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Investigation of the compressive strength of pit sand, and sea sand mortar prisms produced with rice husk ash as additive

Samuel Kofi Tulashie [a,*], Francis Kotoka [a], David Mensah [b], Anthony Kwame Kwablah [a]

[a] University of Cape Coast, College of Agriculture and Natural Sciences, School of Physical Sciences, Department of Chemistry, Industrial Chemistry Unit, Cape Coast, Ghana
[b] Cape Coast Technical University, Department of Building Technology, Cape Coast, Ghana

HIGHLIGHTS

- Adding 11.11%–22.22% rice husk ash enhances the compressive strength of the cement.
- Pit sand is far better than sea sand for compressive strength enhancement.
- The rice husk ash impact on compressive strength can be defected by the source of sand used.
- Higher ash composition can potentially distort the desired mortar compressive strength.

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ABSTRACT

This study investigates the compressive strength of ordinary Portland cement mortar prisms with rice husk ash (RHA). Pit sand–cement, and sea sand-cement mortar prisms were separately prepared using cement-sand mix ratio 1:3, and RHA composition of 0–44.44%. The optimum strength of the pit sand-cement mortar prisms after 1, 2, 7, and 28 days was recorded at 11.11% RHA by the mass of the cement. However, the compressive strength of the sea sand-cement mortar prisms with 11.11% RHA decreased on the 7th and 28th day. Thus the inconsistencies in the compressive strength indicate that, sea sand is not a good candidate for constructions.

1. Introduction

The addition of pozzolanic materials to cement to improve mortar and concrete properties has recently become an emerging issue in the cement and construction industries. The cement and construction industries would save energy and reduce cost when by-products from industries which had the potential of improving cement properties were partially incorporated into Portland cement [1]. Some agricultural by-products had largely been noted to exhibit good pozzolanic characteristics which can significantly improve cement mortar and concrete properties, especially, the compressive strength [2]. Rice husk ash (Fig. 1) had been mentioned to be one of the common and abundant candidates that have such excellent pozzolanic characteristics [3]. The presence of amorphous silica (more than 80–85% silica) which reacts readily with the cement lime [4–7], and its specific surface area [8] account for those characteristics. For instance, rice husk ash had been reported to have reduced the heat of hydration [9], improved corrosion resistance [10], improved workability [11], decreased permeability [12], and most importantly, elevated the compressive strength and flexural strength [13,14] of the mortar, and concrete studied.

Significantly, several studies have been done on the effect of RHA on the compressive of cement mortal, concrete and bricks. For example, the compressive strength of bricks was improved in the range of 20.9–31.5 MPa when RHA was used as the main binder material [15]. Generally, the optimum replacement levels of cement with rice husk ash, which improved the compressive strength of the cement mortar and concrete had been reported to be 10% [13], 15% [12], 20% [16], 25% [17] and 30% [8]. Other studies too have considered combining different materials such as fly ash, wood fiber waste, fibers derived from fiber board, and rice stalk fiber with rice husk ash to improve compressive strength and other properties by 20–30% partial replacement of the cement [17–20].

* Corresponding author.
E-mail address: stulashie@ucc.edu.gh (S.K. Tulashie).

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Fig. 1. (a) Rice husk heap captured at one of the rice refinery mini-factories in Ghana; and (b) Rice husk collected from the heap.

Obviously, most studies have focused on the partial replacement of cement with rice husk ash. However, little exploration had been done on the direct addition of the rice husk ash as additive to the cement to reinforce the compressive strength, considering the sources of sands used. Also, large quantities of rice husks are traditionally and industrially disposed as waste causing environmental nuisance [21].

This present study therefore investigates the compressive strength of ordinary Portland cement mortar prisms produced with varying composition of rice husk ash additive. The optimum compressive strength of the prisms will be presented and discussed. The effect on compressive strength of mortar prisms using pit sand, and sea sand will also be presented and discussed.

2. Materials and methods

2.1. Materials

The pit sand sample as depicted in Fig. 2 was collected from a construction site on University of Cape Coast campus, geographically located in the Central region of Ghana. Sea sand sample was also collected from the Tema fishing harbor geographically located in the Greater Accra region of Ghana. Each of the sand samples were stored in polyethylene bags and carried to the laboratory for study. The rice husk used for this work was obtained from Oheamadwen, geographically located in the Shama district of Ghana.

The husk sample was sun-dried for three days. The dried husk was burnt into ashes in a muffle furnace for 2 h at 1100 °C as shown in Fig. 3, which was then ground and kept ready for analysis.

Tables 1 and 2 show the physical and chemical properties of the ordinary Portland cement (grade 32.5 R), rice husk ash, pit sand and sea sand used for the study.

2.2. Determination of standard consistency and setting time of cement paste

The IS: 4031-PART 4-1988 procedure was adopted [22]. The standard consistency of the cement paste, and mortar mixture were determined experimentally by Vicat apparatus. For the cement paste, 450 g of cement and 25% of water by weight of the cement were initially mixed vigorously on non-porous surface by means of two trowels for 240 s. The mold was filled immediately with the cement mixture paste and the surface of the mixture was smoothened in the mold. The plunger was lowered to touch the surface of the cement mixture paste and allowed to sink through the surface to examine the depth of penetration. The entire process was repeated and the water content was varied incrementally until the depth of penetration was within 33–35 mm during which the standard consistency was determined to be 32.9% (148.05 g of water). The setting times were determined at 27 °C and 65% relative humidity by adopting IS: 4031-PART 5-1988 procedure [23]. The standard consistency (P), and setting times (initial and final) were calculated as shown in Eqs. (1)–(3), respectively.

$$p = \frac{w}{c} \times 100 \tag{1}$$

$$\text{Initial setting time} = a - b \tag{2}$$

$$\text{Final setting time} = c - d \tag{3}$$

where, W = Quantity of water added; C = Quantity of Cement used; a = time when water was first added to the cement; b = time at which the needle could not penetrate 5 mm–7 mm from the mold bottom; c = time at which the needle impressed but the attachment could not.

Fig. 2. A heap of pit sand.

Fig. 3. Ground rice husk ash.