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ORIGINAL ARTICLES

Structural behaviour of bamboo-reinforced foamed concrete slab containing polyvinyl wastes (PW) as partial replacement of fine aggregate

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Abstract This paper reports the findings of experimental study to investigate the structural behaviour of bamboo-reinforced foamed concrete slab with polyvinyl waste as partial replacement of fine aggregates. The structural properties studied were: compressive strength, density, crack development pattern and propagation, failure pattern, load–deflection characteristics and the ultimate moment. Compressive strength and the density tests were also conducted using $150 \times 150 \times 150$ cube specimens. The flexural behaviour was investigated by using $1300 \times 500 \times 100$ mm slab specimens. The results showed that: (i) partial replacement of sand with polyvinyl waste (PW) improved the compressive strength of the foamed aerated concrete specimens, (ii) that slab specimens with polyvinyl waste as partial replacement sand exhibited shear bending failure, (iii) all the slab specimens with polyvinyl waste as partial replacement sand recorded lower values of deflection for the same loading, as the level of sand replacement with polyvinyl wastes increased, and (iv) increase in the amount of sand replaced with polyvinyl wastes resulted in improved bending performance of the slab specimens.

1. Introduction

Innovative structural and construction materials are believed to have the potential to curb the seeming overdependence on non-renewable materials like, sand, cement, etc. that are used globally for construction. This will definitely help to arrest the accompanying environmental degradation that accompanies extraction of non-renewable materials. Some innovative structural materials to date are obtained by partially replacing one of the major components of concrete with any of the many wastes (industrial, agricultural, construction, etc.) and non-waste materials. Some of the waste materials that have been used innovatively for structural concrete include: palm kernel fuel ash (Hussin and Abdullah, 2009), silica fume (Yilmaz, 2010) rice husk ash (Givi et al., 2010), fly ash

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(Wilson and Ding, 2007), pulverized bone (Falade et al., 2013a,b), etc. Other non-wastes materials that have been used innovatively for structural concrete, especially as alternatives to the traditional reinforcement include fibres (Ramaswamy, 2014), stainless steel clad black steel, microcomposite reinforcement, carbon fibre reinforced polymer (Hill et al., 2003), bamboo (Ikponmwosa et al., 2014a,b), etc. In the present study, the possibility of using polyvinyl waste (PW) as partial replacement of fine aggregates in the production of foamed aerated concrete slab is investigated. Polyvinyl are materials made from polymers of vinyl compounds, which are subsequently used to manufacture building materials (roofing sheets, windows, vinyl siding), consumer products, disposable packaging, and many every day products (Chej, 2004). According to Thornton (2002), annual generation of polyvinyl waste (PW) stands at about 12 million tones. He further concluded that these wastes pose a serious environmental threat because of the fact that they are difficult to dispose and recycle. Thus the aim of this work is to find out some structural properties of foamed aerated concrete slab, reinforced with bamboo, and containing polyvinyl wastes (PW) as partial replacement of fine aggregates. Ikponmwosa et al. (2014a) have previously studied beam specimens reinforced with bamboo. In the present work however, bamboo is being used as reinforcing material for slab specimens. The parameters investigated in the present work are: compressive strength, density, crack development pattern and propagation, failure pattern, load–deflection characteristics and the ultimate moment.

2. Materials and method

2.1. Materials and mix design

The materials used for these investigations are: cement, fine aggregates, water, polyvinyl wastes, foaming agent and bamboo.

2.1.1. Cement

The cement was Ordinary Portland cement produced to satisfy the requirements in BS 12 (1996) and NIS 444 (2003).

2.1.2. Fine aggregate

As fine aggregates river sand which was obtained from Ogun river basin in Nigeria was used. The sand was dried and sieved through sieve 2.36 mm and treated in accordance with BS 882 (1992).

2.1.3. Water

The water used for the experiment was potable tap water, free from any dissolved metal or ions that might inhibit the setting and hydration process of the foamed concrete. The water was also used to dilute the foaming agent for aeration process.

2.1.4. Polyvinyl wastes

The polyvinyl waste (PW) was obtained as waste material from a polyvinyl-based roofing sheet manufacturing company, Nigerite Limited, based in Ikeja, Nigeria. The waste was ground and packed in bags to be stored subsequently in a cool place.

2.1.5. Foaming agent

In order to aerate the mortar, a polyurethane foaming agent was used. It was obtained from Lagos in Nigeria.

2.1.6. Bamboo as reinforcement

The characteristics of bamboo used for these works were in accordance with the results of works done by Salau et al. (2012), and they include: (i) bamboos with at least three years old and showing a pronounced brown colour, (ii) bamboos without decay, fungus growth, or holes due to white ants, deformation with large diameter and straight long, (iii) bamboo having greater number of nodes. The selected bamboos were air dried for over 30 days (seasoning in air), and then sawn into strips size of $10 \times 10 \times 1200$ mm. In order to reduce water absorption and increase the bond with lightweight aerated concrete matrix, the bamboo strips were coated with bitumen. Wound around the bamboos is 1 mm diameter coir rope at a pitch of about 25 mm along the strip from end. The coir rope was also coated in hot bitumen after being wound round the bamboo strip. This gave a surface similar to a ribbed steel surface. The ribbed surface was expected to improve the bond considerably and the structural behaviour of the bamboo reinforced aerated concrete. Also, fine sands were sprinkled over the coats of bitumen with the aim of inducing roughness on its surface.

2.1.7. The mix design

Based on the equations suggested by Jones and McCarthy (2005), the following mix ratio: cement: sand ratio of 1:3, water: cement ratio of 0.5, and foaming agent: water ratio of 1:33 were used. The mix design was chosen for the target density for the foamed aerated concrete between 1600 and 1900 kg/m^3. All the measurements were by weight.

2.2. Experimental investigations

2.2.1. Density and compressive strength test

The density and compressive strength were performed in accordance with BS 12350: Part 6 (2000) and BS EN 12390-3 (2009). For the tests, $150 \times 150 \times 150$ mm cube specimens were used. This test was performed to confirm whether the targeted 28-day compressive strengths for both the normal weight and the foamed aerated concrete were achieved. The cubes were tested for their compressive strength at 7, 14, 21, and 28 day curing ages respectively. The strength characteristics of each cube were determined on 600 kN Avery Denison Universal Testing Machine at a loading rate of 120 kN/min. Three specimens were tested at each age and the values of the crushing load were averaged and used to evaluate the mean strength for each batch. The cubes were weighed on the Avery weighing machine prior to testing on the testing day, and the values recorded were used to compute the density of the specimens. A total number of 12 cube specimens were produced and tested.

2.2.2. Flexural test

Flexural tests were performed on foamed aerated concrete using $1300 \times 500 \times 100$ mm slab specimens. Before the commencement of concreting, the moulds were properly scraped and oiled to prevent adhesion of the concrete to the moulds.