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COMPRESSIVE STRENGTH OF PALM OIL WASTE LIGHTWEIGHT AGGREGATE CONCRETE CONTAINING PALM OIL FUEL ASH AS PARTIAL CEMENT REPLACEMENT

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ABSTRACT

The increasing amount of by-product generated by Malaysian palm oil mills namely oil palm shell (OPS), palm oil clinker (POC) and palm oil fuel ash (POFA) which are disposed without any profitable value at dumping site has caused huge land consumption and also pollution to the environment. Thus, this problem has lead towards researcher's effort towards integrating these by-products in concrete production. Integrating POFA as partial cement replacement, OPS as coarse aggregate and POC as fine aggregate in lightweight aggregate concrete would reduce huge amount of waste disposed at the landfill. This paper addresses the compressive strength of palm oil waste lightweight aggregate concrete containing various percentage of POFA as partial cement replacement. Palm Oil Waste lightweight aggregate concrete mixes were produced by replacing various percentage of POFA ranging from 10, 20, 30, 40 and 50%, respectively by weight of cement. In this investigation, all the specimens were prepared in form of cubes (100 mm x 100 mm x 100 mm) and water cured until the testing age. The compressive strength test was carried out at 7 and 28 days following the procedures in BSEN 12390 – 3. The finding shows that specimen produced using 20% POFA exhibit encouraging result value of compressive strength as compared to control specimen. Incorporation of palm oil wastes as mixing ingredient in lightweight concrete production would reduce the amount of waste disposed thus ensuring ecological balance as well as sustainable environment for future generation.

Keywords: Palm oil fuel ash, oil palm shell, palm oil clinker, lightweight aggregate concrete, compressive strength

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1. INTRODUCTION

At present, more than 4.49 million hectares of land in Malaysia is under oil palm cultivation and titled as the second largest palm oil producing countries in the world. Hence, the production from palm oil industry also generates many types of waste products and most were disposed in landfill. Among the by-products that generated from palm oil industries are oil palm shell (OPS), palm oil clinker (POC), empty fruit bunches (EFB), palm oil fibres and palm oil fuel ash (POFA) Ahmmad et al (2016). According to Muthusamy et al (2015), dumping these waste products in the landfill would only solve problems temporarily and will create other types of environmental problems in future. Another researcher Teo et al (2007) stated the leftover agricultural wastes have been cumulative and caused land and air pollution to the environment. At the same time, the growing demand for ordinary Portland cement (OPC) production and increasing river sand mining activity is seen to create larger adverse effect to the environment unless action taken to solve this issue. The widely used construction material that is ordinary Portland cement (OPC) for concrete production is not environmental friendly. This is because of the pollution caused during its production process, energy intensive and greenhouse effects (Ma and Rao, 2012). The increasing of river sand mining demand would create negative impact to the river and environment finally causing ecological imbalance that would finally affect the quality life of community surrounding. The negative impact issue of natural sand mining has been discussed by Manap and voulvoulis (2015) and Asyraf et al (2011). Smart move of incorporating the freely available environmental polluting palm oil wastes in concrete production would reduce high dependency on natural resources by concrete producer and able to preserve these valuable non-renewable assets for future generation.

So far, palm oil fuel ash has been successfully used as partial cement replacement to produce concrete with enhanced strength such as plain concrete (Abdul Awal, 1996), aerated concrete (Hussin et al, 2008), high strength concrete (Ismail et al., 2010), lightweight aggregate concrete Muthusamy and Zamri (2015), and ultra high performance concrete (Aldahdooh et al, 2013). Oil palm shell has also been used as mixing ingredient to produce lightweight concretes (Mannan and Ganapathy, 2001; Teo et al., 2006b; Harimi et al., 2007; Shafigh et al., 2011 and Muthusamy and Zamri, 2014) that various range of strength There are also researchers (Hilton et al., 2007. Bashar et al., 2011. Rasel et al., 2014 and Kanadasan and Razak, 2015) who used palm oil clinker to produce lightweight concrete. However, strength performance of palm oil waste lightweight aggregate concrete with zero granite content and combination of three types of solid wastes namely POFA, OPS and POC with lesser amount of natural resources from environment remains to be explored. Success in producing palm oil waste lightweight aggregate concrete suitable for structural application would offer benefits in terms of lesser amount of palm oil waste disposed, saving of landfills and also reduction in the cost spent by palm oil industry for waste management. The present research investigates the possibility of integrating palm oil clinker as sand replacement in lightweight concrete production, oil palm shell as full coarse aggregate replacement and palm oil fuel ash as partial cement replacement. The paper discusses the effect of palm oil waste content in concrete towards workability and strength performance of palm oil waste lightweight concrete.

2. EXPERIMENTAL METHODS

2.1. MATERIALS AND SAMPLE PREPARATION

Green lightweight aggregate concrete in this research were made of ordinary Portland cement, oil palm shell (OPS), palm oil clinker (POC), palm oil fuel ash (POFA), water and superplasticizer. Type I ordinary Portland cement (OPC) complying with MS 522: Part 1 (2003) for Portland cement specification was used as primary binder. Palm oil waste namely oil palm shell, palm oil clinker and palm oil fuel ash used throughout this research were collected from a local palm oil mill as shown Fig. 1, 2 and 3 respectively. OPS collected were washed to remove dirt and oven-dried until it turns into saturated surface dry (SSD) condition. POC which is obtained in larger piece from its origin was crushed using jaw crusher and used as fine aggregate. POFA which act as partial cement replacement in this study has undergone several processes such as sieved and ground using modified Los Angeles abrasion machine until reached the desired fineness. The POFA used is classified as class C pozzolana in accordance with ASTM C618 (2012). Tap water was used for washing, mixing and curing purpose. Type A water reducing agent according to ASTM 494 (2005) was also employed to produce homogeneous concrete and workable concrete.

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Fig. 1. Oil palm shell **Fig. 2.** Palm oil clinker **Fig. 3.** Palm oil fuel ash

2.2. Mix Proportion and Testing

The mix proportion of plain palm oil waste lightweight aggregate concrete that consists of 100% OPC as binder and different percentage of POFA by weight of cementitious materials are shown in Table 1. In this experimental work, the cement was replaced with various percentage of palm oil fuel ash (POFA) by weight of the binder. The percentage of POFA replacement used are 0%, 10%, 20%, 30%, 40% and 50%. The concrete slump test was also carried out to investigate the effect or POFA percentage towards concrete workability by following the procedures in BS EN 12350: Part 2 (2000). The specimens were prepared in form of 100 x 100 x 100 mm standard cubes and then water cured until the testing date. The compressive strength of the specimens were determined by subjecting it to compressive strength test at the age of 7 and 28 days curing. The compressive strength test was conducted in accordance with BS 12390: Part 3 (2002).

Table 1. Mix proportion of palm oil waste lightweight aggregate concrete (kg/m^3)

MIX	OPS	POC	OPC	POFA	SP	w/c
P0	300	600	500	-	6	0.42
P10	300	600	450	50	6	0.42
P20	300	600	400	100	6	0.42
P30	300	600	350	150	6	0.42
P40	300	600	300	200	6	0.42
P50	300	600	250	250	6	0.42

3. RESULTS AND DISCUSSION

3.1 WORKABILITY

The results obtained from Figure 1 indicate that amount of POFA added in the concrete mix have influence on the slump value. The slump values of palm oil waste LWAC with different percentage of POFA mixtures were measured between 10 and 100 mm. The concrete slump values observed to be gradually increasing from 0% up to 20% of POFA cement replacement content. Afterward the concrete slump value were gradually decreasing along with the increasing POFA content as cement replacement. The increasing slump value is due to finer size of POFA particles. On the other hand, the decreasing slump is due to high water absorption of POFA porous particles when utilizing of more than optimum amount of replacement. The reverse effect of the concrete strength was also reported by Muthusamy et al. (2015) when using more than sufficient amount of palm oil fuel ash as partial cement replacement. Slump with POFA

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replacement between 10 to 20% produces true slump with a medium degree of workability. Therefore, the suitable percentage of POFA to be integrated to produce palm oil waste LWAC with POFA with better workability is between 10% to 20% replacement.

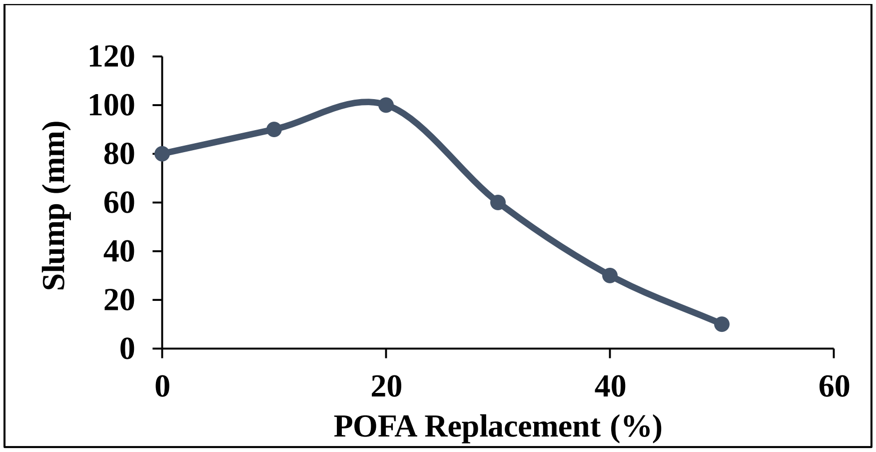

Figure 1. Workability of palm oil waste LWAC concrete with different POFA content

3.2 COMPRESSIVE STRENGTH

Figure 1 shows that the amount of POFA added influence the overall strength of palm oil waste lightweight aggregate concrete. Replacement of POFA from 10% to 20% increases the compressive strength of mix to be higher than control specimen. The maximum strength gain was noted at 20% POFA replacement. The increase in strength of palm waste lightweight aggregate concrete is due to some factors which is high fineness and high silica content. High fineness provides a filler effect and high silica content effect on the pozzolanic reaction. Pozzolanic reaction would result in pore refinement by consuming the weaker calcium hydroxide binder and forms a stronger binder of secondary calcium silicate hydrate. This would significantly increase the concrete density with additional strength improvements. However, excessive use of POFA at 40% and 50% reduces the strength of concrete significantly due to lower cement content. This occurred because lesser hydration process produced in the concrete. Too much cement replacement with POFA leads to lower amount of calcium hydroxide to be used during pozzolanic reaction for the formation of secondary C-S-H gel. Similarly, previous researchers Sooraj, (2013) and Momeen Ul Islam et al., (2016) has noted that integration of high volume of POFA reduces the concrete strength significantly. Thus, it can be concluded that suitable amount of POFA content would enhance the strength of this novel lightweight aggregate concrete.

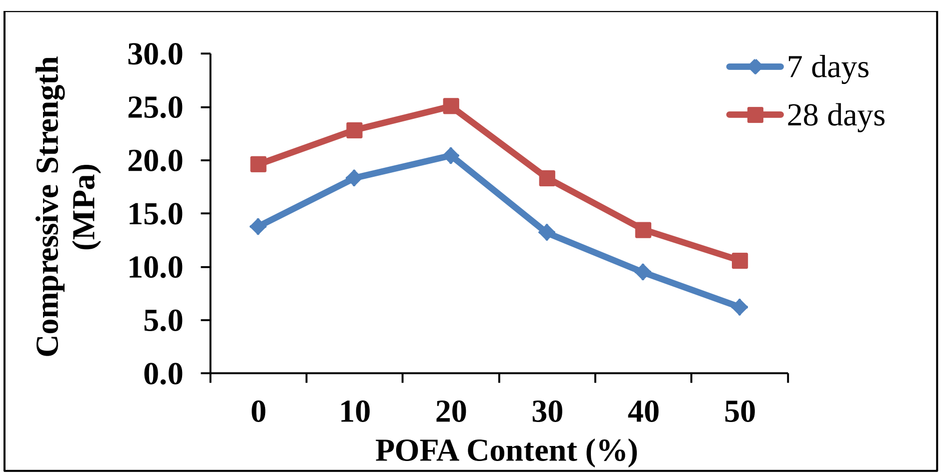

Figure 2. Compressive strength of palm oil waste LWAC concrete with different POFA content

4. CONCLUSION

This investigation reveals that there is a promising potential for the use of three types of palm oil waste namely palm oil clinker, oil palm shell and palm oil fuel ash in lightweight aggregate concrete production in which will significantly reduce huge amount of palm oil waste ended at landfill. Replacement of palm oil fuel ash which is around 20% would be able to produce lightweight concrete suitable for structural application.

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