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Effect of Rice Husk Ash (RHA) on Physical Property and Mechanical Strength of Concrete

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Abstract. Fast depleting natural resources, huge consumption of energy, and environmental hazards involved in the production of cement has inspired researchers to find partial replacement of cement using other or similar materials. Rice husk ash (RHA), an agricultural waste, is classified as “a highly active pozzolan” because it contains a very high amount of amorphous silica and a large surface area. Rice husk is natural fiber that has the advantages of low density, low cost and biodegradable. In Malaysia paddy is grown locally especially in northern states of Peninsular Malaysia. Rice husk is a by-product of paddy being process into rice. These make it a natural candidate for cement replacement agent especially in Paddy producing countries. In this paper, RHA was introduced as the micro filler in concrete mixtures. The replacement of RHA which is lighter as compared to the Ordinary Portland Cement results in decreasing density of cement fiber composite and less permeable concrete.

Introduction

In 2010, world paddy production was recorded to be more than 700 million tons [1]. From this agricultural crop, 22% of the total mass is the rice husk [2]. Rice husk is one of the waste materials in the rice growing regions and it has a negligible protein content. Hence, it is not useful for animal feeding and to disposed this material it is usually burn in the paddy field or rice mill . Due to the abundant amount of rice husk, there is an urge to utilize the material in current industry. Rice husk ash (RHA) is a product from rice husk incineration process, leaving approximately 20% of the total mass of raw rice husk. RHA contains as much as 80-85% silica which is highly reactive, depending upon the temperature of incineration. Specifically, in construction industry, incorporation of RHA is not only beneficial in agricultural waste reduction but it will also reduce the consumption of energy used in the production of cement. RHA has the potential to be used as a substitute of cement without sacrificing the strength and durability.

There are many applications of RHA in manufacturing processes. One of the applications of RHA is in the manufacturing of refractory bricks because of its insulating properties. RHA has been used as silica source for cordierite production. Replacement of kaolinite with RHA that contained silica in the mixture composition, yields higher cordierites with a lower crystallize temperature and decrease in activation energy of crystallization [3]. Due to the presence of large amount of amorphous silica content in ash, extraction of silica is very useful in the industry. Some of the uses of silica are in rubber industry as reinforcing agent, in cosmetics and toothpastes as a cleansing agent and in the water purification as water purifier [4].

The objective of this research is to study the effects of rice husk ash on the physical and mechanical properties of concrete.

Methodology

Material. Main binder used in this research was Ordinary Portland Cement (OPC). This material was supplied by Lafarge Malayan Cement Berhad which in accordance to the quality requirements specified in Malaysian Standard MS 522: Part 1: 1989, Specification for Ordinary Portland Cement.

RHA was obtained from Firma Rina Sdn. Bhd. in Tanjung Karang, Hulu Selangor. The RHA was burnt twice. The first burning process was done in the furnace at the temperature of 160^{o}C. After that, the RHA was burnt again at 650^{o}C for 12 hours. Then the RHA was ground using the ball mill grinder to reduce the particle size.

Fine aggregate and coarse aggregate utilized in this research was bought from the local supplier in Gombak. The fine aggregate was classified as in zone 3, passing 5mm sieve size. Meanwhile, the coarse aggregate used was crushed aggregate with maximum size of 20mm according to BS 812-103.2 1989 [10].

Admixture was used to increase the workability of the concrete without compromising concrete strength development. The type of admixture used was polycarboxylic ether (PCE) in compliance with ASTM C494 for Type F and G admixtures. The amount of admixture adopted in this research was 1.2% weight of the cement content.

Mix Design. In this research program, the performance of the concrete with and without RHA content were studied. As for concrete with RHA, 5% of RHA was used as cement replacement material (CRM) and was labelled as 1, while 0 % of RHA usage (OPC concrete) was labelled as sample 2. Table 1 shows the mix design for both types of concrete with their target strength of 50 MPa.

Table 1. Mixture design concrete with and without RHA incorporation

Sample code	Coarse aggregate (kg)	Fine aggregate (kg)	RHA content (kg)	Cement content (kg)	Water amount (kg)	Admixture (kg)	Water to cement ratio (w/c)
1	50.37	32.89	0.88	16.76	6.35	0.21	0.36
2	50.37	32.89	0	17.64	6.35	0.21	0.36

Experimental Procedures. Concrete cubes of 150 x 150 mm containing 5% RHA and without RHA were cast. The constituents based on Table 1 were weighted accordingly. The cement (OPC) and 5% RHA were mixed together in two minutes at dry condition for sample 1 and 100 % of OPC cement was weighted for sample 2. Then 75% water was poured into the mixture, and was blended two minutes by a mixer at middle speed. Water must be added at the right time during mixing period to ensure excellent consistancy of concrete. The remaining 25% of water was poured after the mixture was well mixed and was mixed further for 10 minutes. The admixture was added last and mixed for another 10 minutes until homogeneously concrete mixed was achieved. Then the concrete mix was tested for workability. The concrete cubes were cured at room temperature for 24 hour followed by 28 days water curing. In total there were 9 numbers of concrete cubes with RHA and 9 cubes without RHA.

Field Emission Scanning Electron Microscope (FESEM) test was conducted to look at concrete interfacial transitional zone. Meanwhile, for fresh concrete test, slump test was carried out as per BS EN 12350-2:2000. As for harden properties of concrete, water absorption test was carried out in accordance to BS 1881: 122 and compression test in accordance to with BS EN 12390-4 for 150mm cubic sample.

Results and Discussion

Field Emission Scanning Electron Microscope (FESEM) Analysis. Microstructure properties of both mixes were analysed using FESEM. From Figigure 1, it was observed that there were many voids and porosity in the cement matrix for concete without RHA. The reason for the formation of this porous microstructure was due to the variable spatial distribution of cement paste particles of the freshly mixed concrete. This void was resulted from insufficient dispersion of flocculated cement grains, or some other inability of mixing to disperse variably sized particles homogeneously [5]. Beside voids and interfacial transitional zone , the result of SEM in the Figure 1 also shows that there was many microcracks formed on the surface of the OPC concrete. The interfacial transitional zone formation was obvious as well. During drying or curing, the microcracking might propagated because of thermal shrinkage. The shrinkage in cement matrix is due to the self-equilibrated stresses in the cement paste that led towards the formation of microcracks. This microcracking was also due to the restraint effect of sand grains, which prevent the cement paste from hydrating. The microcracks through the interfacial transition zone and the cement paste can lead to the material failure [4].

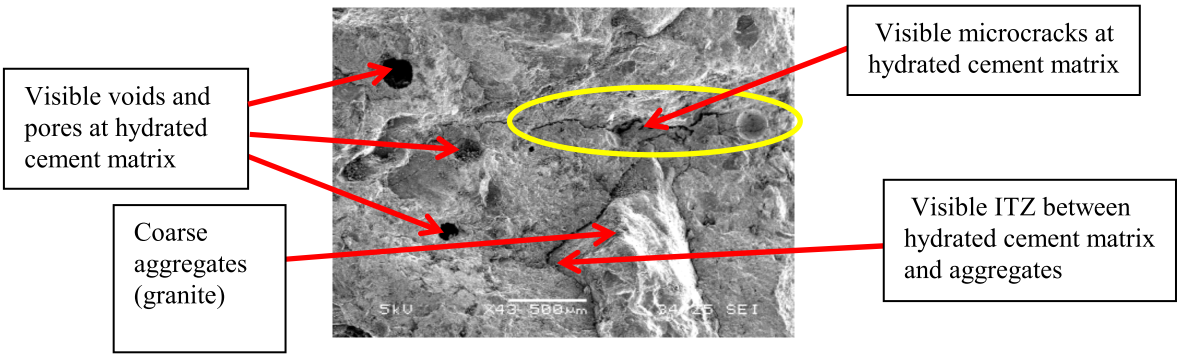

Fig. 1. FESEM image of concrete without incorporation of RHA (0% RHA) at 43 magnification.

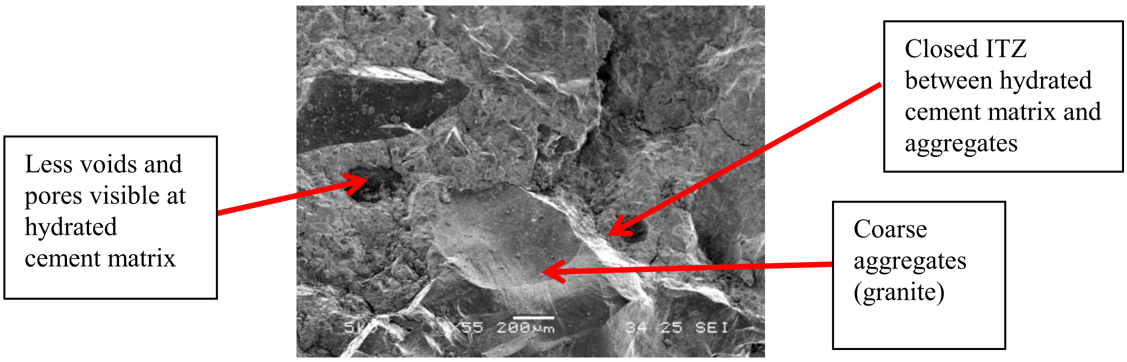

Fig. 2. FESEM image of concrete with incorporation of RHA (5% RHA) at 43 magnification.

Meanwhile, Based on Figure 2, the formations of microcracks formed in the cement matrix. The ITZ gap of concrete incorporating RHA was closed and barely seen as compared to OPC (0% RHA) concrete. This phenomena occurred due to packing between courser particles. In addition, higher silica contain in concere cubes containing RHA led to the greater formation of Calcium Silicate Hydrate (CSH) that contributed towards strength development to the concrete during curing [7]. Moreover, the Calciun Silicate Hydrate paste filled up the pore and capillary of concrete which make it a denser concrete.

Workability Test. Slump test result for both fresh concrete with and without RHA replacement d fresh concrete were conducted after concrete mixing.The test is to measure workability of the fresh concrete. Table 2 shows the result for slump test for both types of concrete. From the result, it was recorded that the slump test for 5% RHA cement replacement was 121mm and 100% Ordinary Portland Cement fresh concrete is 163mm. Based on the result it can be concluded that the workability of OPC fresh concrete was higher compared compared with 5% RHA cement replacement. The existence of the RHA reduced the workability of the concrete. This was due to the hygroscopic nature of RHA, the permeability of concrete specimens increased as RHA content was added to the concrete [8]. Hygroscopic is the ability of a substance to attract and hold water molecules from the surrounding environment.

Table 2. Slump test result for concrete mixture with and withoutRHA.

Fresh concrete(Grade 50)	Expected Result	Experimental Result
RHA(5%RHA,95%Cement)	125mm +/- 25mm	121mm
OPC(0%RHA,100%Cement)	125mm +/- 25mm	163mm

Water Absorption Test. The average of water absorption for concrete cubes both with and without RHA is shown in the Table 3. It was observed that small percentage of water absorption for concrete cubes that contain RHA. This result indicates that, the permeability of concrete cubes were reduced with the RHA content although the portion of RHA cement replacement was small which is 5%. This is due to the filler effect of the RHA content that improved the microstructure without the counter hygroscopic effect of the RHA [8]. The RHA will fill the micro pores or voids inside the concrete and tends to produce a more compact microstructure concrete specimen.

Table 3. Average Percentage Water Absorption of 28 days cured concrete.

Sample	Cube 1-3 (5%RHA)	Cube 4-6 (0%RHA)
Average Water Absorption (%)	0.45	0.57

Compression Test. The average comprehensive strength result of 18 concrete cubes with and without RHA replacement is presented graphically in Figure. 3. Three samples of concrete cubes were tested for each type for 3, 7 and 28 days . Form Figure 3 it is found that the compressive strength of concrete with 5% RHA cement replacement was lower than the ones without RHA replacement. This is so for all the days tested/ However the target strength for 28 days concrete of grade 50 was achieved for both 5% and 0% RHA replacement. The compressive value of 5% RHA concrete increased at slower rate compared to concrete without RHA cement replacement, but the compressive strength at 28 days was almost equal for both types of concrete. This indicates that RHA will slow down the hydration process which resulted a lower compressive strength at 3 and 7 curing days. Since at 28 days the strength difference between the two is small and the target strength is achived it is recommended to use RHA for cemetn replacement. Furthermore, it is economical as the price of RHA is cheaper than cement. Therefore, it means that waste material can be commercialized and used in construction industries. The usage of RHA in contruction industry is environmental friendly and at teh same the same lead to cost reduction production of of concrete.

Water cement ratio is inversely proportional to concrete strength. By adding RHA, it was observed that the water demand was higher as compared to conventional concrete in order to maintain its workability level. However with the use of superplasticizer or Polycarboxylate no extra water is needed to improve the workability. Due to the hygroscopic nature of RHA, the permeability of concrete specimens increased as RHA is added to concrete [8]. Addition of Superplasticizer to RHA mixes can improve the compressive strength of the concrete [9].

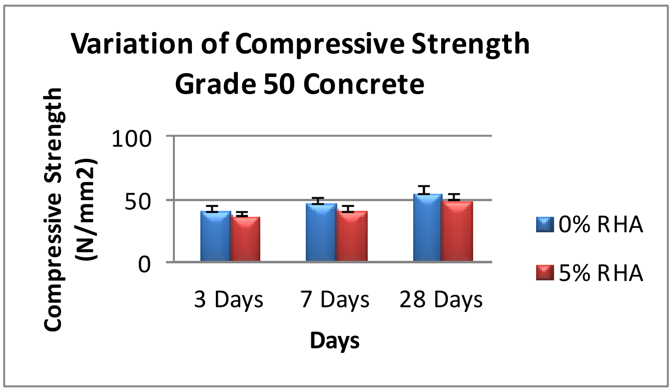

Fig. 3. Average compressive strength Grade 50 concrete with and without incorporation of RHA.

Conclusion

In brief, this project achieved the objective successfully. In term of morphology , the RHA concrete shows less porosity in the interfacial transition zone (ITZ) due to the filler effect of this natural fiber. The microcracks observed in matrix and along interfacial transition zone in concre with RHA replacement is lower compared with concrete without RHA replacement. This is because the higher content of Calcium Silicate Hydrate from the reaction of silica from RHA with calcium hydroxide making the concrete denser. The workability of concrete with RHA replacement is lower compared with the ones without RHA replacement. Water absorption of concrete with RHA repacement is lower than concrete without RHA. This is due to the rice husk ash filling the micro pores or voids inside the concrete that tends to produce a more compact microstructure concrete specimens. The compressive strength test of concrete with 5% RHA repacement is lower than without RHA repacement. However, the target compresive strength of is achieved. Since the difference in compresive strength between the two is small, there is a potential for RHA to be uses on concete because it is cheaper and more environmentally friendly a compared to cement.

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