WORKABILITY AND COMPRESSIVE STRENGTH OF CONCRETE CONTAINING CRUSHED PALM OIL CLINKER AS PARTIAL FINE AGGREGATE REPLACEMENT

K. Muthusamy, Z. Mohd Jani, N.F.A, Jamaludin, M.S. Zawawi

Abstract

Growing demand for river sand supply to cater to the need of expanding concrete industry has a negative impact on the river environment when the mining activity is carried out uncontrollably. Palm Oil Clinker (POC) is a waste material generated from the palm oil industry, which is thrown as environmental polluting waste. This experimental study aims to investigate the effect of POC as partial fine aggregate replacement material on the workability, compressive strength and water absorption of concrete. A total of six concrete mixes containing 0%, 10%, 20%, 30%, 40% and 50% POC as partial fine aggregate replacement were prepared. All specimens were subjected to water curing until the testing date. Compressive strength and water absorption tests were conducted at 28 days. Incorporation of 20% POC is able to produce concrete with targeted compressive strength. Success in utilising POC as partial fine aggregate replacement in concrete will reduce waste thrown at dumpsites.

Keywords Palm oil clinker; Fine aggregate replacement, Workability, Compressive strength, Water absorption

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Faculty of Civil Engineering Technology, UMP Research Series: Construction Engineering and Management, Vol. 1, [insert doi here later]

Introduction

Concrete is the most widely used material that is responsible for the majority amount of construction in Malaysia. Sequentially, this has caused a steady increase in demands for concrete that typically consists of cement, water, fine and coarse aggregate. Natural aggregate alone possesses up to 70% to 80% of the total volume in a concrete mix (Chandra & Berntsson, 2002; Clarke, 2005; Bogas et al., 2013; Mo et al., 2016). After the year 2010, it is reported that 8 to 12 billion tons of natural aggregates will be utilised by the concrete industry annually (Momeen et al., 2015). This, in turn, causes an immediate increase in uncontrolled sand mining, thus enabling uncontrolled sand mining that reduces the water quality and the habitat of the aquatic ecosystem at the affected river to fulfil the construction industry's increasing demand (Ashraf et al., 2011). On top of that, the whole sand mining process from prospecting, extraction, concentrating and transporting sand enhances the risk of disturbing the natural environment (Rabie et al., 1994). Excessive sand mining has already happened in Bestari Jaya catchment, Selangor, where instream sand mining is 40 times the number of sand input (Ashraf et al., 2011). Hence, it is integral to discover new local materials that can replace sand as fine aggregate to decrease the dependence on sand mining industries (Sulaiman et al., 2020).

Malaysia is one of the largest producers of palm oil globally (Mannan & Ganapathy, 2004). In 2017, Malaysia produced 19.92 million tons of palm oil, increasing over 15% compared to the previous year at only 17.32 million tons produced palm oil (Kushairi et al., 2018). This, in turn, has caused the palm oil industry to be the top contributor to our country's pollution problems. Approximately 2.6 million tonnes of solid waste are generated by palm oil mills annually (Abutaha et al., 2016). After the oil extraction process at the palm oil mill, the extracted fibre and shell are burnt to generate energy for the mill operation. During the combustion process, palm oil clinker (POC) is formed in the incineration chamber. These final rock-like by-products possess low commercial value, thus were thrown away as waste material at the factory dumping site (Abutaha et al., 2016).

Continuous dumping of POC would result in excess usage of landfills, creating lesser space and worsening the area's environment (Muthusamy et al., 2019). It would create an unhealthy environment, as the waste would be piled up and consume larger space at the dumping area (Sulaiman et al., 2020). Thus, transforming POC into finer size to function as partial sand replacement in concrete would benefit the environment and contribute towards healthier surrounding for nearby communities.

Experimental Programme

This experimental work is divided into three stages, which consist of material preparation, preparation of the concrete specimen and testing.

Materials Used

The materials used to prepare the specimens in this research are ordinary Portland cement, tap water, sand, coarse aggregate and POC. The POC was collected at a palm oil mill, as shown in Figure 1. Initially, the raw large chunks of POC were collected at the dumpsite within the mill area, as illustrated in Figure 2, and delivered to the concrete laboratory in Universiti Malaysia Pahang. At the laboratory, a jaw crusher was used for crushing the POC into smaller sizes, as shown in Figure 3. The POC was then oven-dried at 105°C for 24 hours. After that, the dried POC was sieved passing 600µm sieve. Figure 4 illustrates the POC that has been sieved by 600µm sieve size.

Figure 1: POC collection

Figure 2: Chunk of POC

Figure 3: Crushed POC

Figure 4: Fine POC ready to be used

Mix Proportion and Specimen Preparation

The trial mix method has been used to produce the concrete with the targeted workability of 50-90 mm and a 28-days compressive strength of 30MPa. Six concrete mixes were utilised in this research. The control mix is produced using 100% river sand as fine aggregate. Other mixtures (POC-10, POC-20, POC-30, POC-40 and POC-50) were produced by partially replacing the river sand at 10%, 20%, 30%, 40% and 50% by weight of sand. The mix proportions used are stated in Table 1. Before the concrete mixing, the required moulds were cleaned from debris and oiled. The mixing materials were accurately weighed. The mixing process began with the coarse, fine aggregates and cement mixed in the rotary drum mixer. Then, the water is added to the dry mix and mixed uniformly. After that, the concrete was poured into the mould and compacted. The freshly mixed concrete is then poured into the mould and left overnight. After that, the specimens were removed from the mould and placed in a water curing tank until the testing age. The whole preparation process can be summarised, as shown in Figure 4 to Figure 7.

Table 1: Mix proportion (kg/m^3)

Mix No.	Cement	POC	Sand	Aggregate	Water
POC-0	382	0	751	996	260
POC-10	382	75	676	996	260
POC-20.	382	150	601	996	260
POC-30	382	226	526	996	260
POC-40	382	301	451	996	260
POC-50	382	376	376	996	260

Figure 4: Weighing Process

Figure 5: Well mixed concrete mixture

Figure 6. Concrete casting

Figure 7. Curing process

Testing Procedure

The effect of palm oil clinker as partial fine aggregates replacement towards the concrete workability was determined through slump test. The slump test was carried in accordance with BS EN 12350-2 (2009). The compressive strength of the concrete mix was carried out at 7 and 28 days of curing age. The testing was conducted, following the testing procedure in BS EN 12390-3 (2001). The water absorption test was conducted on concrete cubes adhering to the procedure in BS 1881-122 (1983).

Results and Discussion

Workability

Based on Figure 8, it can be observed that the use of POC as fine aggregate replacement reduces concrete workability. The concrete mixture becomes stiffer as the quantity of integrated POC becomes larger. The reduction of concrete slump height with the increment of POC content can be observed in Figure 9. This attributed to the physical appearance of POC particle that has visible small voids that are able to absorb more water as compared to a solid sand particle. A similar observation regarding the porous nature of palm oil clinker has been reported by Kanadasan and Razak (2015). The presence of voids on clinker particles used as partial sand replacement absorbs mixing water resulting in lower concrete workability (Sulaiman et al., 2020). Past researchers, Nazrin et al. (2016) and Abutaha et al. (2017)), have also reported a similar pattern of slump test results when POC has been used as the partial fine aggregate replacement in the concrete mix.

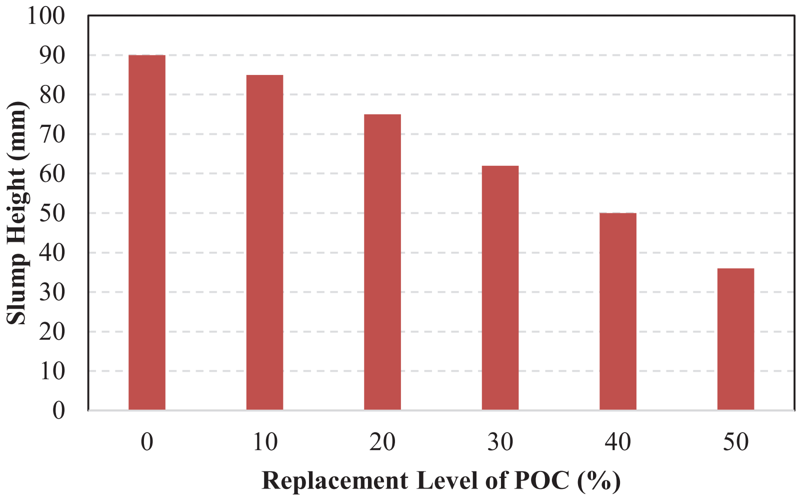

Figure 8: Slump test result

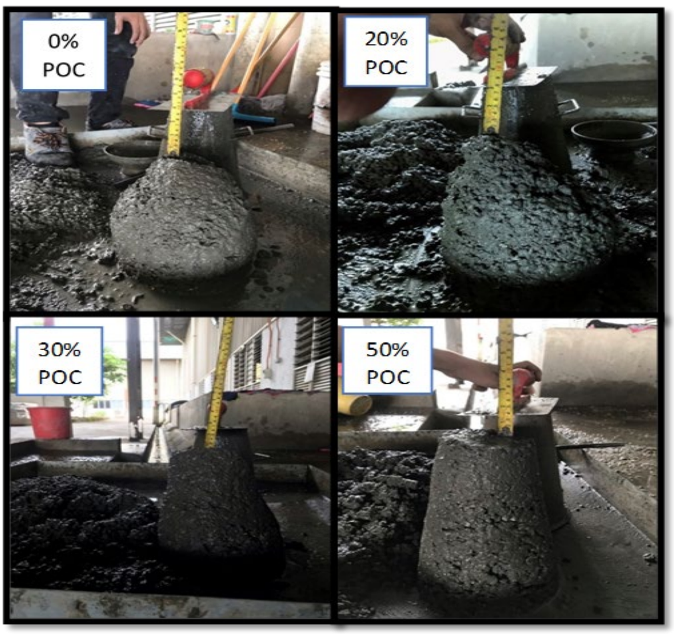

Figure 9: Effect of POC towards slump pattern

Compressive Strength

As illustrated in Figure 10, the compressive strength of concrete is influenced by the percentages of palm oil clinker used as partial fine aggregate replacement. Overall, all mixes exhibit strength increment as curing age becomes longer. The use of the water curing approach promotes an undisturbed hydration process that contributes to the densification of concrete microstructure resulting in strength enhancement. Continuous water curing is vital for enhancing concrete strength and ensuring an uninterrupted hydration process (Brandt, 1994). The concrete compressive strength is reduced when POC is used as partial fine aggregate replacement. According to Azillah et al. (2016), porous aggregates absorb water, affecting the amount of water required to make a paste. As POC is porous, it absorbs more mixing water, lowering the workability of the mixture (Sulaiman et al., 2020). This creates difficulties during compaction and results in a loss of adhesion due to insufficient water for the hydration process, resulting in weaker concrete. As more POC is added, the mix becomes stiffer and more difficult to compact, resulting in more voids formed in hardened concrete with lower bearing capacity.

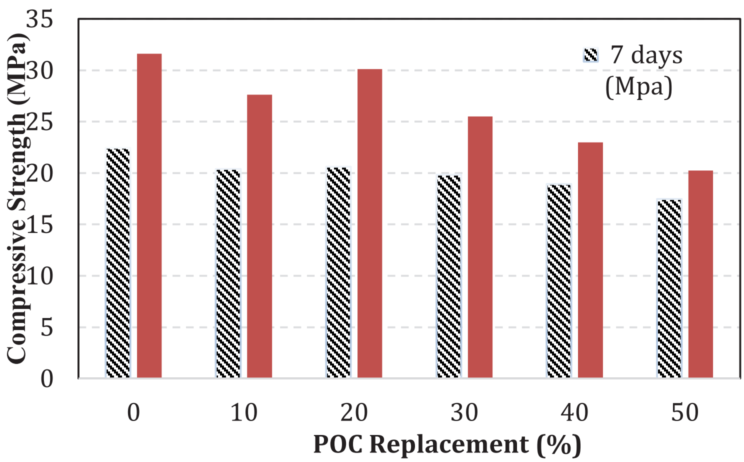

Figure 10: Compressive strength result

Water Absorption

Figure 11 shows the water absorption percentage of POC concrete specimens containing various percentages of POC. Concrete produced using 100% river sand exhibits the lowest water absorption. The water absorption value becomes higher as the quantity of POC used increases. Concrete prepared using 50% POC replacement possesses the highest amount of water absorption. Abutaha et al. (2016) also stated that POC possesses high concrete water absorption due to its porous physical properties. Due to that, the inclusion of POC in concrete mixture causes the concrete to exhibit a higher water absorption value. Similarly, past researcher, Sulaiman et al. (2020), also reported that the water absorption rate of the concrete increased proportionally with the percentage of POC as fine aggregates replacement in the concrete mix. However, all the mix containing replacement of POC as fine aggregate are categorised as good quality concrete, because lower than 10%. As mentioned by Neville (2010), concrete lesser than 10% is classified as high-quality concrete.

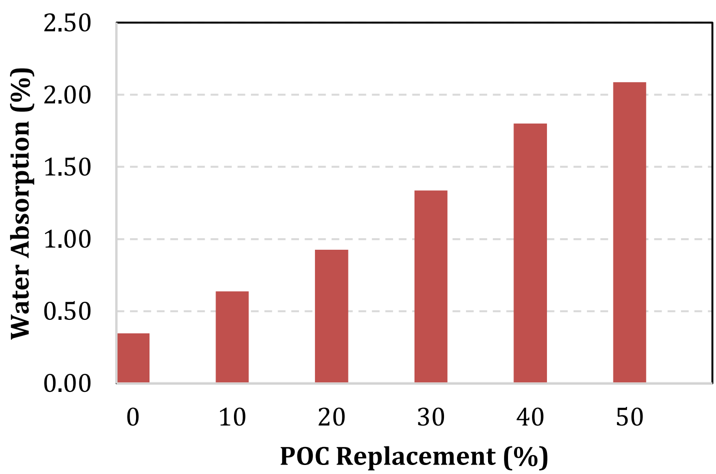

Figure 11: Water absorption result

Conclusion

The usage of POC as partial fine aggregates replacement influences the concrete workability and its compressive strength. Concrete containing POC up to 50%, in which a water absorption value is less than 10%, is categorised as good quality concrete. Meanwhile, the usage of palm oil clinker as partial fine aggregates replacement in concrete also reduces the overall compressive strength of the concrete.

Acknowledgement

The authors would like to thank UMP for funding this work under an internal grant RDU190342.

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