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PROPERTIES OF COARSE AND FINE PALM OIL CLINKER AGGREGATES

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Abstract. Palm oil clinker (POC) is a waste from the incineration of palm oil shell and fibre. It can be easily obtained from palm oil mill and is abundant available resources. This paper focused on characterization of POC used as fine and coarse aggregates in concrete. The utilization of POC has been accepted to produce lightweight concrete, apart from overcoming the POC disposal problems. Moreover, the use of POC in concrete also could overcome the depletion of sand and granite which can cause nature imbalance. In this study, the characterization of aggregates covers the physical and strength properties. In order to obtain the physical properties, the specific gravity, water absorption, sieve analysis, fineness modulus and moisture content tests were conducted. For strength properties, Los Angeles abrasion value test was conducted. It was found that the coarse and fine POC aggregates have a density of 817.17 kg/m^3 and 917.82 kg/m^3, respectively, which were lighter than normal granite and sand as much as 36.85%% and 29.45%. This is due to its porous nature of POC aggregates. This nature tends to absorb excessive water which contributes to higher moisture content and water absorption. This study concludes that POC aggregates have a potential in producing lightweight aggregate for concrete.

Keywords: *Palm oil clinker, fine aggregates, coarse aggregates, lightweight aggregates*

1.0 Introduction

Construction industry contributes directly to the development of a country. With the increasing number of population, continuously development of infrastructure, public facilities, road and highway and residential are essential. In conjunction to this, the demand of concrete which commonly contain cement, sand, crushed granite and water has been increasing by time. Natural aggregate consumes about 70% - 80% of the total volume of concrete (Chandra, 2002; Clarke, 2005; Bogas *et al*., 2015; Mo *et al*., 2016). The unacceptable scene of sand and granite extraction triggered the consciousness of public, especially researchers.

Many researches currently being conducted to find the alternative solution to overcome the depletion of affected natural sources. Many researchers used industrial and agricultural wastes as an alternative replacement in concrete. Examples of these wastes that potentially to be utilized are tile and ceramic waste, brick, granulated blast furnace slag, palm oil shell and palm oil clinker (POC) (Omar and Mohamed, 2002; Hilton *et al.*, 2008; Mannan, 2010; Jumaat *et al.*, 2015; Hartono *et al.*, 2016). Utilizing waste in concrete not only can overcome the depletion of natural sources, but also can stop the disposal problem of those wastes. Waste such as granulated blast furnace slag and POC cannot be disposed directly into the environment. From all the wastes listed, POC was chosen for this study. POC can be easily obtained from palm oil mill. Malaysia as the second largest palm oil producer in the world has huge oil palm planted area distributed all over the country. In 2015, total oil palm planted area was 5.64 million hectares. Sabah is the largest oil palm planted state with 1.54 million hectares followed by Sarawak with 1.44 million hectares. Crude palm oil produced in 2015 was 19.96 million tonnes with an increase of 1.5% from previous year (MPOB, 2015). This indirectly generated large amount palm oil waste including POC. The palm oil industry was also a major contributor to the pollution problem occurring in the country, with an estimated 2.6 million tonnes of solid waste produced annually (Abutaha *et al*., 2015).

One of the important factors that contribute to concrete performance is the aggregates physical properties (Neville, 2011). The shape, gradation, surface texture, water absorption and strength determine the capability of aggregate to be used in concrete. The objective of this study is to characterize the physical and strength properties of POC aggregates. It is important to study about physical properties of an aggregate before it can be utilized in concrete. POC was compared in two categories; (a) between granite and coarse POC aggregates (b) between sand and fine POC aggregates. To make the signification comparison and discussion; (a) the specific gravity and bulk density (b) water absorption and moisture content are reasonable comparing even though several findings are from similar test. For this study, physical properties such as specific gravity, dry loose bulk density, moisture content, water absorption, sieve analysis, fineness modulus and Los Angeles abrasion value were examined. All testing were conducted in accordance to American Society for Testing and Materials (ASTM).

2.0 Materials

POC is a waste produced from the incineration process at palm oil mill. The incineration process involves palm oil fibre and palm oil shell at an estimated ratio of 30:70 to generate electricity (Ahmmad *et al*., 2015). Palm oil fiber and palm oil shell were transported to the boiler by using conveyor belt where the incineration process took place. Both materials were then burnt at a temperature of about 850°C to heat the water until steam was generated (Ahmmad *et al*., 2015). This incineration process finally produced POC which porous, solid and christened structure as shown in Figure 1.

(a) (b)

Figure 1: Palm oil clinker, POC (a) POC boulder (b) Porous structure of POC

POC normally available in boulder sizes of 150 mm to 200 mm. All aggregates sampling was accordance to ASTM D75. In this study, POC boulders were crushed into smaller sizes by using grinding machine. It was then washed and sieved to fine aggregate where the size ranged from 150 µm to 4.75 mm while for coarse aggregate the size ranged from 4.75 mm to 9.5 mm. Based on previous study, (Kanadasan *et al*., 2015), the POC contains between 60% and 75% of silica dioxide (SiO_2).

3.0 Physical and Strength Properties

3.1 Specific Gravity and Water Absorption

Specific gravity and water absorption tests were conducted for POC coarse and fine aggregates, respectively. However, the tests for both POC aggregates were conducted at different methods. For coarse POC aggregates, the specific gravity and water absorption tests were conducted in accordance to ASTM C127 (2007). Sample was immersed in water for 24 hours to ensure all pores were filled with water. The sample was let free until saturated surface dry condition achieved and mass was determined. Subsequently, the apparent mass of sample in water was determined. Finally, the sample was oven dried at a temperature of 110 °C ± 5 °C for 24 hours and the mass determined.

For fine POC aggregates, the standard procedure ASTM C128 (2007) was used to determine the specific gravity and water absorption. The mass of pycnometer with 500 g sample and water were filled until calibration mark was determined. The sample was then removed and oven dried about 110 °C ± 5 °C for 24 hours. The mass of pycnometer and water to the calibration mark was recorded. Both specific gravity and water absorption values of coarse and fine POC aggregates can be obtained from the calculation as given in the method.

3.2 *Sieve Analysis and Fineness Modulus*

In order to investigate the consistency during initial resizing of POC aggregates, the sieve analysis and fineness modulus were investigated. ASTM C136 (2006) standard was used for both coarse and fine POC aggregates. The sample was oven dried at a temperature of 110 °C ± 5 °C for 24 hours. A total of 3 kg sample was prepared; 2 kg for coarse and 1 kg for fine POC aggregates. Each sample was divided into few portions and each portion was sieved individually. For coarse aggregates, sieves sizes used were 19.0 mm, 12.5 mm, 9.5 mm, 4.75 mm and 2.36 mm. While for fine aggregate, sieves sizes used were 9.5 mm, 4.75 mm, 1.18 mm, 300 µm and 150 µm. Fineness modulus was calculated by adding the total cumulative mass retained and divided by 100.

3.3 *Moisture Content*

Since nature of POC has open cellulose structure, the moisture content of POC needs to be observed. This parameter also important to control the water to cement ratio during design of the concrete. In this case, the standard of ASTM C566 (2013) was used to determine the moisture content for coarse and fine POC aggregates. The mass for POC aggregates in room temperature was determined, thus the samples were oven dried for 24 hours at a temperature of 110 °C ± 5 °C. Moisture content can be obtained by difference between the mass of sample after oven dried and mass of sample in room temperature and dividing to the mass of the sample after oven dried. Then the value times to the 100.

3.4 *Dry Loose Bulk Density*

Physically, the POC is lighter than granite and sand. The bulk density is one of the parameters investigated in this study. The value of bulk density is used for design the concrete which the aggregates is measured by volume of the concrete. ASTM C29 was used to determine the dry loose bulk density for coarse and fine aggregates. In this test, 3 kg of samples were prepared for both coarse and fine aggregates. Both samples were oven dried at a temperature of 110 °C ± 5 °C for 24 hours. The sample was poured into the cylinder until the cylinder was fully covered and mass was determined. The volume and mass of cylinder were then determined and SI unit for dry loose bulk density is in kg/m^3.

3.5 *Los Angeles Abrasion Value*

Los Angeles abrasion value test is one of the common tests to determine the strength of POC aggregates. The test was conducted strictly as in accordance to ASTM C131(2003). However, the test is limited for coarse aggregates and in this case, only coarse POC aggregates was involved. A total of 5 kg sample was inserted in the Los Angeles machine together with 12 spheres. Los Angeles machine was rotated at a speed of 20-33 rev/min until it reached 500 revolutions. Material coarser than 1.75mm was washed, dried in an oven at a temperature of 110 °C ± 5 °C for 24 hours and the mass was determined. The Los Angeles abrasion value is measured by Los Angeles abrasion loss in percentage weight.

4.0 Results and Discussion

4.1 Specific Gravity and Bulk Density

Coarse and fine POC show lower values than granite and sand as shown in Figure 2 and 3. The specific gravity of coarse POC was 27.55% lighter than crushed granite and fine POC was 23.85% lighter than sand. The same trend can be seen for dry loose bulk density where coarse POC was 36.85% lighter than crushed granite and fine POC was 29.45% lighter than sand. The lower values of specific gravity and dry loose bulk density were contributed by the porous nature of POC aggregates. According to ASTM C330 (2014), aggregates were considered as lightweight when the dry loose bulk density was less than 880 kg/m^3 for coarse aggregate and less than 1120 kg/m^3 for fine aggregate. Both POC coarse and fine aggregates fall under lightweight aggregate requirement.

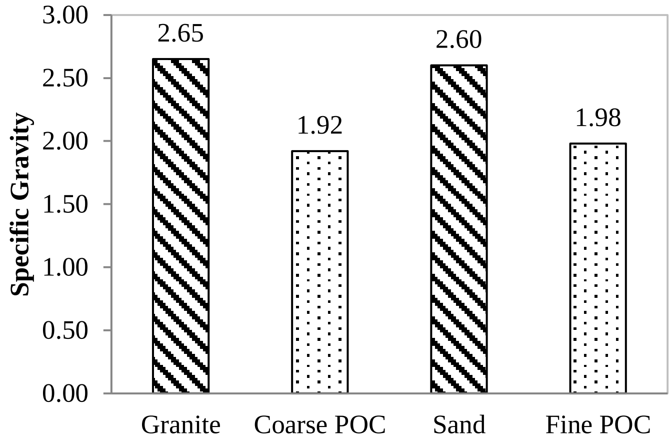

Figure 2: Comparison of specific gravity

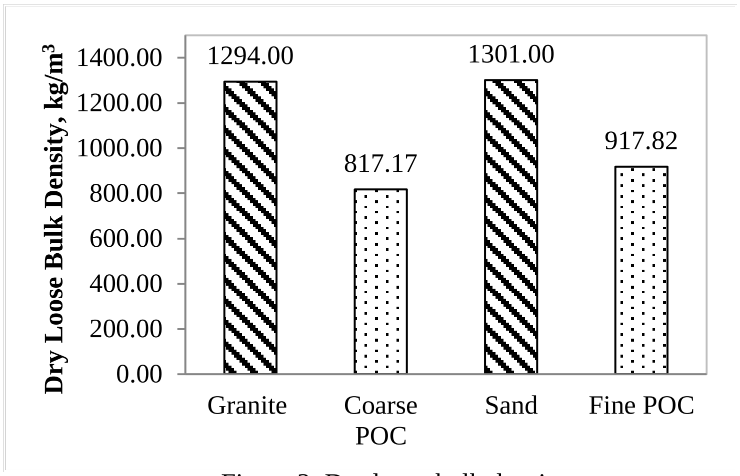

Figure 3: Dry loose bulk density

4.2 Sieve Analysis and Fineness Modulus

Figure 4 and 5 show the particle size distribution for fine and coarse POC obtained through sieve analysis test. It shows that the gradation of POC fine and coarse aggregates comply with ASTM C33 (2008) requirement. Both POC aggregates were in the range of upper and lower limit in accordance to ASTM C330. This indicates that fine and coarse POC aggregates can be considered as a well-graded aggregate and has fewer voids. Concrete with poorly graded aggregate requires a great amount of cement and water content to fill the voids. The increment of cement content eventually leads to uneconomic concrete.

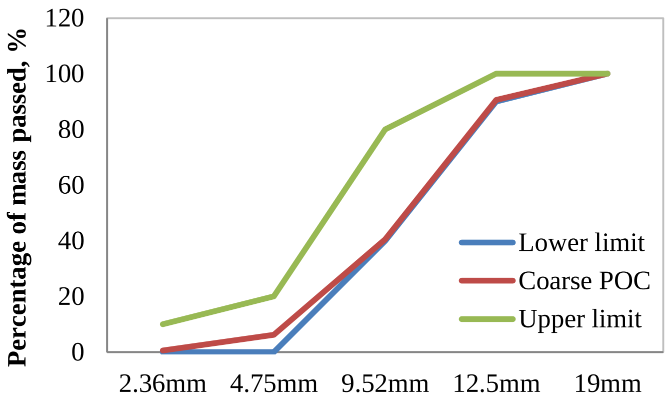

Figure 4: Sieve analysis of coarse POC aggregates

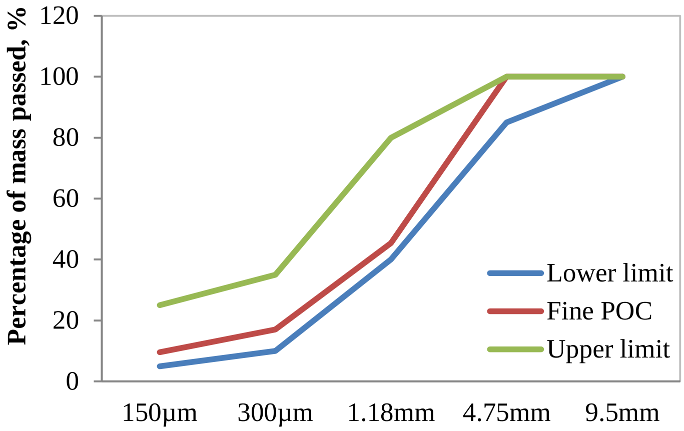

Figure 5: Sieve analysis of fine POC aggregates

Fineness modulus of aggregate is important in estimating proportions of fine and coarse aggregates in concrete. Figure 6 shows the fineness modulus for fine and coarse POC aggregates. Both fine and coarse POC aggregates show smaller values compared with granite and sand. Smaller fineness modulus indicates that the aggregate is finer. Workability of concrete can be affected by aggregate fineness modulus value. ASTM C33 suggests fine aggregates to be used in concrete to have fineness modulus not less than 2.3 or more than 3.1. Fine POC aggregates satisfied the requirement.

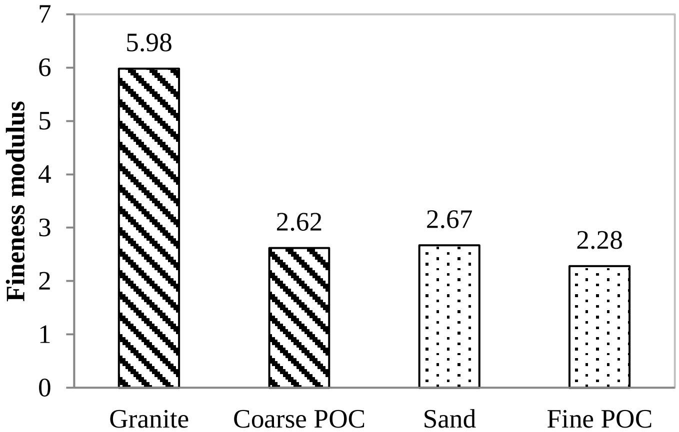

Figure 6: Fineness modulus of fine and coarse POC

4.3 Water Absorption and Moisture Content

In this study, it was observed that POC aggregates recorded higher moisture content and water absorption as compared to granite and sand as shown in Figure 7. These were mainly due to the porous structure of POC. Water absorption value is important especially in designing a concrete mixture. Aggregate with lots of pores tends to absorb water and this will affect the amount of water needed to create a paste. In addition, the aggregates with porous structure stored water and this stored water later helps in curing process and makes it less sensitive to poor curing (Mohammed *et al*., 2014). It is important to obtain the water absorption value of aggregate so that precaution action could be taken. Aggregate with porous structure normally was pre-soaked for 24 hours. This action will prevent further absorption by aggregates during mixing (Kanadasan *et al*., 2014).

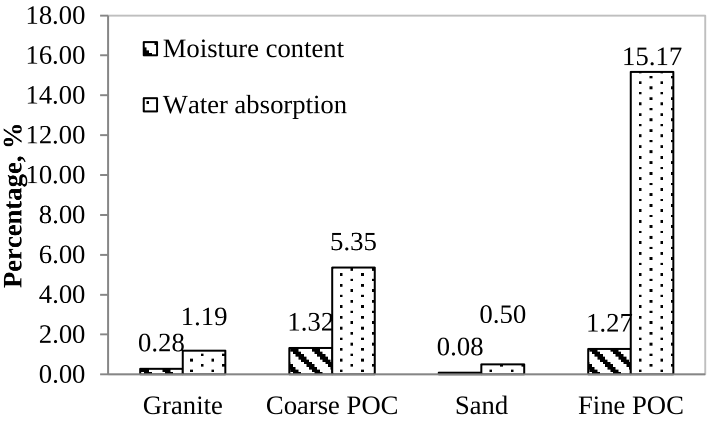

Figure 7: Water absorption and moisture content of POC aggregates

4.4 Los Angeles Abrasion Value

Figure 8 shows the Los Angeles abrasion value for coarse POC aggregates. It was found that the coarse POC aggregates registered higher value compared to granite. Higher Los Angeles abrasion value indicates that POC aggregates is weak in strength. The lower strength is expected based on its physically angular shape and porous nature. POC aggregates will suffered earlier crack when the load transferred from cement paste (Kanadasan *et al*., 2015). The high percentage of Los Angeles abrasion value also indicates that POC aggregates has a low resistance of coarse aggregates to degradation which indicates POC as softer aggregates than granite. The lower strength properties, however, will be compensated by the filling of cement paste in the voids, thus providing acceptable load resistance. This scenario gives insight that both materials between POC aggregates and cement paste give compatible bonding. The expectation on this case due to the both materials is pozzolanic based materials. However, the future research need to be conducted by considering the strength between concrete containing POC aggregates and normal concrete.

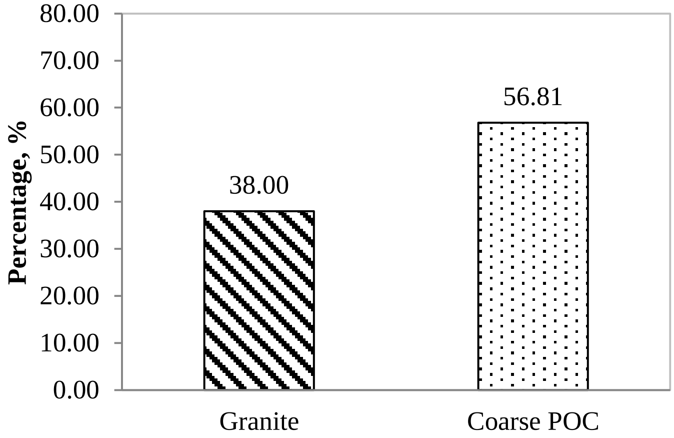

Figure 8: Los Angeles abrasion value of POC aggregates

5.0 Conclusions

Based on the experimental results of this study, fine and coarse POC aggregates were found to be lighter in density compared to conventional aggregates. Other than that, physically, the POC aggregates had high moisture content, high water absorption, and low strength. However, further research is needed by considering the performance of concrete containing POC aggregates. As expected, POC has high potentiality to be used in concrete due to its lower density in producing lightweight concrete masonry or wall panels for IBS construction.

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