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Physical and chemical contributions of Rice Husk Ash on the properties of mortar

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HIGHLIGHTS

- Physical and chemical contributions of RHA on properties of mortar are determined.
- Influence of RHA on mortar is mainly due to pozzolanic reaction of RHA.
- Pozzolanic reaction of RHA depends significantly on its particle size.
- Filler effect of RHA improves the durability properties of mortar.

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ABSTRACT

Rice Husk Ash (RHA) contributes to the properties of concrete and mortar significantly by both physical/-filler and chemical/pozzolanic effects. Most of the researchers have demonstrated the total effect of RHA in concrete and mortar. However, the unique filler effect or pozzolanic effect of RHA in cementitious system is not studied comprehensively. The aim of this research is to determine the physical and chemical effects of RHA on the properties of mortar including mechanical properties (compressive strength, flexural strength) durability properties (water absorption, porosity) and microstructure development. In this regard, RHA and natural sand (NS) were ground to have median particle sizes (d_{50}) of 6.72, 18.6 and 6.85, 18.9 μm, respectively. Portland cement Type I was replaced by ground RHA and sand separately at the rate of 2.5%, 5%, 7.5%, up to 20% by weight of cementitious materials to cast the mortar. Compressive strength, flexural strength, water absorption and porosity of RHA and NS mortars were determined at various curing ages. Maximum compressive strengths of mortar due to pozzolanic reaction of RHA are found to be 21.5 MPa (when d_{50} = 6.72 μm) and 10.1 MPa (when d_{50} = 18.6 μm) after 90 days of curing and 20% cement replacement level. Results also show that for specific cement replacement level, compressive strength due to filler effect of ground NS is almost constant and maximum 3.3 MPa at 20% replacement of cement. Similarly, finer RHA (d_{50} = 6.72 μm) blended mortar shows improved flexural strength (10.4 MPa), minimal water absorption (2%) and total porosity (1%) than coarser RHA (d_{50} = 18.6 μm) blended mortar at 90 days curing age and 20% replacement level. These results are also coherent with the microstructural studies of mortars. The results indicate that the influence of RHA on the properties of mortar is mainly attributed from the pozzolanic reaction of RHA which depends significantly on its particle size.

1. Introduction

Rice is considered as main food in many countries like China, Indonesia, India, Pakistan, Bangladesh, Malaysia etc. because of food habit of the population and weather condition. Along with the rice production, a large amount of rice husk is also produced in these countries every year. The most popular use of rice husk is to use as boiler fuel in order to steam or generate electricity. However, it can contribute about 20% of its weight to Rice Husk Ash (RHA) after incineration [1–3]. Chindaprasirt and Rukzon reported that the properly burnt and ground RHA is suitable for use as a pozzolanic material [4]. Gastaldini et al. stated that burning and grinding process modifies the color, impurities and the

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structural transformations of the ash [5]. On the other hand, Venkatanarayanan and Rangaraju obtained significant results by using both ground and unground low carbon content RHA [6].

Several previous studies reported that well burnt and ground RHA can contribute to the properties of concrete and mortar significantly by both filler and pozzolanic actions [7–11]. Usually, in most cases the total performance because of the filler and pozzolanic effect of RHA in cementitious system (concrete and mortar) is reported in most of the previous studies. It is not clear whether the advantageous use of RHA is because of the filler effect or the pozzolanic reaction. Very few studies reported the individual effects of pozzolanic materials in cementitious system. In order to separate the pozzolanic effect of pozzolans from its filler effect, some researchers have utilized non-reactive filler material as a filler representative to that of pozzolans.

Detwiler and Mehta reported that both physical and chemical effects of silica fume are significant on the compressive strength of concrete at the age of 28 days [12]. The carbon black in concrete as a filler representative of silica fume [12]. However, Goldman and Bentur described that micro-filler effect of non-reactive carbon black is more pronounced than the pozzolanic reaction of silica fume in concrete [13,14]. On the other hand, Cordeiro et al. suggested that packing or filler effect of ground sugar cane bagasse ash (SCBA) mortar and crushed quartz (CQ) mortar are similar whereas the compressive strength of SCBA mortar is 31% higher than the strength of CQ mortar because of the pozzolanic activity of SCBA [15]. Isaia et al. concluded that the pozzolanic effect is stronger in the binary and ternary mixtures prepared with Rice Husk Ash in proportions of 25% or higher [16]. Cheerarot et al. and Tangpagasit et al. found that the pozzolanic effect of fly ash is higher than the filler effect of ground river sand on the compressive strength of mortar [17,18]. Jaturapitakkul et al. also reported similar effect of ground palm oil fuel ash in cement mortar [19]. Recently, Jamil et al. analyzed pozzolanic contribution of RHA in cementitious system based on the hydration reaction of cement and the pozzolanic reaction of RHA with the hydration product [20].

However, to the best of authors' knowledge, the individual filler and chemical contribution of RHA in cement mortar is still not investigated experimentally. Very few researchers have determined the physical and chemical contributions of other pozzolans (fly ash, slag, silica fume, palm oil fuel ash, sugar cane bagasse ash, etc) [12–19]. Therefore, the current study aims at quantifying the physical or filler and chemical or pozzolanic effects of Rice Husk Ash on the properties of mortar. Moreover, in the previous studies, larger range of replacement percentages (like 10%, 20%, 30% etc.) of RHA was used. Nevertheless, probabilities of the optimum strength due to the filler and/or pozzolanic effect may lie in between two larger ranges of replacement percentages. Therefore, an experimental work is also carried out using RHA and natural ground sand of different sizes at lower range of cement replacement percentages (like 2.5%, 5%, 7.5% etc.) in mortar. In addition to this, a comprehensive micro-structural study is also presented by comparing mortars containing RHA and NS.

2. Materials and methods

2.1. Materials

2.1.1. Rice Husk Ash

Raw rice husk was collected from local paddy mill in the state of Kuala Lumpur, Malaysia. It was burnt using a gas furnace available at the National university of Malaysia (UKM), Malaysia. The incineration process of raw rice husk was performed in accordance with the process described by Zain et al. [21]. It is expected that more than 90% amorphous silica can be produced by this process [21]. After proper incineration, the produced RHA was received.

2.1.2. Natural Sand

Locally available natural sand (NS) was selected as non-reactive material. The non-reactive natural sand was used as a filler representative of RHA.

2.1.3. Cement

Ordinary Portland cement (OPC) conforming to Type I of ASTM C150 [22] was used as binding material.

2.1.4. Standard sand

Standard sand conforming to EN standard was used as fine aggregate. Standard sand was used to minimize the effect of fine aggregate on the strength of mortar.

2.2. Preparation of RHA and NS

Grinding of RHA and NS were performed using a Los Angeles abrasion machine. In order to improve fineness of RHA, 16 steel ball of 20 mm diameter were used as grinding rods with grinding duration 60 and 90 min, respectively, to get two different size RHA. The rotational speed of the machine was kept 30–33 rpm. Similarly, dry NS was ground using same grinding rod specifications with prolonged grinding duration 180 and 240 min, respectively. Then ground RHA and NS were classified in two different particle sizes by dry sieving and denoted as follows:

- Small-size particles: About 5 ± 2% by weight of the materials were retained on a 45-μm sieve. The materials were designated as small-size rice husk ash (SRHA) and small-size natural sand (SNS).
- Large-size particles: About 34 ± 2% by weight of the materials were retained on a 45 μm sieve. The materials were named as large-size rice husk ash (LRHA) and large-size natural sand (LNS).

2.3. Determination of properties of RHA and NS

The particle size distribution of the materials was performed using a laser diffraction particle analyzer. The chemical composition of the materials was determined using X-ray fluorescence (XRF) technique. The crystalline or amorphous phase of materials was investigated using X-ray diffraction (XRD) analysis. The microstructure of the materials was observed using a scanning electron microscope (SEM). All the obtained physical and chemical properties are described in Section 3.1.

2.4. Preparation and testing of mortar specimens

The preliminary objective of this research is to separate the physical and chemical effects of RHA in the strength of mortar. In order to achieve this, compressive strength of RHA and NS mortar was determined through experiment. In the experiment, a constant ratio of cementitious materials (Portland cement plus Rice Husk Ash or non-reactive material) to fine aggregate (standard sand) was set at 1:2.75 by weight. The water to cementitious materials ratio was maintained at 0.485. Normal municipal water supplied in the lab was used to mix the mortar. Portland cement Type I was replaced by RHA or NS at the rate of 2.5%, 5%, 7.5% up to 20% by weight of cementitious materials. First, cement and fine aggregate were mixed properly in dry condition. After that, required amount of water was added to the mix to get moldable mortar. All the specimens were cast in 50 mm standard cube molds and removed from it after 24 h of casting. All the specimens are