Mix Design: Effect of Mixing Constituents towards Palm Oil Clinker Lightweight Aggregate Concrete

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Abstract— Use of waste materials as substitutes in the production of concrete that improve some important properties of the hardened lightweight aggregate concrete such as mechanical and durability properties are grabbing the researchers' attention nowadays. This is due to lightweight aggregate concrete low density that resulted in reduction of dead load, faster building rates in construction and also lower transportation and handling costs compared with normal concrete. Palm oil clinker, one of the by-product produced abundantly from palm oil industry is dumped as waste without any profitable value which caused negative effects to the environment. At the same time, large quantities of coarse aggregate are produced from quarries around and has disastrous environmental consequences. To produce coarse aggregate for concrete, mountains had to be 'slaughtered' in which intensifies erosion problem. Due to this activity, natural resources is becoming a deficient commodity and hence exploring replacement to it has become imminent. Thus, this research was conducted to investigate the best mix proportion to produce palm oil clinker lightweight aggregate concrete. In this research, a by-product from palm oil industry called as palm oil clinker was used as conventional aggregate replacement in concrete mixture. The result shows that it is possible to produce high strength lightweight aggregate clinker with strength of 75 MPa with suitable mix proportion. As a conclusion, recycling this palm oil waste not only helps reduce the huge amount of global palm oil waste sent for disposal, but also helps conserve natural resources by replacing the need for virgin materials.

Keywords— Palm Oil Industry, Palm Oil Clinker, Lightweight Aggregate Concrete, Compressive Strength, Dry Density

1. INTRODUCTION

Nowadays, increased demand of materials for infrastructure, buildings and transportation purpose has made large demand on construction materials causing huge shortage of natural building materials especially granite aggregate. Thus, in order to solve this problem, various types of material including industrial wastes that is useful for construction has been converted into building materials. Many types of waste materials from wide range industrial that can be utilized into concrete as aggregate has been discovered by researchers. This not only helps to preserve the natural resources, but also assist towards a safer method of depositing these waste materials instead of dumping them into the landfills. So far, among the waste materials that has been successfully integrated as mixing ingredient in concrete are palm oil fuel ash [1-3], fly ash [4], oil palm shell [5], cockle shell [6] and many more. At the same time, Malaysia is one of the world largest palm oil producer. The large amount of waste produced is one of the main contributors to the nation's pollution problem. Oil palm shell, palm oil fuel ash and oil palm clinker are among the by-product which dumped as solid waste. Palm oil clinker (POC) is a chunk of rock produced from burning of oil palm shell and fiber incineration process [7]. In practice, it is disposed as profitless waste at dumping site. Continuous dumping of this waste in large amount would pose greater negative impact towards environment in future. This is due to the increasing cost on handling for waste management that have to be spent by the palm oil mill management. Realizing the problem, researcher have conducted study and discovered that this material can be used as aggregate to produce lightweight palm oil clinker concrete with the strength of 75 MPa.

2. MATERIALS AND METHODS

A. Sample Collection and Material Preparation

To produce high strength palm oil clinker lightweight aggregate concrete, the materials needed are ordinary Portland cement (OPC) confirming with [8], palm oil clinker, river sand, tap water and superplasticizer. The superplasticizer used is categorized as Type A water reducing admixtures in accordance with [9]. Palm oil clinker collected from single source palm oil mill in Gambang, Pahang, Malaysia was washed and dry. Then, it was crushed with the jaw crushing machine and sieved using 10 mm and 5 mm sieve. POC particles below 10 mm sieve and retained inside 5 mm sieve was taken and used as coarse aggregate in concrete.

B. Mix Proportioning

Eleven concrete mixes consisting of variety proportion of cement, sand, palm oil clinker, admixture and water were prepared. Three types of testing that are workability, compressive strength and dry density were investigated. The workability of high strength palm oil clinker lightweight aggregate concrete was indicated using slump flowability following the procedures in [10]. The concrete strength development was determined using 100 x 100 x 100 mm standard cubes specimen and tested using compressive strength machine according to the procedure in [11]. The test specimens was water cured and tested at the age of 7 and 28 days. The mix proportioning used is illustrated in Table. 1.

3. RESULTS

From the results in Fig. 1, it shows that higher amount of clinker reduces concrete strength due to higher porous nature of palm oil clinker aggregate. This resulted in high water absorption of palm oil clinker lightweight aggregate concrete. High amount of water absorption by clinker aggregate resulted in reducing concrete workability making it harder to compact during mixing process. Low compaction produces low density concrete thus lead to decrease in strength. The effect of sand content towards lightweight aggregate concrete is presented in Fig. 2. From the figure, it shows that increasing amount of sand in concrete resulted in increasing concrete strength. Low amount of sand leads to segregation and bleeding of concrete. In contrast, larger amount of sand produces denser and stronger concrete. However, the highest amount of sand content that can be utilized in POC lightweight aggregate concrete is 750 kg/m^3. Adding sand beyond 750 kg/m^3 would result in concrete with higher dry density (more than 2000 kg/m^3) thus cannot be considered as lightweight aggregate concrete.

The effect of cement content towards palm oil clinker lightweight aggregate concrete is presented in Fig. 3. According to the figure, adding larger amount of cement contributes towards increase in concrete strength. This is due to the larger amount of cement that increases hydration process thus enhancing the concrete strength. Apart from that, water curing in which by far is the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration. For hydration to proceed, it is important to saturate calcium silicate hydrate (C-S-H) gels with water. Proper curing reduces the rate of moisture loss and provides a continuous source of moisture required for the hydration that reduces the porosity and provides a fine pore size distribution in concrete [12]. On the other hand, lower quantity of cement in concrete decrease the binding capacity of concrete particles and prevent this type of concrete to achieve the targeted strength.

The effect of superplasticizer content towards palm oil clinker lightweight aggregate concrete is presented in Fig. 4. As for influence of superplasticizer, one percent content turns out to be the optimum percentage for palm oil clinker lightweight aggregate concrete. This is due to the water reducing admixtures that ensure proper dispersion of the cement particles in concrete thus prevent difficulties during concrete mixing. This result in segregation reduction and hence, lead towards more compact and higher strength concrete. However, it shows reduction in strength as the percentage of superplasticizer increased. Too large superplasticizer dosage causes bleeding and segregation of the concrete mixes.

Inclusion of adequate amount of water assist towards occurrence of better hydration process thus making the concrete structure denser and stronger. From Fig. 5, it shows that water-cement ratio of 0.45 lead to the highest strength without compromising the workability. However, too much water will result in segregation of clinker and sand from the cement paste. Moreover, water that is not consumed during hydration process will leave concrete as it hardens, resulting in microscopic pores that will reduce final strength of concrete. On the other hand, lower water-cement than the optimum dosage resulted in concrete did not mix thoroughly thus increase concrete porosity when hardened. This will eventually affects the overall concrete strength.

Table 1: Mix Proportion of the mixes (kg/m^3)

Mixes	Mix Proportions (kg/m^3)				
	Cement	Sand	POC	Sp (%)	w/c
M1	480	750	565	1	0.45
M2	480	750	620	1	0.45
M3	480	750	700	1	0.45
M4	480	650	565	1	0.45
M5	480	850	565	1	0.45
M6	470	750	565	1	0.45
M7	460	750	565	1	0.45
M8	480	750	565	0.8	0.45
M9	480	750	565	1.2	0.45
M10	480	750	565	1	0.55
M11	480	750	565	1	0.35

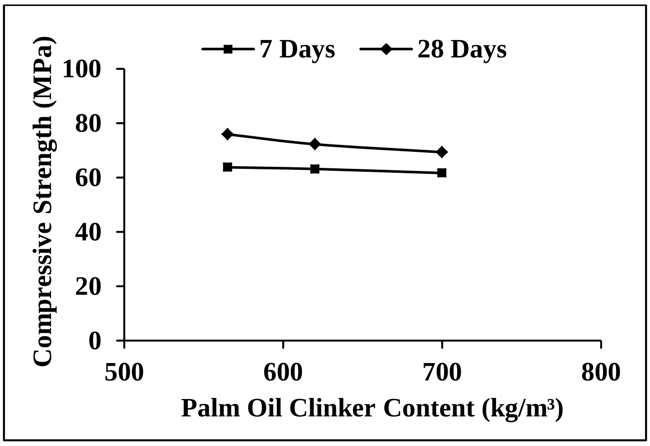

Figure 1: The effect of palm oil clinker content towards lightweight aggregate concrete

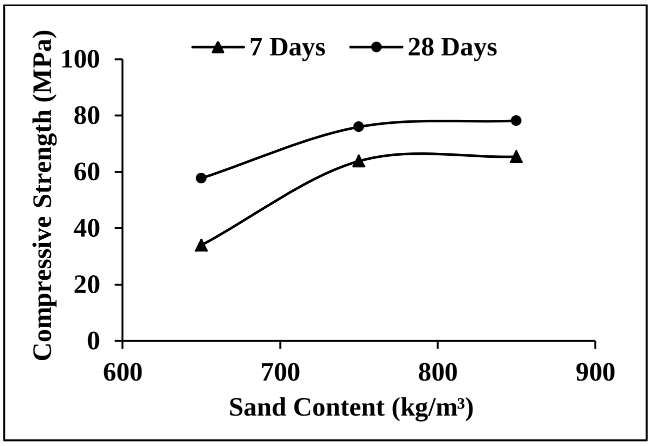

Figure 2: The effect of sand content towards POC lightweight aggregate concrete

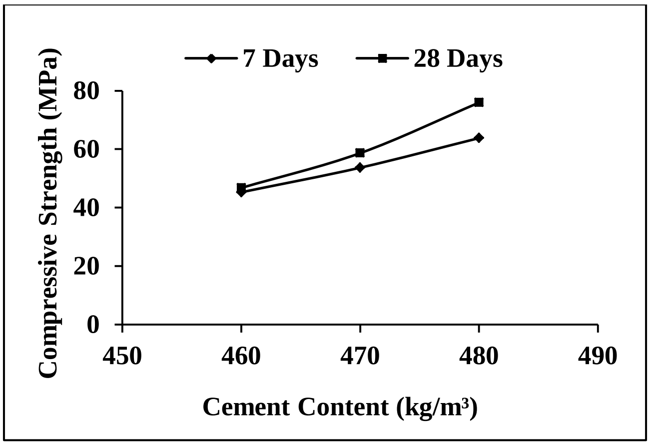

Figure 3: The effect of cement content towards POC lightweight aggregate concrete

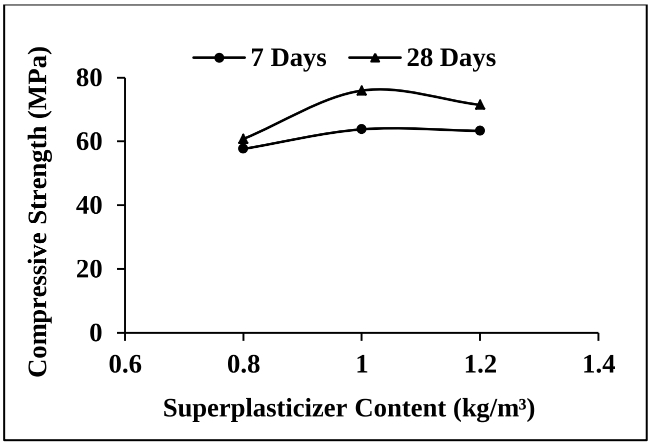

Figure 4: The effect of superplasticizer content towards POC lightweight aggregate concrete

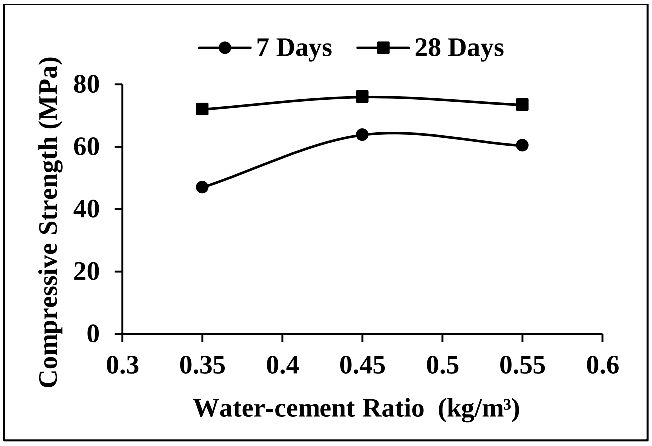

Figure 5: The effect of water-cement ratio towards lightweight aggregate concrete

Table 2 Summary of Concrete Mixes Results

Mixes	Testing Results		
	Slump (mm)	Compressive Strength (MPa)	Dry Density (kg/m^3)
M1	90	75.94	1878
M2	75	72.27	1998
M3	40	69.34	2200
M4	85	57.72	1860
M5	100	78.12	2216
M6	75	58.64	1765
M7	60	46.75	1860
M8	70	60.78	1800
M9	110	71.47	1912
M10	100	73.40	1943
M11	35	71.98	1777

Amongst all the mixes as summarized in Table 2, Mix-1 exhibits the highest compressive strength with the density value of 1878 kg/m^3 which is less than 2000 kg/m^3 and approximately 15% lighter than normal concrete. The slump produces is categorized as medium degree of workability with 90 mm slump. Medium workability mixes is suitable for manually compacted flat slabs and heavily reinforced sections with vibrations.

4. CONCLUSION

From the experimental programme, it can be concluded high strength palm oil clinker lightweight aggregate concrete can be reached by utilizing appropriate amount of mixing ingredients. In this research, Mix-1 gives the highest performing results in terms of strength and workability with dry density of not more than 2000 kg/m^3 thus can be selected as the best optimum mix choice. Palm oil clinker lightweight aggregate concrete not only promote green construction material but also simultaneously help to solve solid waste problem by reducing the palm oil solid waste dumped at the landfill.

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