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Research article

Combination of ground rice husk and polyvinyl alcohol fiber in cementitious composite

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ABSTRACT

In this study, ground rice husks (GRH) in combination with polyvinyl-alcohol (PVA) fiber were used to produce low-cost and high-quality hybrid cementitious composites. Different amounts of GRH (2.5, 5.0, 7.5 and 12.5% in weight of cement) were added to the concrete. The work presented in this paper provides an insight into the use of an agricultural waste as effective additive in cement based materials. The properties of resultant cementitious composites including density, water absorption, flexural behavior and compressive strength were investigated. The results have shown that incorporation of ground rice husk in combination with PVA fiber can be effective in improvement of the flexural properties of cementitious composite. The study explored the effectiveness of this type of agricultural waste as a beneficial material in fine aggregate concrete materials.

1. Introduction

There is a great deal of current interest in the application of natural fibers in concrete materials. The various advantages of using natural fibers in cement-based materials are reported in the literature (Yue et al., 2000; Savastano et al., 2003; Roma et al., 2008; Pacheco-Torgal and Jalali, 2011). The natural fibers may improve the mechanical performance of concrete including flexural strength and toughness, impact toughness and load bearing capacity in post-crack areas (Bilba and Arsene, 2008). Due to their lower cost and density in comparison with synthetic fibers, they offer cost effective benefits and low density cementitious composite products.

Rice husk (RH) is an agricultural residue material with a cellulosic non-wood fibrous nature. Rice husk as an organic waste is obtained from the outer covering of rice grains during the milling process. These organic wastes constitute about 20% of the rice produced annually in the world by volume, which are approximately 80 million tons (Shafigh et al., 2014). The most common uses of RH are as a fertilizer additive, animal food, stock breeding rugs, cooking fuel, paving applications, filling materials and energy generation (Pode, 2016). Commonly, the RHs are burned after harvest because of its significant problem in rice-cultivating areas. The burnt RHs cause environmental problems, thus the recycling and use of this waste material in new products can reduce atmospheric pollution (Haider, 2013).

The burning of rice husk under controlled temperature produces the rice husk ash, which is predominantly composed of amorphous silica (Benassi et al., 2015). Several investigations have been done and their results are published on the performance of rice husk ash (RHA) as a mineral admixture for concrete materials (Zhang et al., 1996; de Sensale, 2006; Zain et al., 2011). The researches have demonstrated that RHA is one of the most promising supplementary cementitious materials due to its high specific surface area and significant pozzolanic activity (Antiohos et al., 2014; Chatveera and Lertwattanaruk, 2011).

However, only limited information is available on the use of their original form in concrete production. Yuzer et al. (2013) investigated the mechanical properties of normal strength concrete containing different weights of ground rice husk (1.5, 3 and 5% of cement by weight). They reported that the use of GRH in concrete has some benefits when the concrete is subjected to high temperature. They found that an increment in the amount of raw rice husk (RRH) resulted in a dramatic drop in the compressive strength of concrete. Akturk et al. (2015) conducted a series of physical and mechanical tests on high strength concrete containing RRH in different proportions by the weight of the cement (0.5, 1.5 and 3%). They observed that the raw rice husk was found to be effective in preventing spalling and can be an alternative to polypropylene

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fiber in high strength concrete under high temperature. They also reported that the addition of RRH caused slight drops in the compressive and splitting tensile strength of the concrete.

Physical, mechanical and thermal properties of low strength concrete containing different amounts of original rice husk were studied by Sisman et al. (2011). The results have indicated that rice husk had potential as a material to produce lightweight concrete. Lightweight concrete produced with original rice husk exhibited lower thermal conductivity than that of an equivalent normal weight concrete. Moreover, some of the literature has reported on the production of low cost insulating concrete materials using rice husk (Salas et al., 1986; Ahmad et al., 2015).

Combination of sticky rice with lime can develop a special inorganic-organic composite building material (sticky-lime mortar-SLM). This material was extensively used in the ancient Chinese important buildings such as tombs, urban constructions, walls and water conservancy (Zeng et al., 2008). Sticky-rice lime mortar (SLM) produced from cooking the sticky-rice and then mixing with sand and lime can result in good strength, toughness and waterproofness materials which called Chinese concrete (Xiao et al., 2014).

The objective of the present investigation is to evaluate the hybrid performance of PVA and ground rice husk as reinforcement in cementitious composites. The present study has investigated the performance of ground rice husk in combination with PVA fiber as reinforcement for composites to explore its potential application in cementitious materials which can be used as a way to reduce its environmental pollution problems. Therefore, a series of cementitious composites containing different amounts of GRH were prepared and tested to determine density, water absorption and mechanical performance.

2. Materials and methods

The cement used in this study was Portland cement Type I, from Tehran Cement Co., Iran. The specific gravity and average grain size silica sand were 2.61 and 110 μm, respectively.

Ground rice husk at different volume percentages was combined with PVA fiber to produce hybrid composites. The details of the mix proportions of samples are presented in Table 1. A high strength cementitious matrix containing micron-sized ingredients was selected for this work. The rice husks used in this study were from Guilan province, Iran. More than half of the rice production in Iran occurs in the north regions. Raw rice husks were fed into a milling chamber equipped with a rotating knife cutter where they are cut into small pieces. By repetition of this process and using a screen inserted at the bottom of the milling chamber a fine ground rice husk were produced.

The microscopic images of PVA fiber and rice husk are demonstrated in Fig. 1. The polyvinyl alcohol (PVA) fiber with a diameter of 14 μm and length of 6 mm, which have a tensile strength of 1400 Mpa and elastic value of 20 GPa were used. The PVA fiber volume fraction in all the mixtures was constant.

2.1. Production of test specimens

At first, the solid ingredients were poured and mixed for 5 min. Then water and superplasticizer were added to the ingredients and mixed for another 10 min to produce uniform slurry. The PVA fiber was slowly added to the paste by hand. After uniform distribution of PVA fibers, the ground rice husk was added to the mixture and mixed for 5 min.

The addition of GRH decrease the viscosity of fresh mortar which can adversely affect fiber dispersion. To overcome problem associated to viscosity reduction a higher amount of Superplasticizer was used to reach a uniform distribution for PVA fibers.

After casting in plastic molds and vibrating, the composites were covered with a plastic sheet and stored in the laboratory environment. The specimens were demoulded after 48 h of casting and stored in a humidity chamber for 28 days before the test. Five specimens were prepared for each sample and the results were obtained as an average of the tested specimens.

Table 1
Mix design for hybrid composites (in respect to the weight of cement).

Sample ID	Cement	Fly ash	Sand	Water[a]	Sup.[b]	PVA fiber[c]	Ground Rice husk
1PV(Control)	1	1.2	0.8	0.56	0.012	0.022	0.000
1PV1RH	1	1.2	0.8	0.56	0.012	0.022	0.025
1PV2RH	1	1.2	0.8	0.56	0.012	0.022	0.050
1PV3RH	1	1.2	0.8	0.56	0.012	0.022	0.075
2PV5RH	1	1.2	0.8	0.56	0.016	0.022	0.125

[a] Weight to cement ratio.
[b] Superplasticizer, weight to cement ratio.
[c] It is equal to fiber content of 1.0% by volume in cementitious composite.

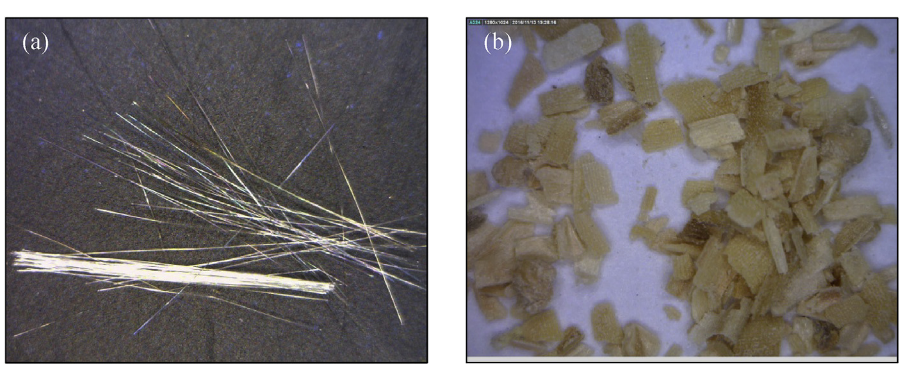

Fig. 1. Microscopic images of; (a) PVA fibers, (b) ground rice husk.