Effect of Grinding on Workability and Strength of Penang Rice Husk Ash Blended Concrete Grade 30

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ABSTRACT

The practice of replacing with conditioned waste materials in construction is well known for conservation of natural resources. Ecological was damaged due to quarrying caused depletion of natural resources (limestone, iron ore, clay). Many researchers proving that these by-products have pozzolanic properties which improve the quality of concrete. Global production of rice husk is approximately 580 million tonnes a year and this is rising as the world population and consumption of rice increases. This paper reports the effect of rice husk ash (RHA) grinding time on the workability and strength of concrete. Concrete mix proportions were introduced with RHA and superplasticiser (Sp) as additives. Three RHA with different fineness, i.e. RHA1(5) Sp, RHA2(5)Sp and RHA3(5)Sp were used for study .Based on analysis, it is found that the increasing of fineness decreases the workability but increases the compressive strength of the concrete. The use of RHA3(5)Sp results in highest strength at 28 days, which is due to the better dispersion and filling effect as well as an increase in pozzolanic reaction. From the research, it is shown that RHA has the potential to be a cement replacement material. The research has an important implication on environmental for sustainability due to usage of waste product as construction material.

1.0 INTRODUCTION

Landfill of waste is a problem to the environment. Hence, many researchers are looking into the utilization of waste material. Fortunately, from their studies, some of the waste materials have pozzolonic characteristics due to the presence of SiO_2, $Al2O_3$, MgO and Fe_2O_3[1]. Those wastes are agricultural by product such as palm oil bottom ash (POBA)[2,3] and RHA [4-6]. The husk of the rice is removed in the farming process before it is sold and consumed. It has been found beneficial to burn this rice husk in kilns for various purposes. The rice husk ash is then used as a substitute or admixture in cement. Therefore the entire rice product is used in an efficient and environmentally friendly approach. Processes of burning rice husk were under control and sustain at lower temperature. Reactivity of rice husk ash depend on amorphous form and particle size of the material. Hence, finer material cause high reactivity due to high specific surface area exposed for hydration. High production cost of cement causes high cost in concrete construction industry.

By applying supplementary cementitious material (SCM) concept, cement usage can be minimized or reduced while the strength and durability of the concrete can be improvised compared to the conventional concrete [7-9]. In addition it reduces the concrete production cost as well as the negative impact on the environmental [5,10,11]. So far, RHA has not been utilized yet in the construction industry. The reason for not utilizing this material may be probably due to lack of understanding of the RHA blended concrete characteristic. Many researchers have already published on properties of the blended RHA concrete such as strength and durability. However, only few researchers were found on the effect of RHA fineness on the properties [12]. This paper highlighted the study on the effect of fineness on the workability and compressive strength of concrete which the fineness of RHA was obtained based on the grinding method. The grinding times were varies from 30, 60 and 90 minutes by using ball bearing mechanism. The workability and compressive strength of Grade 30 N/mm² concrete with partial cement replacement of RHA were reported.

2.0 MATERIALS AND MIX PROPORTIONS

2.1 Materials

Ordinary Portland cement (OPC) used in this work was a type I cement. RHA was used as cement partial replacement which replaced 5% of the cement content. Rice husk ash were ground into 3 lots which were 30, 60 and 90 minutes times of grinding. Crushed granite with maximum size of 10 mm with specific gravity of 2.4 for surface saturated density was used. Mining sand was used which maximum size of 5 mm with percentage passing 600 μm was 25%. SiO_2 content is more than 92% where the chemical analysis of OPC and RHA been extracted from previous studies by Sumrerng *et al*., [13,14], Kartini *et al.,* [5,6], Habeeb *et al*., [12], Tuan *et al*., [15], Rukzon *et al*.,[16], and Abu Bakar *et al*., [17] is shown in Table 1.

Rice husk was collected and transported from Bernas factory at Kampung Bukit Tengah, Seberang Perai Tengah, Penang, Malaysia. Abu Bakar *et al*., [17] suggested that essentially amorphous silica can be produce by maintaining or control the combustion temperature below 500°C. Study done by Habeeb *et al*., [12], the RHA was burned in the muffle furnace with incinerating temperature not exceeding 700°C. In this research, incineration was self- sustained with the total duration of 7 hrs at 250°C. The burnt RHA was later left inside the furnace to cool for 24 hrs. After that, burnt RHA was divided into 3 parts for grinding. RHA was grinded using Los Angeles mill machine for 30, 60 and 90 minutes.

Two sizes of steel balls used for grinding; 25 and 12 mm in diameter. For each lot, 1 kg of 25 mm and 0.5 kg of 12 mm steel ball were used for every grinding time. In order to ensure the uniformity and consistency of the RHA, necessary measures were taken to control treatment include mass of RHA fed into the ball mill, milling speed, thickness of rice husk layer in the furnace during incinerating and the duration as well as the temperature of incinerating.

Table 1: Chemical analysis of OPC and RHA

Oxides	OPC (%)	RHA(%)
SiO_2	15.05 - 20.09	92.00 - 96.70
Al_2O_3	2.56 - 4.76	0.21 - 1.01
Fe_2O_3	3.42 - 4.00	0.05 - 0.21
MgO	1.25 - 1.27	0.37 - 1.59
CaO	65.41 - 72.17	0.41 - 1.28
Na_2O	0.08 - 0.74	0.05 - 0.26
K_2O	0.35 - 0.41	0.91 - 2.31
SO_3	2.71 - 2.96	0.94 - 2.90
LOI	0.96 - 1.33	2.36 - 4.81

2.2 Mix proportions and curing

The OPC was partially replaced with pozzolans at the dosage of 20% by weight of cementitious materials. The control OPC concrete was designed to achieve 30 N/mm² using DOE method [18]. Based on this method, cement content of 380 kg/m³ was adopted to all mixes. The water binder ratio (w/b) of control mix was 0.61 with a slump ranged 60-180 mm. Since, rice husk being cellular in nature [4], the used of RHA tend to increase water requirement therefore Sp need to be considered. The mix proportions and abbreviations are given in Table 2. They were demoulded at the age 1 day and cured in water maintained at room temperature until the test aged.

Table 2: Concrete mix proportion

Materials	Concrete Mix			
	OPC	RHA1(5) Sp	RHA2(5) Sp	RHA3(5) Sp
OPC (kg/m³)	380	361	361	361
RHA (kg/m³)	0	19 (30min)	19 (60min)	19 (90min)
Fine aggregate (kg/m³)	955	955	955	955
Coarse aggregate (kg/m³)	560	560	560	560
Water (litre)	235	235	235	235
Sp (%)	0	0.5	0.5	0.5

3.0 TESTING

3.1 Workability

The workability test is accordance to BS EN 12350-2[19] which specified for slump test to measure the desire slump.

3.2. COMPRESSIVE STRENGTH

For the compressive strength test, the cube samples of 100 x 100 x 100 mm were prepared in accordance with BS EN 12390-3 [20] using 3000 kN concrete compression machine. Samples were tested at the ages 7, 14, 28 and 60 days.

4. RESULTS AND DISCUSSIONS

4.1. Workability

The grinding of RHA increased its fineness and reactivity [10]. The longer RHA is ground, the finer RHA size obtained resulting in increment of pozzolanic reactivity due to the higher surface area of rice husk [12]. Since, rice husk being cellular in nature, the use of RHA tend to increase water requirement therefore Sp need to be considered. The slump design to achieved desire range between 60 – 180 mm. The result was in the range of 150 - 50 mm. For the same percentage of RHA replacement, increment of RHA grinding time decreases the concrete workability. There are two reasons for this; its absorptive characteristic [6] and fineness of its size as referred by Habeeb and Fayyadh [12] in (Zhang *et al.,* 1996; Ganesan *et al.,* 2008). Both of these features results in high water demand to wet the surface area of RHA.

According to Habeeb *et al.,* [12] increases the specific surface area of RHA which therefore more water requires to wet the surface area of RHA. Since, the water/binder ratio was maintained, Sp was added up as aid to enhance the fluidity. It was found that Sp increase the slump of the first mix (RHA ground 30 minutes) by 10 mm in comparison with the control mix. However, the slump decreases when the grinding time increases as shown in Table 3. Sp is absorbed onto the cement particles and impart a very strong negative charge which helps to lower the surface tension of the surrounding water considerably and thus greatly enhances the fluidity of the mix [21]. As evident in Table 3, it is seen that for the same amount of water and Sp, and increase in the grinding time, decreases the slump reading. Figure 1 shows some typical slumps for the various RHA concrete.

Table 3: Slump and compressive strength of concrete mixes

Mixes	Slump (mm)	Density (kg/m³)	Compressive Strength (N/mm²)			
			7d	14d	28d	60d
OPC	140	2317.8	18.3	20.1	29.5	32.2
RHA1(5)Sp	150	2345.9	23.9	30.1	29.9	40.1
RHA2(5)Sp	90	2384.9	24.9	29.2	34.1	44.3
RHA3(5)Sp	50	2428.3	26.1	29.2	40.6	47.1

Result pattern changes of slump with respect to grinding time were shown in Figure 2. Table 3 shows the RHA 1(5)Sp had highest slump because it was add with superplasticiser in comparison to the concrete control even the RHA increases the water demand in concrete. In comparison to the other mixes contained RHA also shows RHA 1(5)Sp was highest slump even the Sp was maintained. It shows that, RHA with shortest grinding time absorb less water compare to others duration. Hence, it can be concluded that RHA with 30 minutes grinding time had bigger size among RHA and directly indicates that it had smallest specific surface area as been specified by Habeeb *et al.,* [12] in their study. Hence, it proves the evidence increasing grinding time increase the fineness thus directly increased the specific surface area of particles that increase water demand [10,12,15].

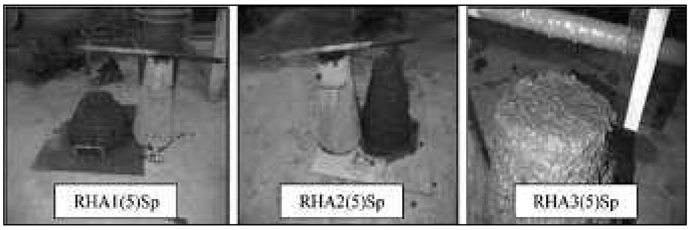

Figure 1: The slump for various mixes of fresh RHA concrete

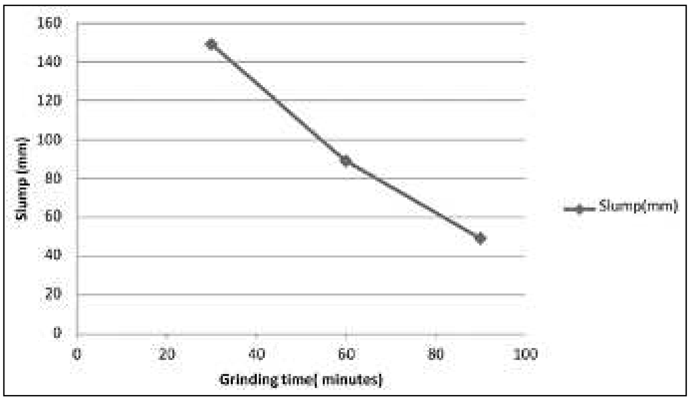

Figure 2: Effect of grinding times to the slump of concrete

4.2. COMPRESSIVE STRENGTH

The results of the compressive strength for the various mixes of grade 30 were presented in the Table 3 and Figure 3. RHAs concrete with Sp from Figure 3 are well above the target strength of 30 N/mm² at 28 days. The strength of concrete can be discussed in term of in the early age strength (7 and 14 days) and late age strength (28 and 60 days). At early age, the compressive strength of concrete containing RHA increases tremendously with respect to the grinding time. It is due to the fineness of RHA particles that have high specific surface area which increases and fasten the pozzolonic reactivity. At the age of 28 days, it is found that the concrete mix containing RHA ground for 90 minutes (longest period) shows the highest compressive strength which is 40 N/mm². Normally, compressive strength increases as the grinding time of RHA also increases [12]. It can be seen that the combination of RHA and Sp effect of compressive strength contribute from inclusion of Sp while maintaining w/b 0.61 i.e. 29.9 N/mm² for RHA 1(5)Sp, 34.1 N/mm² for RHA 2(5)Sp and 40.6 N/mm² for RHA 3(5)Sp concrete at age 28 days. Thus suggesting that inclusion of Sp is important to maintained under same water cement ratio condition. Finer RHA, water will be absorb more. Hence, if the quantity of water was maintained, the increasing if fineness will reduce the fluidity which the water should be add in order to maintained desire slump. But then, the w/b ratio was maintained in this study. Improvement of workability was done by adding Sp into the concrete mix. Hence, water was not added thus the strength of the concrete was not affected. In addition of that Sp improves the strength. It was due to the fact that adding Sp (while keeping w/b ratio constant), it enhances the fluidity of the mix even the increasing fineness of RHA due to grinding time that cause loosing of water demand (reduce slump),thus improved the workability and the strength [4,5].

From Figure 3, compressive strength also reached target strength at 14 days for all RHA concrete mixes but the rate of increasing was varies. RHA 3(5)Sp show high growth rate of compressive strength. Since, RHA was pozzolans, it contribute additional formation of calcium silicate gel (C-S-H) that contribute to the development strength of the concrete because the C-S-H gel was produce twice [1]. These gel volumes will filling the void between cement matrix and cause the densification effect [1]. As been study by Habeeb *et al.,* [12], the increasing grinding time will increase fineness and specific surface area. Thus, the process of secondary hydration will be much better with respect to the grinding time due to higher specific surface area.

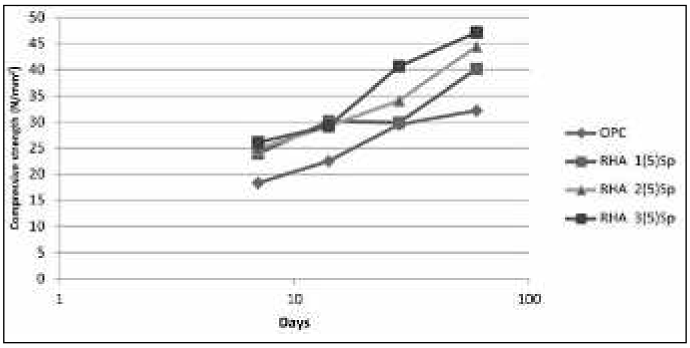

Figure 3: Compressive strength of concrete mixtures

From Figure 4, the strength of concrete were below 30 N/mm² but due to increasing to grinding time, the compressive strength were increase even the increment was not drastic. At age 14 days, the strength of concrete was static/ stagnant even the grinding time was increase as in Figure 4. At 7 days, strength of concrete increase tremendously due to additional C-S-H gel produce from second hydration which totally depend on calcium hydroxide [$Ca(OH)_2$] produce from primary hydration [1,22] but the strength are stop in increasing at age 14 days due to reduction of $Ca(OH)_2$ which mostly had been used by second hydration at early age.

Generally, from Figure 4 it can be seen that the compressive strength of all RHA concrete are well above target strength of 30 N/mm² and 40 N/mm² for age 28 and 60 days respectively. According to Habeeb *et al.,* [12], specific surface area increase when the fineness increased. The finer particles, the more activity of pozzolanic hydration occur [10,15]. Therefore, higher quantity of C-S-H gel produced which increased the strength of the concrete. In comparison the activity of producing C-S-H occur only once for control specimen. Sizes of RHA influence a lot to the rate of pozzolonic hydration (due to the surface area being exposed to the chemical hydration) and some mechanical properties of concrete [4-6]. Hence, it showing at late age, secondary hydration received adequate $Ca(OH)_2$ from primary hydration which can be proved by additional of C-S-H gel due to aggressively increment in strength. However, this increment of strength was developed with the aid of curing process for every age had been tested.

5.0 CONCLUSIONS

It can be concluded that the differences of grinding times produced different fineness. Fine rice husk ash reduces the water binder ratio (w/b) and improved the strength compared with coarser rice husk ash. The used of RHA3(5)Sp results in a good strength in comparison with other RHAs owning to the better dispersion and

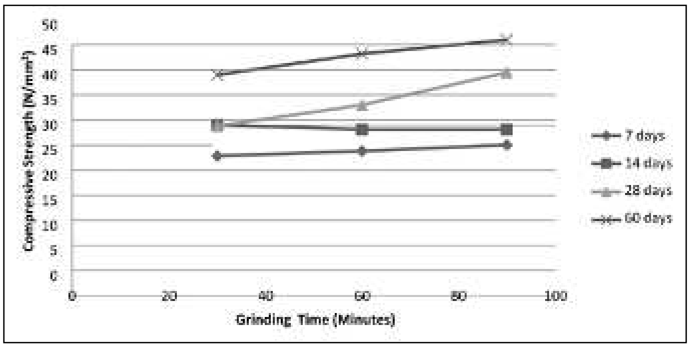

Figure 4: Effect of grinding times to the compressive strength at different days

filler effect despite an increase in the pozzolanic reaction. Due to high specific surface area of rice husk ash (RHA), the dosage of superplasticiser had to be increase along with RHA fineness to maintained desired workability. Increased in the grinding time of RHA resulted in a dry and unworkable mixture unless Sp is added. Maintaining of Sp into RHA concrete while sustaining water binder ratio but increase in grinding time decreased the slump and interrupts the cohesiveness of the concrete.

6.0 ACKNOWLEDGEMENTS

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