with 300 min grind showing lower permeability in comparison with normal concrete and other mixes.

c. After being subjected to grinding for 90 min, the rebound value of the RHA concrete decreased. An increase in the grinding time from 0 to 60 min did not substantially affect the rebound value. Increasing the grinding time further from 90 to 300 min increased the rebound value because of the increase in the irregularly shaped particles. As the grinding time of RHA increases, ultrasonic wave velocities decrease. Research results also indicate that the ultrasound wave velocity increases with increased curing time.

## 5. ACKNOWLEDGMENTS

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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