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Review

Use of highly reactive rice husk ash in the production of cement matrix reinforced with green coconut fiber

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ABSTRACT

This study evaluated the influence of partial replacement of Portland cement by rice husk ash (RHA) to enable the use of green coconut husk fiber as reinforcement for cementitious matrix. The use of highly reactive pozzolanic ash contributes for decreasing the alkaline attack on the vegetable fiber, originated from waste materials. The slurry dewatering technique was used for dispersion of the raw materials in aqueous solution, followed by vacuum drainage of water and pressing for the production of pad composites, as a simplified simulation of the Hatschek process for industrial manufacture. Five formulations were evaluated, two of them without any mineral additions. One of the mixtures served as a reference (without green coconut fibers) and the remaining ones were reinforced with the green coconut fibers (5% by weight of binder) and with the content of Portland cement replacement by RHA equal to 0, 30, 40 and 50%. The composites were analyzed at 28 days of age and after aging by immersion in warm water (65 °C), which lasted for 28 additional days. Physical and mechanical tests were applied for assessment of the performance of composites. Thermogravimetric analysis was used to observe the consumption of portlandite and chemically combined water content in the hydrated products for pastes presenting the same levels of Portland cement replacement by RHA (i.e., 0–50%) and with the water/binder ratio kept constant and equal to 0.5. The mechanical performance evaluated by bending test after 28 days reached the MOR of 15.7 MPa after the accelerate aging, for the composites reinforced with the green coconut fiber and with high levels of Portland cement replacement by RHA demonstrating that the use of green coconut fiber for reinforcement can be very promising for the production of binary cement based matrix. The thermogravimetry showed that the replacement of Portland cement by the RHA helped in maintaining the mechanical behavior of the green coconut fiber in the composite subjected to the accelerated aging tests, and resulted in improved mechanical performance, providing a lightweight composite.

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1. Introduction

In the coming years, the construction industry has the challenge of incorporating sustainability in their production processes, either by searching for new raw materials and products more environmentally friendly and/or contributing for the reduction of CO_2 into the atmosphere. The possibility of incorporating waste from other industrial activities in their production processes can help with this goal, reducing the generation of CO_2 emissions during the conventional construction. Ramakrishna and Sundararajan (2005) discussed composites based on lignocellulosic fibers used in building construction. Particleboards can be produced from any lignocellulosic materials in principle, which confer high mechanical strength and specific predetermined weight (Ashori et al., 2012, Ashori et al., 2011). Vegetable fibers are also widely available in most developing countries, which make them convenient materials for brittle cement matrix reinforcement, even though they present relatively poor durability performance (Agopyan et al., 2005).

The world production of coconut (*Cocos nucifera* L.) was around 60 million tons in 2008 – 85% in Asia, 8.5% in America, 2.9% in Africa and 3.2% in Oceania. Brazil is the fourth largest producer of coconut in the world, with production of about 2.8 million tons per year, accounting for more than 80% of the coconut production in South America. It is estimated that 350 million liters of green coconut water are consumed in Brazil every year (Martins and Jesus, 2011; Prieto et al., 2011). After the consumption of the coconut water, the resulting waste generate significant and increasing volumes of useless material, since 80–85% of the gross weight of the green coconut are nominated as residues. 70% of the waste generated in Brazilian coastal urban centers is green coconut husk (Rosa et al., 2001; Prieto et al., 2011). Although being an organic material, the residue degradation is slow and can take more than eight years to fully degrade (Carrijo et al., 2002). Estimates indicate that the volume of waste generated from the green coconut is equivalent to 6.7 million tons of husks/year, becoming a serious environmental problem (Machado et al., 2009).

The green coconut fibers in cement composites can be used as reinforcement in the early ages. The adhesion between the matrix and the reinforcing component has a strong influence on the characteristics of the composite, contributing to an adequate stress transfer between the fibers and the matrix. These fibers increased the impact resistance by 3–18 times, respectively, compared to plain cement specimens. The main drawback for the use of vegetable fibers is the durability of these fibers in a cementitious matrix and also the compatibility between both phases (Agopyan et al., 2005).

The recycling of various types of cellulose pulps for the production of fiber cement has shown a significant effect on the mechanical properties and absorption. Yadollahi et al. (2013) found that relatively denser, stronger, and stiffer composites were obtained from the boards made with 40% pulp and paper sludge.

To use alternative binders by the inclusion of pozzolanic additions are necessary to reduce the alkalinity of the matrix and the content of calcium hydroxide (portlandite), avoiding the long-term degradation in non-conventional fiber cement material employing vegetable fibers as reinforcement.

The hydration process depends on the type and the fineness of the cement, the water/cement ratio, curing temperature and the presence of chemical admixtures and mineral additions. When mineral additions with high pozzolanic activity are incorporated into the cement matrix, can chemically react with calcium hydroxide, resulting from cement hydration to form an additional amount of hydration product in cement matrix. Results showed that RHA can be applied as a pozzolanic material to cement and also can improved resistance to water absorption (Hamzeh et al., 2013). The amount of this hydration product can reduce the porosity of the matrix and the porosity of the fiber-matrix transition zone and the permeability of binder materials, contributing to an increase in durability.

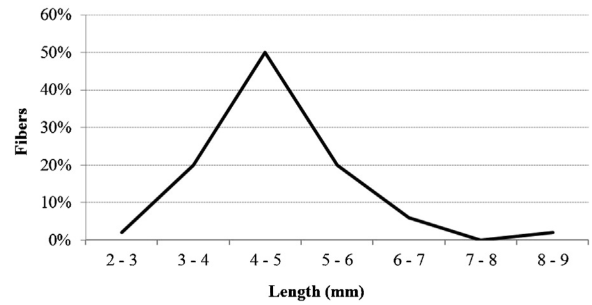

Fig. 1. Distribution of length for green coconut fiber.

The ash production is generated by the burning process of rice husk as sources of energy and cogeneration for power. If adequately processed, the ash becomes a pozzolan predominantly amorphous, which is soluble in an alkaline medium and reacts in an aqueous solution with Ca^{2+} and OH^- ions. The final result of the reaction is the calcium silicate hydrate (CSH), the main product of hydration of the ordinary Portland cement.

The rice husk ash and active silica are highly reactive pozzolan, as they are essentially composed of pure silica in non-crystalline form. The non-crystalline rice husk ash (RHA) is obtained by burning at temperatures below 700 °C, and consists of a disordered structure of silicon (Si) and oxygen (O) resulting from the decomposition and sintering without fusion of the amorphous silica (Payá et al., 2001).

The techniques of differential thermal analysis (DTA) and thermogravimetry (TG and DTG) have been frequently used by different researchers, to determine the amount of chemically combined water proportional to the hydrates (Dweck et al., 2000; Marsh and Day, 1998; Vedalakshmi et al., 2003). Using thermogravimetry it can be observed that the hydration products in the matrix release the chemically combined water in characteristic peaks that may occur in specific temperature ranges, as follows: calcium silicate hydrate (CSH), ettringite and calcium aluminate hydrate – 100 and 300 °C and calcium hydroxide – 425 and 550 °C (Taylor, 1997). Studies carried out by Roszczynialski (2002) and Giergiczny (2006), using thermal analysis (DTA/DTG), showed the influence of the fly ash in the chemically combined water content of hydrates in the cementitious matrix. Payá et al. (2003) used TG techniques for monitoring the pozzolanic reaction of spent FCC catalyst. Rodríguez et al. (2012) determined by TG the consumed portlandite by different types of silica fume.

The use of supplementary materials in non-conventional fiber cement can provide increments in performance, both in fresh and hardened state, improving its mechanical properties and durability. The use of pozzolan like rice husk ash as a partial substitute to ordinary Portland cement allows enabling the production of non-conventional fiber cement reinforced with natural fibers, once it