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ScienceDirect

Procedia Engineering 184 (2017) 778 – 783

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Production of A Green Lightweight Aggregate Concrete by Incorporating High Volume Locally Available Waste Materials

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Abstract

Lightweight concrete offers numerous benefits compared to normal weight concrete such as reduction in dead load and construction costs. One of the most common methods of producing structural lightweight concrete is the use of lightweight aggregates. The application of waste substances as cement substitutes or aggregates in concrete can support a solution in order to decrease negative influences of the concrete industry. One of the agricultural solid wastes derived from the industry of palm oil is oil palm shell (OPS) which processes about 50% lower weight compared to normal weight aggregates. The paper reports an investigation on the oil palm shell as coarse aggregate as well as fly ash and rice husk as supplementary cementitious material to generate more environmentally friendly lightweight concrete. Based on the research findings, the environmentally friendly structural lightweight aggregate concrete has the potential to be made through combining three kinds of waste substances: oil palm shell as coarse aggregate and blended RHA-FA as a substitution for cement (by mass) up to 70%. The act of replacing the cement by blended RHA-FA in OPS concrete leads to density reduction.

Keywords: Lightweight concrete; Oil palm shell; Solid waste; Supplementary cementitious materials; Rice husk ash, Fly ash.

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Peer-review under responsibility of the organizing committee of the Urban Transitions Conference
doi:10.1016/j.proeng.2017.04.158

1. Introduction

Today, concrete has become the most commonly used building material in the construction industry. One of the remarkable benefits of concrete is its excellent mechanical and physical characteristics, if properly designed and manufactured. It has excellent resistance to water, the components of structural concrete have the potential to be shaped into different sizes and patterns and it is a highly cost-effective and easily accessible substance for the operation [1]. The popular interest for concrete in construction, employing normal weight aggregates like granite and gravel has tremendously decreased natural stone deposits, which resulted in irreversible destruction to the environment [2]. Developed countries have been utilizing the lightweight concrete (LWC) for many years. The most popular way of achieving LWC production is by using lightweight aggregate (LWA) [3].

The main natural LWAs are diatomite, pumice, scoria, volcanic cinders and tuff [4]. An alternative LWA in tropical regimes and countries that have a palm oil industry is Oil Palm Shells (OPS), sometimes called Palm Kernel Shells (PKS) [5]. Employing OPS as a lightweight aggregate to generate lightweight concrete was first studied in 1985 by Abdullah in Malaysia [6]. From the results of several studies, oil palm shell has the potential to be employed as coarse aggregate in order to produce structural lightweight aggregate concrete [7-11].

The global usage of Portland cement has increased from under 2 million tons in 1880 to 1.3 billion tons in 1996 [12]. Nowadays, 1.5 billion tons has been reported predicting to get to 2.5 billion tons by 2020 [1]. Production of this amount of cement demands a huge amount of natural resources. A substantial quantity of waste materials is produced globally as by-products from different sectors, such as industrial and agricultural wastes which have the potential to be utilized as the supplementary cementitious materials (SCM).

Pozzolan as one of the agricultural and industrial by-products such as rice husk and fly ash are recently obtaining a huge interest as their applications typically enhance the characteristics of the blended cement concrete, along with the expenses and also the reduction in the negative influences on the environment. Rice husk is considered as one of the main by-products from the agricultural field and is easily accessible in various parts around the globe. In some of the countries, rice husk has been widely used in generating electricity power from the plants and in the form of a fuel in rice mills to reduce the rice husk volume [13]. Previous studies concluded that RHA is applicable for partial substitution, due to its extremely high silica (SiO_2) which is around 90%. Moreover, it should be mentioned that in the form of amorphous, it is applicable for applying as a pozzolanic material [14]. The RHA’s silica content helps to improve the concrete’s mechanical features [15]. On the other hand, Fly ash (FA) is found as the most frequently used pozzolan and is highly in demand for its application around the world in concrete works. FA is made through mechanical or electrostatic tools from the flue gases of furnaces in the stations of coal-fired power. Employing fine fly ash has been observed to highly enhance the characteristics of concrete and mortar [16, 17].

This paper aims to study the potential of making structural sustainable lightweight aggregate concrete through combining high volume of agricultural and industrial wastes. An OPS has been uses as coarse aggregates and 70% of OPC has been replaced by RHA and FA.

2. Experimental Details

2.1. Materials Utilized

Ordinary Portland cement (OPC) with surface area of $3.51m^2/g$ and specific gravity of 3.15 was used. The rice husk was obtained from a local rice milling plant. Rice husk was burnt in ferrocement furnace. The temperature was controlled by the structure of the furnace. Fly Ash (FA) which was obtained from a local power station was classified as class F based on ASTM: C618. Table 1 displays the chemical composition of FA, OPC and RHA.

Coarse aggregates were replaced by OPS. OPS has been washed and soaked in the water for 24 hours before casting and then dried in the room temperature up to total drying of the surface. Table 2 displays the physical characteristics of OPS. It can be observed that the local mining sand with fineness modulus of 3.00, the highest particle size of 4.75 mm, and water absorption of (< 1%) along with specific gravity of 2.55 was employed as the fine aggregate in this study. Fine aggregate of zone 2 was used based on experimental works. In addition, Sika ViscoCrete-2199 was used as superplasticizer. Its chemical base is modified polycarboxylate.

Table 1 Chemical Composition of OPC, RHA and Fa

Oxides	SiO_2	Fe_2O_3	CaO	MgO	K_2O	SO_3	Al_2O_3	LOI
OPC	16.68	3.64	68.36	1.29	0.36	4.80	4.41	1.42
RHA	91.02	1.19	0.80	0.90	3.17	0.30	0.30	1.4
FA	50.24	10.37	6.95	1.84	1.53	0.94	23.53	5.9