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Research Article

Exploratory Study of Oil Palm Shell as Partial Sand Replacement in Concrete

K. Muthusamy, N.A. Zulkepli and F. Mat Yahaya
Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang

Abstract: Malaysia being one of the world largest palm oil producers has been disposing oil palm shell, which is a by-product from palm oil mill thus causing negative impact to the environment. At the same time, extensive mining of natural river sand in large amount to meet the increasing demand of concrete production for the use in rapidly developing construction industry has posed the risk of natural aggregate depletion and ecological imbalance in future. The effect of finely Crushed Oil Palm Shell (COPS) as partial sand replacement material in concrete mix towards density and compressive strength was investigated in this study. Total of five mixes consisting various content of crushed oil palm shell as partial sand replacement ranging from 0, 25, 50, 75 and 100% were prepared in form of cubes. All the specimens were water cured before tested at 7, 14 and 28 days. Compressive strength was conducted in accordance to BSEN 12390. Generally, the compressive strength and density decrease with the increase in the crushed oil palm shell replacement level. Between 50 to 75% replacement, the mix produced possess lower density enabling it to be categorized as lightweight concrete and has the potential to be used as non-load bearing structure. The application in structural concrete material is suited for mix consisting around 25% of crushed oil palm shell.

Keywords: Crushed oil palm shell, compressive strength, concrete, density, partial sand replacement, water curing

INTRODUCTION

The growing need of construction trade and issue of environmental problem created from the by-product of palm oil industry has initiated research towards producing a new green concrete material. The consumption of natural fine aggregate specifically river sand for concrete production to meet the escalating demand construction industry has open the door for water pollution and ecological imbalance at river bed environment and also possible depletion of this material in future. The sand mining impose negative impact to the environment in terms of reduced water quality, destabilization of stream bed and bank which in turn cause the destruction of riverine vegetation (Asyraf *et al*., 2011) leading to ecological imbalance. At the same time, Malaysia being the second largest world palm oil producer (Sudesh *et al*., 2011) has been disposing oil palm shell which is a by product of palm oil mill in increasing quantity. Previous researcher Teo *et al*. (2006) has reported the produced oil palm shell which is approximately 4 million tonnes annually were incinerated or dumped as solid waste thus resulting in environmental pollution. Leaving this agro waste material to biodegrade by itself would take longer time and the pollution created by this waste while rotting can pose negative impact to the healthy lifestyle of community surrounding.

Therefore, placing the issue of environment preservation for the future generation being the utmost importance has lead towards the effort of integrating this agro waste as a mixing ingredient in concrete production. So far, this material has been successfully incorporated as coarse aggregate replacement in lightweight concrete (Mannan and Ganapathy, 2001; Shafigh *et al*., 2012). However, potential of this material to play the role as partial sand replacement in concrete formation is yet to be studied. It is anticipated that formulation of concrete integrating crushed oil palm shell to substitute the use of sand partially would offer alternative to the concrete manufacturer to use this waste material in the production rather than heavily relying on natural sand. Application of this material as one of the mixing ingredient in concrete making would expand the functionality of this waste thus reducing amount of oil palm shell ending up at landfill.

In this recent research study, the effect of replacing various percentage of sand with Crushed Oil Palm Shell (COPS) towards the concrete properties were investigated through experimental work conducted at laboratory of Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang. The present study discusses the performance of various concrete mixes in terms of density and compressive strength.

Corresponding Author: K. Muthusamy, Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang

EXPERIMENTAL PROGRAMME

A single batch of Ordinary Portland Cement (OPC) complies with the Type 1 Portland cement as in ASTM (American Society for Testing and Material) (2005) was used in this experiment. Supplied tap water was used during the study in mixing, curing and other processes. The coarse aggregate integrated in the mix consist of single sized 10 mm crushed granite and the fine sand used was local river sand with fineness modulus of 1.08. Oil palm shell was collected from a palm oil mill factory located in Felda Lepar Hilir in the state of Pahang, Malaysia. After that, it was crushed using Jaw crusher until become smaller particles and then sieved passing 4.5 mm sieve before stored in a dry place. The originally collected Oil Palm Shell (OPS) and the sample of Crushed Oil Palm Shell (COPS) to be used as fine aggregate replacement material is illustrated in Fig. 1 and 2 respectively.

Five mixture proportions prepared using water cement ratio of 0.5 were used to achieve the objectives of this experimental work. The total cementitious' material content has been kept constant in all the mixes except for the variation in the percentage of river sand used. The first is a reference concrete mix (control mix) consisting 100% river sand. Then, the remaining four mix is prepared by integrating Crushed Oil Palm Shell (COPS) by weight. The proportion of fine aggregate replaced ranged from 25 to 100% with 25% interval. All mixes were cast in cubes (100×100×100 mm) and then demoulded after 24 h of the casting before subjected to water curing until the testing date. Compressive strength test was determined for 7, 14 and 28 days according to British Standard Institution (2009).

Fig. 1 : Oil Palm Shell (OPS)

Fig. 2: Crushed Oil Palm Shell (COPS)

RESULTS AND DISCUSSION

Compressive strength and density: Both result on compressive strength and density of mix consisting various percentage of Crushed Oil Palm Shell (COPS) mixes presented in Fig. 3 and 4 indicates that characteristic of COPS influence the pattern of concrete structure which in turn causes variation in their engineering properties. Since compressive strength increase linearly with density and vice versa (Narayanan and Ramamurthy, 2000), the reduction in the weight of specimens containing COPS together with the lower bearing capacity of the mix as percentage of COPS added increases is justified. The lighter particle of COPS as compared to dense river sand produces two types of mix that is normal weight concrete and lightweight concrete depending on the percentage of COPS used. Apparently replacement up to 25% produces hardened concrete with density within the range (2000- 2400 kg/m^3) which can still be considered as normal weight concrete. Since range of lightweight concrete density is between about 300 and 1850 kg/m^3 (Neville, 2005), mixes consisting beyond 50% replacement concrete displays the density less than 1800 kg/m^3 leading it to be categorized as lightweight concrete.

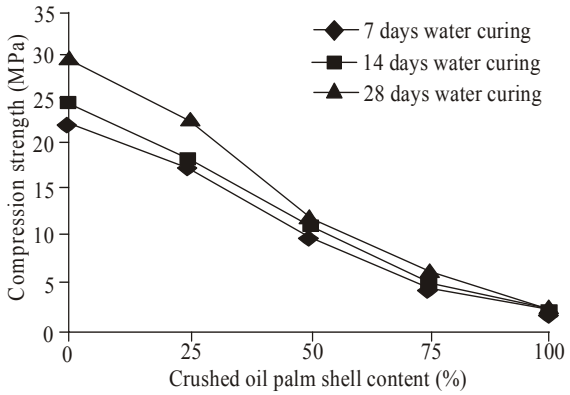

Fig. 3: Effect of crushed oil palm shell content on compressive strength of concrete cubes at the age 7, 14 and 28 days

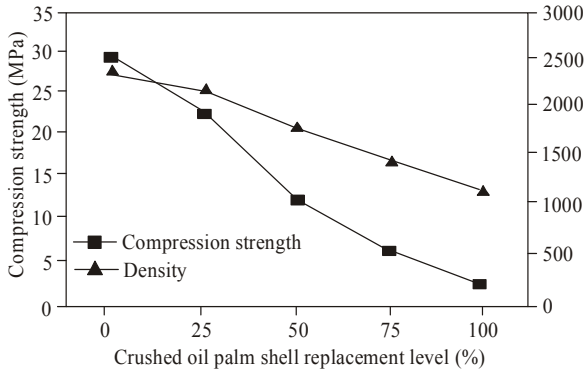

Fig. 4: Relationship between strength and density of concrete consisting a range of crushed oil palm shell at 28 days

Fig. 5: Failure of control specimen without COPS

Fig. 6: Failure of concrete with 25% COPS

Fig. 7: Failure of concrete with 50% COPS

Fig. 8: Failure of concrete with 75% COPS

Fig. 9: Failure of concrete with 100% COPS

Discussing factors affecting the mixes strength performance, the lower strength exhibited by mixture with higher percentage of COPS when compared with the one consisting smaller percentage is due to reduction in the quantity of cement used as adhesive materials. For a given percentage, existence of higher amount of COPS replacement possessing larger proportion of bigger particle size compared to natural sand means the presence of higher effective surface area in the mix which needs to be coated by cement paste. This condition would lead to insufficient proportion of cement paste thus reduced the bonding properties of the matrix with aggregates. The excessive reduction in concrete work ability with increase of shell content beyond 50% replacement makes the mix difficult to be compacted resulting in hardened concrete with higher porosity thus exhibit lower strength. However, strength exhibited by the mix consisting 50 to 75% COPS fulfills the strength requirement in ASTM (American Society for Testing and Material) (2011) indicating that this mixes has the potential to be used as non load bearing structure.

Knowing compressive strength of concrete is significant for construction of concrete structure, it could be concluded that replacement up to 25% of COPS has the potential to be used for structural concrete. The failure pattern of concrete mix with 25% COPS which does not vary much from the control and also exhibit better stiffness and compactness compared to the rest of replacement mixtures which shows increased brittleness and porosity as can be observed in Fig. 5 to 9. On overall, the findings of this study is in agreement with facts highlighted by Nawy (1985) who stated that concrete properties can be affected by the properties of fine aggregate. Conclusively, the proportion and characteristic of crushed oil palm shell used as partial fine aggregate replacement influence the density and strength performance of concrete. It is believed that the strength performance of the mix consisting COPS can be improved much more through modification in the particle size of COPS and addition of mineral admixtures, which remains to be investigated in future study.

CONCLUSION

This study intended to find effective way to reuse OPS waste as partial fine aggregate replacement in concrete. The data presented in this study shows that there is a promising potential for the use of crushed oil palm shell in concrete. Replacement of crushed oil palm shell which is around 25% would be able to produce mix with compressive strength suitable for application in structural concrete material.

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