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Strength of Palm Oil Fly Ash (POFA) Incorporated with Sawdust in Concrete Pavement

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Abstract

Jengka is the largest FELDA in Malaysia located in the state of Pahang Darul Makmur. Jengka consists of 25 FELDA plans which are palm and rubber producers. The production of Palm Oil Fly Ash (POFA) is rising every year, it is disposed of in landfills, now becoming an important environmental disposal issue. The government needs to focus on assigning more hectares of land for disposal of these huge amounts of waste, and financial losses are also increased for transporting as well as maintenance purposes of these wastes. The pollution problem is increased in this sector which includes the annual production of 2.6 million tonnes of solid waste in the form of POFA. The large quantity of this waste can create an environmental problem if disposed of in the wrong way. However, reduction of dumped waste and environmental sustainability can be ensured by proper consumption or recycling of these materials. Therefore, this research innovation used waste material of POFA in a concrete mixture to produce eco pavement block. The compliance testing for the concrete mix was investigated. The optimal mix design proportion in order to increase the compressive strength, density and durability of POFA concrete was established. Mix proportion containing 5 % POFA mixtures exhibited substantially higher rates of strength gain as compared with other mixtures containing 10 % and 15 % of POFA. The workability of POFA concrete increases, thus, the permeability and bleeding in concrete decrease. Implementation of POFA waste not only decreases environmental damage but also saves concrete materials.

Keywords: Palm Oil Fly Ash (POFA), recycling, waste material, compressive strength, durability

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1. Introduction

Increasing world population and life demand is continuously raising the price of raw materials and reducing the natural resources, for these reasons research has been concentrated to use waste materials as a potential alternative in the construction industry. Recycling wastes as building materials appears to be a viable solution not only to such pollution problems but also to the economic design of buildings (Bechio et. Al, 2009). Waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications.

Sawdust has been used from time to time for making lightweight concrete, it could also be classified as waste-based concrete but it has severe limitations (Swamy, 2006), low strength and durability problems. The density and compressive strength of concrete decreased as the percentage replacement increased but the replacement of sand with sawdust produced a higher percentage reduction in compressive strength (Ugwu, 2019). Sawdust can potentially be used as aggregate in the production of both non-structural lightweight concrete. In using sawdust as a sand replacement to produce low-cost and lightweight concrete for use in construction, it was found that at 10% sawdust replacement, production costs and weight were reduced by 3% and 10% respectively (Adebaku, 2012). The strength of concrete was found to be reduced with sawdust as a fine aggregate due to its higher rate of water absorption (Usman et. al, 2012).

However, its combination with sawdust Palm Oil Fly Ash (POFA) remains to be tested. Palm Oil Fly Ash (POFA) is a by-product of the palm oil industry. It is from the combustion of palm oil plant residues. Dumping of POFA creates environmental pollution and health hazard and also occupies the land. The recycling of POFA not only helps conserve natural resources but also helps to solve the growing waste disposal and gas emission crisis. POFA has been discovered as a suitable supplement. POFA is a good pozzolanic material (Abu, 1990), it can be used to replace up to 30% of the OPC (Hussain and Awal, 1996) and it has been extensively studied. POFA being a pozzolan reduces the cost of construction and is used for making green concrete, so its adoption enables more sustainability in the concrete industry. A concrete mix with POFA can provide environmental and economic benefits. Compressive and flexural strengths are the most important properties that affect the performance of concrete pavements (Kumar et. al., 2017). POFA concrete enhances workability, compressive strength, and flexural strength and also increases its workability, durability and concrete finishing. It also reduces corrosion and decreases its permeability and bleeding in concrete. All POFA mixtures exhibited substantially higher rates of strength gain as compared with non- POFA control mixes (Mullick, 2019). Sanawung, et al. carried out studies on the effects of water-binder (w/b) ratios and POFA on compressive strength, water permeability, and chloride resistance of concrete (Sanawung, 2017). POFA was used to partially replace OPC at 15, 25, and 35% by weight. The w/b ratios were 0.40 and 0.50. The compressive strength of POFA blended concrete at 15% was found to have the same strength as OPC concrete. Wi et al. investigates the effects of micro palm oil fuel ash (mPOFA) on compressive strength and pore structure of cement mortar. Cement was replaced with 10% by weight of mPOFA and was found to give the highest level of compressive strength, achieving a 23% increase over the control specimens after 3 days of curing (Wi et al., 2018). Pone et al. also investigate the potential of POFA as an alternative material to replace OPC. The results showed improved compressive strength, especially at an early age (pone wt. al, 2018). POFA specimens containing 2.5% and 5% POFA replacement displayed high early compressive strength as compared to the control samples. The results showed good repeatability and highlight the potential of POFA as an effective pozzolan which could enhance the sustainability and economic aspect of concrete.

As such, sawdust and POFA appear to be unique complimentary materials. If this combination proves to have even a few merits, then the large-scale use of agro-waste materials will offset the limitations and open the way for further development, ever-increasing usage and business alternatives. However, the performance and stability of combination, waste-based concrete products over the expected lifespan is of utmost importance and it will require time-based, long-term testing. This study is aimed to investigate the mechanical properties of POFA-sawdust cement concrete for concrete pavement in construction. Thus, through the POFA-Sawdust pavement concrete utilization, sustainable development would be achieved. The topic chosen for this research is of importance especially in UiTM Jengka, Pahang because there is no proper cycling track such as interlocking concrete block pavement. Therefore, by introducing the sustainable concrete mixture from POFA and sawdust, the cycling pavement could be constructed.

2. Methodology

This research consists of activities conducted in laboratory experiments. The methodology of this study encompasses the preparation of the materials and compliance testing for a concrete mixture.

2.1. Preparation of Materials

In this research, coarse aggregates with smooth surfaces sourced from a quarry site were used. Also, the maximum size of 10 mm was adopted. Fine aggregate with a fineness modulus of 3.0 and specific gravity 2.6 was used as fine aggregate. The fine aggregate was sieved in-situ through 2.0 mm sieve to remove all forms of impurities that may compromise the quality of concrete. Ordinary Portland cement (OPC) is the most common type of cement generally use around the world as a basic ingredient of concrete. The color of OPC used in this study is grey. Care has been taken to ensure that the procurement was made from single batching in air-tight containers to prevent it from being affected by atmospheric conditions. The palm oil fruit used in this study was locally sourced from a local palm oil processing plant in Jengka, Pahang. The ash from Palm oil fruit was produced by controlled burning using a kiln at a temperature of 750C. POFA-Sawdust concrete pavement was prepared following the material of the concrete mix. The mix ratio of concrete is 2:4:1 (sand: cement: water) while the sand cement ratio (S/C) of 0.5 and the water-cement ratio (W/C) is 0.5. The percentage volume of POFA use is a different percentage between 5 %, 10 % and 15 %. Meanwhile, 5 % sawdust volume was added to the concrete mix.

(a) (b) (c) (d) (e)

Figure 1. (a) OPC cement, (b) fine aggregate, (c) coarse aggregate, (d) POFA, (e) sawdust

2.2. Preparation of Samples

Three types of specimens which are cube for compressive strength test, cylindrical for tensile splitting test and prism for the flexural test were prepared and tested. The samples were mixed as follows:

M1: OPC + fine aggregates + coarse aggregates + water
M2: OPC + fine aggregates + coarse aggregates + water + 5 % of POFA
M3: OPC + fine aggregates + coarse aggregates + water + 10 % of POFA
M4: OPC + fine aggregates + coarse aggregates + water + 15 % of POFA
M5: OPC + fine aggregates + coarse aggregates + water + 5 % of POFA + 5 % of sawdust
M6: OPC + fine aggregates + coarse aggregates + water + 10 % of POFA + 5 % of sawdust
M7: OPC + fine aggregates + coarse aggregates + water + 15 % of POFA + 5 % of sawdust

The dimension details of the sample are tabulated in Table 1. All samples were submerged in the water tank for curing after 24 hours of casting and removed from the steel mould as shown in Figure 2. The samples were tested at 7 days, 14 days, 28 days and 60 days of curing. The tests included compressive strength, tensile splitting test and flexural test.

Table 1. Samples Dimension Details and Strength Properties

Samples	Dimensions (mm)	Machinery	Strength Property
Cube	100 x 100 x 100	Compression Machine	Compressive Strength
Cylindrical	100 x 200	Compression Machine	Tensile Splitting Test
Prism	100 x 100 x 500	Universal Testing Machine	Flexural Test

(a) (b)

Figure 2. (a) Samples casting, (b) Curing process

2.3 Compressive Strength Test

A compression test was conducted to determine the behavior of materials under compressive load. The compressive strength was tested at age 7, 14, 28 and 60 days of curing process by using a Compression Machine located at Concrete Laboratory, UiTM Jengka, Pahang. The load was applied to the cube that was placed on the center of the lower plate in the compression machine. The compression machine exerted a constant progressing force on the cubes until fail. Once the samples failed, the reading recorded is the maximum compressive strength of the concrete. Figure 3 shows the set-up of the compressive strength test conducted. The compressive strength of POFA concretes performs better than the OPC concrete under different curing techniques. The reason why POFA have better strength performance than OPC concrete could be a result of a high degree of fineness of POFA which enhances its pozzolanic property.

Figure 3. Compressive Strength Test Set-up

3. Results and Discussion

In designing a structure, engineers usually used compressive strength as an indicator to evaluate the strength of the concrete. At 28 days, is the period to measure the required strength of concrete which is in a standard unit of mega Pascal (MPa). The compressive strength of 7 days is also practical to predict the ultimate 28 days compressive strength of concrete. All results of compressive strength for concrete mix design proportion mixture M1 until mixture M7 were observed and recorded in Table 2. Mixture M1 is the basic mix containing cement, fine aggregate (FA), coarse aggregate (CA) and water. Mixture M2 until mixture M4 concrete contained basic mix and different percentages of Palm Oil Fly Ash (POFA), where M2, M3 and M4 contained 5%, 10% and 15% of POFA respectively. Meanwhile, the mixture M5 until M7 contained a basic mix, different percentages of POFA and 5% of sawdust. The detailed mix proportion is shown in Table 2.

Table 2. Compressive Strength for each concrete mix design proportion

		Proportion						
	Time (days)	M1 Basic Mix (OPC+FA+ CA+ Water)	M2 Basic Mix +5% POFA	M3 Basic Mix +10% POFA	M4 Basic Mix +15% POFA	M5 Basic Mix +5% POFA +5% Sawdust	M5 Basic Mix +10%POFA +5% Sawdust	M5 Basic Mix +15%POFA +5% Sawdust
Average Stress (MPa)	7	15.70	10.00	9.50	7.00	11.80	6.70	7.10
	14	16.50	10.90	10.60	9.20	12.10	7.70	8.30
	28	22.10	11.80	11.30	9.80	14.70	9.90	9.30
	60	23.50	14.00	12.50	11.50	14.90	10.50	12.40

Compressive Strength Development Figure 4 and Figure 5 show compressive strength for each concrete mixture M1 until M7 according to concrete age. The compressive strength trend shows that, when the percentage of POFA increases, then the compressive strength of concrete will decrease. Meanwhile, as the percentage of POFA increases and the percentage of sawdust remains, the compressive strength also decreases. However, it differs in mixture M5, where it was found that concrete mixture M5 which is a combination of 5 % POFA and 5 % Sawdust give good concrete strength when incorporated with sawdust, compared to other mixtures. The optimum cement replacement by POFA is 5%, beyond this ratio, compressive strength is reduced. This could be attributed to further pozzolanic reaction between POFA and Sawdust in the concrete mixture when it has the same percentage proportion.

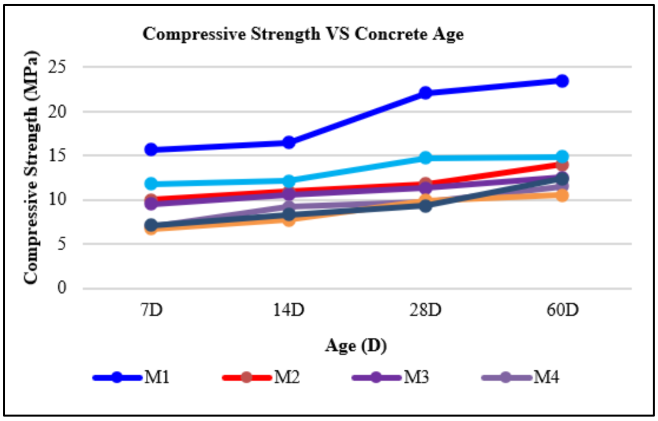

Figure 4. Compressive strength of the concrete mixture M1 until M7 at 7, 14, 28 and 60 days

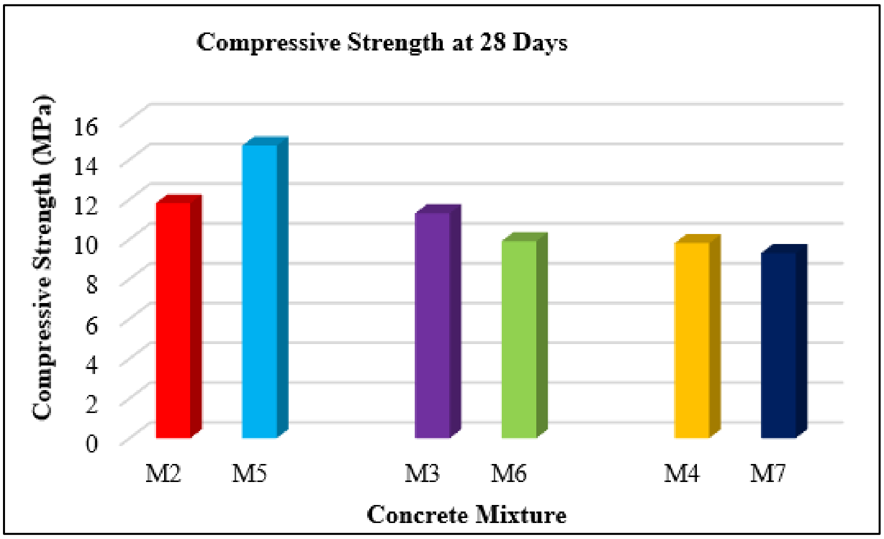

Figure 5. Compressive Strength of Concrete POFA-Sawdust at 28 days

4. Conclusion

The compressive strength of POFA concrete samples was found to be lower than those of normal concrete. However, when incorporates with sawdust, the compressive strength increases, but further studies need to conduct to find the optimum percentage of POFA and sawdust in the concrete mixture. Results suggest that the same percentage replacement of POFA and sawdust could be the optimum level for the production of concrete because the strength of concrete reduced gradually beyond this replacement level. POFA and sawdust used as a material replacement in concrete enable the large utilization of the waste product. Long-term studies on the development of strength as well as durability aspect of concrete containing POFA and sawdust have been recommended for further investigation. POFA and sawdust appear to be unique complimentary materials. Many studies have shown that concrete containing POFA has better compressive strength, durability and other properties than concrete containing Ordinary Portland Cement (OPC) only. Other researchers have shown more advantages of POFA replacement in concrete in specific proportions, especially minimizing CO_2 gas emissions and thus improving environmental conditions. However, the natural sustainability of the POFA used is eco-friendly and will contribute positively to the reduction of the global greenhouse effect as well as the overall sustainable construction materials. Implementation of waste POFA and sawdust not only decreases environmental damage but also saves the concrete materials. Therefore, by introducing the sustainable concrete mixture from POFA and sawdust, it could be applied to the pavement blocks.

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