Properties of Concrete Containing Crushed Palm Oil Clinker as Partial Fine Aggregate Replacement

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Abstract. The growing demand for sand supply for construction industry use especially in concrete production drives the sand mining industry to flourish. However, excessive sand mining would affect the river environment, aquatic life and water quality. At the same time, the increasing quantity of palm oil clinker, which is a by-product at palm oil mill disposed at landfill, poses negative impact to the environment. The use of palm oil clinker waste as sand replacement in concrete production would be able to reduce the use of natural sand from the river and dumping of clinker waste at landfill. The current research investigates the fresh and mechanical properties of concrete containing palm oil clinker as partial fine aggregate replacement. A total five concrete mixes were produced. The control specimen was prepared by using 100% natural sand. Other mixes were formed by integrating crushed palm oil clinker as partial fine aggregate replacement ranging from 10%, 20%, 30% and 40%. All specimens were water cured up to 28 days. The specimens were subjected to slump test, compressive strength test, flexural strength test and water absorption test. The finding shows that suitable amount of palm oil clinker can be used as partial fine aggregate replacement in concrete production. Concrete containing palm oil clinker up to 40% replacement exhibits water absorption value lower than 10%, thus classified as good quality concrete.

1. Introduction

In Malaysia, the continuous growing construction trade and palm oil industry contributes towards the economic prosperity of the country. At the same time, these industries also cause negative impact to the environment. Development in construction industry has increased the demand for building material production especially concrete. The expanding concrete industry also pushes for larger supply of raw materials, which harvested from the environment. Sand is one of the raw materials obtained through mining activity at the river. The use of sand as fine aggregate in concrete plays the role of producing a more compact structure for strength and durability enhancement. Thus, the development in concrete production directly boosts the growth of sand mining industry. However, uncontrolled sand mining would affect the water quality and habitat of aquatic life [1, 2]. Continuous on going mining activity at one location would destroy the green river environment and affect other elements related to it namely fauna, flora and inhabitants. There are rivers in certain parts of the world are suffering the negative

impact of extreme sand mining activity [3]. In addition, acute aggregate shortage problem happened in certain parts of the world [4]. Thus, discovering other alternative material especially from locally generated waste would reduce the harvesting local natural sand and also reduce environmental pollution due to waste disposal. In relation to that, Malaysia being one of the largest palm oil producers in the world palm oil industry contributing to the prosperity of economic also generates large amount of by-products, which disposed as waste. This industry has been flourishing ever since it begins to be commercialized in the end of 20th century. The Malaysian palm oil exported increased from less than 100 000t in 1960 to 16.05 MT in 2016 [5]. At the same time, the quantity of by-product generated from palm oil mills also increased along with the production growth. Approximately, 2.6 MT of solid waste is generated per year [6]. Palm oil clinker is a by-product, which formed in incineration chamber during the combustion of shell and fibre to generate power supply for the palm oil mill. It is thrown as waste material in the factory-dumping site. This rock like is available in abundance and have a small commercial value locally [6]. As the production of palm oil industry continues to increase, it is expected larger quantity of clinker would be produced. Thus, continuous dumping would lead to piling up of the waste at the allocated area creating unhealthy environment to the inhabitants [7]. Utilizing this readily available waste material as fine aggregate replacement in concrete production would contribute to lesser dependency of industry on natural sand supply as well as reduces usage of land to dump palm oil clinker waste. Thus, the present research discusses the effect of crushed palm oil clinker as partial fine aggregate replacement on the workability and mechanical properties of concrete.

2 Method of Research

2.1 Materials

Among the materials used to prepare concrete specimens in this research are cement, water, coarse aggregate, fine aggregate and palm oil clinker. Ordinary Portland cement (OPC) from a single source was used throughout the experimental work. Both coarse and fine aggregate were supplied from the local sources. Tap water was used for mixing and curing purposes. Palm oil clinker (POC) was obtained from a palm oil mill located in East Coast of Peninsula Malaysia. POC was collected from an open dumping area at mill as illustrated in Figure 1. POC were cleaned to remove the debris sticking on it and oven dried for 24 hours. After that, the clinkers were crushed and sieved passing sieve 2 mm. Only clinker passing 2mm were packed and stored for concrete mixing work. Figure 2 illustrates the palm oil clinker before and after crushing process.

Figure 1: Palm oil clinker waste collection

Figure 2: Palm oil clinker before and after crushing process

2.2 Sample Preparations and Testing

In this experimental programme, five concrete mixes consist various quantity of palm oil clinker as partial sand replacement were prepared as in Table 1. Control specimens (POC-0) were prepared by using 100% river sand. Another, four concrete mixes consists of 0%, 10%, 20%, 30% and 40% palm oil clinker by weight of sand were prepared. After casting process, all the samples were covered with wet gunnysack for 24 hours before demoulded. All specimens were water cured up to 28 days. All specimens were subjected to compressive strength test, flexural strength test and water absorption test. The effect of palm oil clinker content on concrete workability were determined through slump test that was carried out following the procedures in BSEN, 12350-2 [8]. The hardened concrete specimens were subjected to compressive strength test and flexural strength test in accordance to BSEN, 12390-3 [9] and BSEN 12390-5 [10] respectively. The water absorption test was carried in accordance to BS 1881 : Part 122 [11].

Table 1: Mix proportion of control specimen

Mixes	**Cement (kg/m^3)**	**Sand (kg/m^3)**	**Granite aggregate (kg/m^3)**	**Crushed Clinker (kg/m^3)**	**Water (kg/m^3)**
POC-0	350	980	850	-	245
POC-10	350	882	850	98	245
POC-20	350	784	850	196	245
POC-30	350	686	850	294	245
POC-40	350	588	850	392	245

3 Result and Discussion

3.1 Workability

Figure 3 and 4 shows that the slump decreases as the percentage of palm oil clinker content replaced becomes higher. The result indicates that concrete become less workable as the amount of palm oil clinker added increases. This implies the need for larger amount of water required to make the mixes more workable. The reduction of workability is due to the porous clinker particle unlike the solid sand particles. Past researcher, Neville [12] has pointed out that physical properties of the aggregate used have influence on the workability of concrete. Similar trend has been reported by Nazrin et al. [13] and Abutaha et al. [14] when clinker is used as partial fine aggregate replacement in lightweight concrete mix.

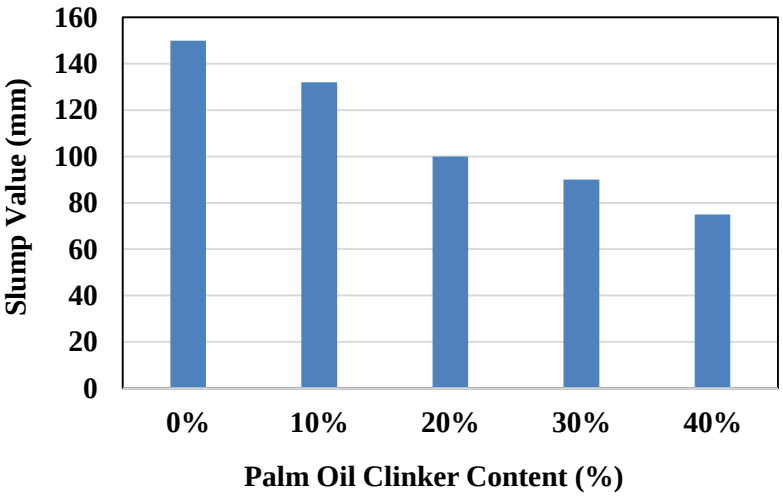

Figure 3: Slump test results

Figure 4: Effect of clinker on slump of concrete mix

3.2 Compressive Strength and Flexural Strength

Figure 5 and 6 illustrate the compressive strength and flexural strength results of the concrete specimens containing various percentage of crushed palm oil clinker. Generally, the strength of all specimens increases as the curing age become longer due to continuous presence of water promoting undisturbed hydration process. As a result, larger quantity of CSH gel was formed in concrete internal structure thus creating a more compact concrete with higher load sustaining capacity. One of the researchers, Neville [12] has highlighted the importance of continuous water supply during curing in enhancing the concrete strength. As for the effect of clinker on concrete strength, it is evident that the use of porous type of clinker as fine aggregate somehow affects the concrete strength. Inclusion of clinker, which absorbs water owing to its porous physical appearance, reduces the concrete mix

workability. This cause difficulty during compaction works and also results in loss of adhesion due insufficient water for hydration process resulting in concrete with lower strength. As larger amount of clinker is added, the mix stiffer and hard to be compacted thus creates more voids that reduce concrete strength.

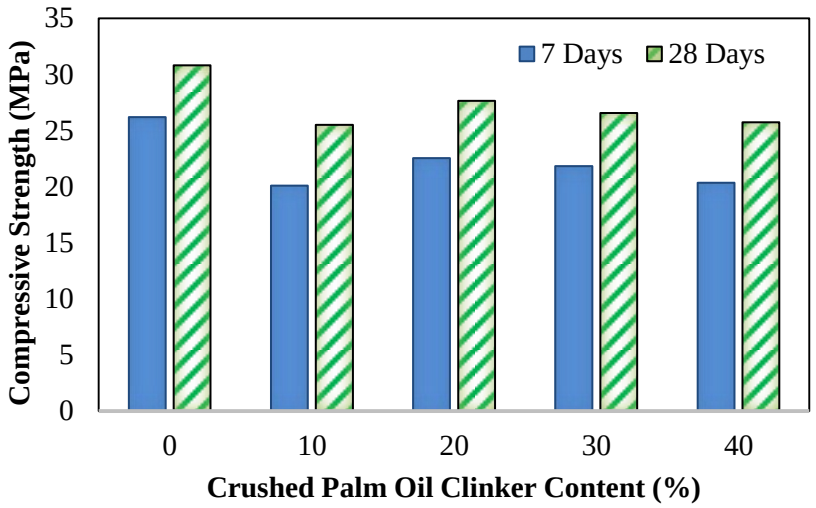

Figure 5: Compressive strength results

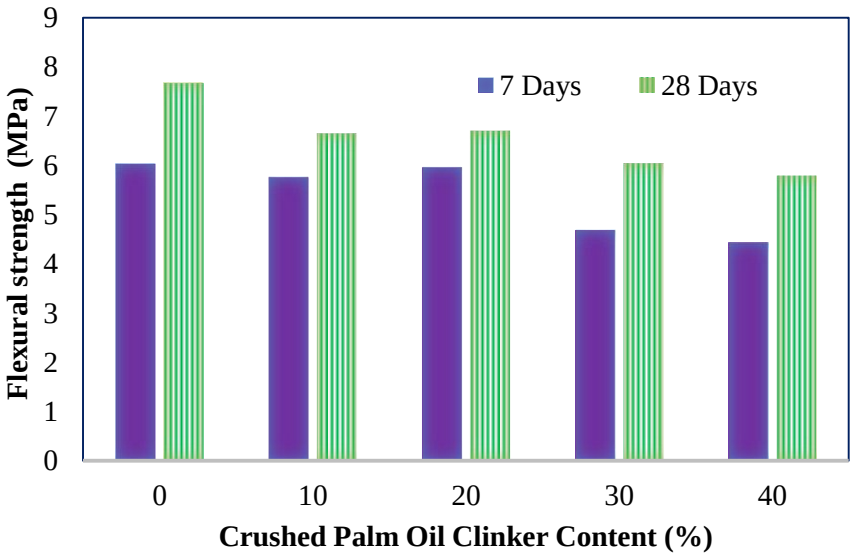

Figure 6: Flexural strength results

3.2 Water Absorption

Figure 7 illustrates the water absorption of concrete containing various POC content. Evidently, the water absorption of concrete increases as more palm oil clinker is replaced. Water absorption was increasing because POC is a porous material, which has the ability to absorb water better than river sand. This finding is in line with, indicates that the absorption capacity of concrete is high due to the porous nature of aggregate used. However, all concrete specimens containing crushed clinker up to 40% exhibit water absorption less than 10% enabling it to be classified as high quality concrete. According to Neville [12], concrete with water absorption below 10% is classified as high quality concrete.

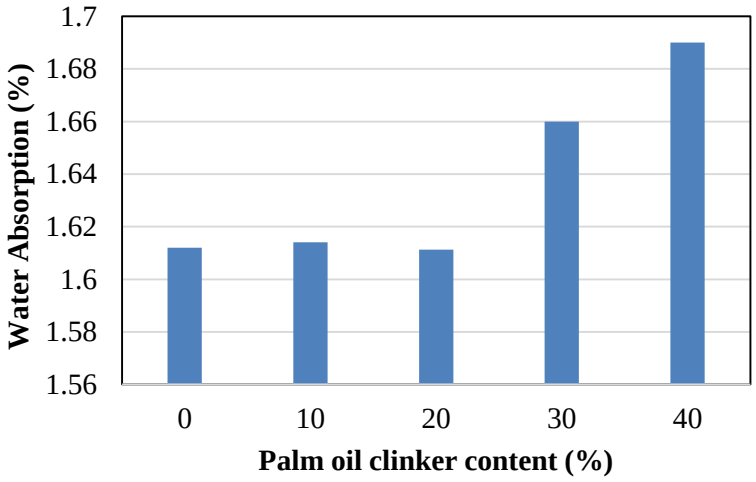

Figure 7: Water absorption test results

4 Conclusions

Based on the results obtained from the experimental work, it is concluded that the use of crushed palm oil clinker content as partial sand replacement effect the concrete properties. Increase in the quantity of palm oil clinker content, reduce concrete workability. The presence of palm oil clinker as partial replacement of sand in concrete reduces the compressive strength and flexural strength of concrete.

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