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Comparing the effects of oil palm kernel shell and cockle shell on properties of pervious concrete pavement

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Abstract

Nowadays, pervious concrete pavement is one of the best materials used in construction industry as a top layer of permeable pavement system to control the storm water at source. In addition, increasing production of waste materials, increased the interest in utilising the waste materials for environmental and technical benefits. Therefore, this paper compared the effect of using two different sizes of oil palm kernel shell (OPKS) and cockleshell (CS) as partial replacement of natural coarse aggregate on properties of pervious concrete pavement. Thirteen mixtures were made, in which 6.30-mm natural gravel was replaced with 0, 25, 50 and 75% of 6.30-mm and 4.75-mm of both shells. The relationships between the properties of pervious concrete mixtures was also determined. The replacement of OPKS and CS as the natural aggregate decreased the compressive strength, while the angular shape of both shells caused higher void content and permeability as compared to those of control pervious concrete. On the other hand, pervious concrete containing CS showed better properties than those of incorporating OPKS. Apart from that, strong relationships between density, void content, permeability, compressive strength values indicated that they can be used as a pervious concrete quality control tests for prediction of properties of pervious concrete pavement before placement in the field.

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Keywords: Pervious concrete pavement; Void content; Permeability; Cockleshell; Palm oil kernel shell

1. Introduction

The effective management of by-product waste materials plays an important role in increasing environmental sustainability. One of the strategies in waste management is the utilisation of by-product waste materials in the construction industry to reduce the landfill of waste materials. Moreover, with the application of waste materials, more sustainable, clean and green construction could be achieved [1]. In addition, most of the raw materials used in concrete production are natural aggregates, and generally the materials are excavated from mines and river beds or dredged from sea shelves [2]. These activities have resulted in severe damage to the environment, including disruption of the ecosystem and contamination of soil, air and water [3]. Therefore, the construction industry encourages the incorporation of sustainability in production issues with the

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application of solid waste materials as aggregate in concrete [4–6]. In addition, it was indicated that by reusing waste materials could also ensure waste conservation, and subsequently, decrease waste disposal in the involved sectors. Two of the waste materials, which were successfully utilised as coarse aggregate in conventional concrete, were oil palm kernel shell (OPKS) and cockle shell (CS). OPKS is a waste product obtained from oil palm fruits during the production of palm oil [7,8]. Malaysia produces over four million tonnes of OPKS annually [8,9], and the country is expected to grow five million hectares of oil palm trees by the year 2020 [10]. Many researchers have previously investigated the properties of OPKS as aggregate in the production of lightweight concrete. In the said studies, they managed to achieve compressive strength ranging from 13 to 30 MPa [11–13]. Olanipekun et al. [15] showed that by increasing OPKS, the compressive strength of concrete decreased. This was due to the lower specific gravity (1.17–1.62) and a much higher water absorption ratio (14–33%) of OPKS in comparison to those of natural aggregates [7,9]. Furthermore, Alengaram et al. [15] reported that the angular and rough edges of OPKS were responsible for lower workability, while higher water absorption of OPKS was a result of the existence of many pores in the shells. However, Shafigh et al. [16] stated that OPKS could be replaced as a lightweight natural aggregate to produce high strength lightweight concrete with a compressive strength of up to 48 MPa at 28 days. This is due to the small size of OPKS and superplasticiser. Islam et al. [17] utilised both OPKS and palm oil fuel ash (POFA) as aggregate and cement replacement respectively to produce lightweight concrete. They concluded that using 10% POFA attained the most optimum performance in terms of the sustainability of the concrete containing OPKS, which was according to the evaluation of the cost and eco-efficiencies of the concrete.

According to the Department of Fisheries Malaysia, 57,544 tonnes of cockles were harvested along the west coast of Peninsular Malaysia. In addition, it was reported that the retail value of cockles in Malaysia was estimated to be at over USD 32 million [18]. Boey et al. [18] also indicated that the active and lucrative industry has resulted in a significant amount of waste shells. Moreover, left untreated and dumped irresponsibly, CS may produce unpleasant odour [19]. Several researchers have previously investigated the effects of replacing natural coarse aggregates on concrete with seashells by-products. Muthusamy and Sabri [20] reported that the replacement of CS as coarse aggregates were able to produce good quality concrete due to their hardness property. However, higher cement paste would be required to obtain the desired workability at higher percentage replacement of CS, owing to the angularity of the shells. In their study, the maximum compressive strength obtained was 34.8 MPa at 20% CS substitution. On the other hand, Cuadrado-Rica et al. [23] indicated that the application of crushed queen scallop shells as aggregate substitution could result in the decrease of mechanical properties. They also reported that the replacement could potentially increase the porosity of concrete, resulting from an increase of entrapped air in the concrete. Moreover, the concrete could also exhibit low workability due to the shells' size, shape and texture [20]. In another study, Nguyen et al. [25] investigated the effects of partial replacement of natural coarse aggregate with crushed crepidula seashells of 2–4 mm and 4–6.3 mm (20 or 40% by mass) on the properties of pervious concrete. They reported that pervious concrete paver containing 40% of crepidula shell (2–4 mm) could achieve 97% of the compressive strength demonstrated by the control pervious concrete (CPC). They concluded that the permeability of the pervious concrete increased with the increasing amount of the seashell used, as a result of the porosity of the seashells. However, to the author's best knowledge, there are currently no reports of the use of CS as the partial coarse aggregate replacement in pervious concrete paver.

In this paper, the effects of OPKS and CS as a partial replacement of natural coarse aggregate on the properties of pervious concrete, were investigated. The production of pervious concrete pavement is a unique and successful strategy to help both the environmental issues and sustainable development. Based on the literature search carried out, there are currently no studies investigating the effects of OPKS and CS on the properties of pervious concrete. On a related note, the aim of this study was to replace OPKS and CS (0, 25, 50 and 75%) with two different sizes (6.30-mm, 4.75-mm) as natural coarse aggregate in pervious concrete. The effects of replacing coarse aggregate with OPKS and CS on fresh and hardened properties of pervious concrete, such as density, void content, permeability as well as compressive strength were investigated and compared against each other and the CPC. In addition, the relationship between properties of pervious concrete mixtures was also analysed.

2. Specimen and preparation

2.1. Materials

The cement used in this study was Ordinary Portland Cement (OPC) type I. To achieve a system with interconnection voids in the pervious concrete, the selection of single-sized aggregates is necessary [23,24]. The details of the aggregates are listed in Table 1. In this study, crushed limestone (LS) with a grain size of 6.30-mm (passed through a 9.5 mm sieve and retained on a 6.30 mm sieve) was used as the natural coarse aggregate. LS presented a specific gravity of 2.7 kg/m^3 and water absorption of 1.8%.

In addition, OPKS and CS were used as a replacement of natural coarse aggregate. In this study, OPKS was collected from a local palm oil producing mill located in Johor, a southern state of Malaysia. On the other hand, CS were obtained from a local market located in the south coast of Malaysia, and were crushed before they were used. Subsequently, both OPKS and CS were sieved and divided

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