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Compressive Strength of Concrete Containing Laterite Stone and Palm Oil Clinker as Fine Aggregate Replacement

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Abstract. The high dependency of construction industry on supply of river sand has initiated research to find other alternative materials that can be used as partial sand replacement in concrete production. Two types of material, that is palm oil clinker (POC) which continuously produced waste from local palm oil industry and freely available laterite aggregate on earth surface have been investigated its potential to be used as partial sand replacement in concrete. The present research was carried out to determine the workability and compressive strength of concrete containing laterite aggregate and crushed palm oil clinker as partial fine aggregates replacement. Concrete mixes have been prepared by integrating various proportions of laterite aggregate and palm oil clinker by weight of river sand. The compressive strength test was conducted on the continuously water cured specimens at 7, 14 and 28 days. The results showed a perfect combination of fine laterite and fine palm oil clinker on S1 (25% of FL + 25% of FPOC) as partial fine aggregate replacement contributed towards enhancement of concrete strength.

1. Introduction

Generally, concrete is one of the most widely used as construction material in construction industry worldwide. About 70% to 75% of volume of the hardened mass in ordinary structural concretes was occupied by aggregates. Fine aggregate is one of the natural materials obtained from the mining activity at the river. The increasing demand of this material by concrete industry has led to active sand mining activities at many places which contribute to economy growth. Unless other alternative material or known as artificial fine aggregate is discovered to play the role as partial sand replacement, continuous exploitation of sand from the river may lead to destruction of habitat of flora and fauna on the river bed. As a result, the ecosystem of the environment would be disturbed. Thus, the needs of research on discovering alternative material such as artificial aggregates are very essential nowadays. More interestingly, success in integrating unwanted industrial by-product as artificial fine aggregate would benefit the environment through waste reduction and contribute towards preservation of natural river sand. Realization over these issues, has initiated researchers [1, 2, 3, 4, 5] to investigate the possibility of integrating locally available waste material as partial fine aggregate replacement in many parts of the world. There are bunch of artificial fine aggregates such as steel slag, fly ash aggregates, blast furnace slag and others. In relation to this issue, Malaysian palm oil industries being one of the largest palm oil producers on the globe are contributing to the prosperous economy growth of this country. Despite its contribution, this industry also facing challenges to manage tones of its solid wastes that is generated at the palm oil mills. Palm oil clinker is one of end- product that disposed as waste. Physically, it looks like white chunk solid material and with many pores on it. It is produced in the boiler during the combustion of husk fiber and shells of palm oil are burned to generate energy for the refineries. In practice, this waste is disposed at landfill and causes pollution. The negative impact to the environment resulting from the disposal of this waste towards soil pollution and impact to ground water supply source has been reported by Kanadasan et. al [6]. Realizing that integration of this by-product in material production is one of the solutions to reduce amount of waste ending at landfill, palm oil clinker has also been investigated its potential to be used in construction material production. So far, attempts have been made to use this material as mixing ingredient playing the role as partial fine aggregate replacement in cement brick [7], aerated concrete [8], palm oil clinker lightweight aggregate concrete [6] and OPS lightweight aggregate [9].

At the same time, the existence of natural laterite aggregate in certain parts of this country [10] and the increasing need for aggregate supply in concrete production has initiated research on laterite concrete. Laterite aggregate can be considered as a material, highly weathered, rich in secondary oxides of iron, aluminum or both [11] formed through weathering process. This red brown aggregate is mostly available in tropical climate countries. The properties of this aggregate are varied from one area to another owing to the degree of weathering. The abundantly available laterite aggregate has led towards exploration on the potential of this material as mixing ingredient in concrete production. Past investigation shows that concrete with targeted strength can be produced through integration of laterite as partial coarse aggregate replacement [3, 12, 13] or also as partial fine aggregate replacement [14, 15]. Research on utilization of fine laterite aggregate as partial sand replacement in concrete is quite extensive. However, not much study reports on the use of fine laterite aggregate together with other material as partial sand replacement in concrete.

The interest of preserving natural river sand from excessively exploited has led Ukpata et. al. [16] to incorporate quarry dust as partial fine aggregate replacement in laterite concrete so far. Fine laterite and fine palm oil clinker used in the mix proportion to replace part of the sand by percentage of its weight. In general, the advantages of using these two alternative materials will reduce the emission factor and also provide a good alternative disposal system for the environment. By introducing these natural and waste products, it helps to provide a constant amount of natural resources to meet the future demand in construction material [17]. Study conducted by Caldeira [18] has revealed that laterite aggregate as partial course aggregate replacement may influence on compressive strength of concrete.

In addition, Kamaruzaman and Muthusamy [19] has revealed that development of strength in concrete containing laterite aggregate will improve when it subjected to water curing compared to air curing and natural curing. Apart from that, POC has low specific gravity and high crushing value making it a good source of alternative aggregate [20]. A study conducted by Ahmmad et. al [21] has found that palm oil clinker concrete was comparatively lean-to normal weight aggregate concrete in term of it compressive strength. Since both materials have play their own roles in the concrete, it is novel to investigate those materials as part of sand replacement.

To the author's knowledge, no other investigation has been carried out so far to integrate two or more materials together as partial sand replacement in laterite concrete. Therefore, the present research investigates the performance of concrete containing various ratio of natural river sand combined with fine palm oil clinker and laterite aggregate. It is expected that; this study would provide more information on the possibility of combining different types of materials as partial sand replacement to produce laterite concrete with enhanced properties.

2. Experimental Work

2.1. Materials

Materials used in this experimental work are Ordinary Portland Cement (OPC), fine and coarse aggregate, water, fine palm oil clinker (FPOC) and fine laterite (FL). Ordinary Portland cement complying with ASTM [22] is used as binder. Crushed granite that sieve through 10 mm sieve and retained were used as coarse aggregate. River sand is used as fine aggregate in concrete mix. The palm oil clinkers were collected from FELDA Lepar Hilir Palm Oil Factory located in Gambang, Pahang. It is produced inside the incinerator that used to burn the pressed oil palm shells and fibres. Laterite stones were collected from the surface of the earth. Supplied tap water is used for concrete preparation and curing purpose.

The works started with collection of raw materials that are palm oil clinkers and laterite stones. At the palm oil mill, the clinkers from the burning chamber which usually dumped as waste, were collected and packed inside the gunny sack when cooled. The laterite aggregates were collected and brought to the laboratory for further processing work. The collected palm oil clinker and laterite aggregates are illustrated in Figure 1 (a) and (b). Both clinkers and laterite stones used in this research undergone few processing stages before ready to be used in concrete making. Laterite aggregates were oven dried for 24 hours before crushed using jaw crusher machine. Then, the crushed laterite aggregates were sieved passing 5 mm to produce FL. Similarly, palm oil clinker also crushed using jaw crusher machine and sieved through 5 mm sieve machine to obtain smaller size of clinkers known as FPOC. All the processed materials were stored in closed container.

(a) (b)

Figure 1. (a) Palm oil clinker, (b) Laterite stone

2.2. Mix Proportion

A total of four mixes containing various percentage of aggregates of different types were prepared. The Plain concrete containing 100% river sand as fine aggregate was prepared as control specimen. The effect of substituting the use of river sand partially or fully with FL and FPOC on concrete strength were observed on mix S1, S2 and S3. Details of the mixes are shown in Table 1. The percentage of concrete mix composition for fine aggregate is based on weight of sand. The mix proportion of control specimen is tabulated in Table 2.

Table 1 Concrete mix composition for fine aggregate

No. of Specimens	Composition of Mixing		
	FL	**FPOC**	**River sand**
Control	0 %	0 %	100 %
S1	25 %	25 %	50 %
S2	50 %	0 %	50 %
S3	100 %	0 %	0 %

Table 2 Mix composition for control concrete

Material	(kg/m^3)
Cement	330
Water	190
River sand	705
Coarse Aggregate	1205

2.3. Testing Procedure

All the concrete mixes were prepared in the form of cubes (150x150x150mm) as shown in Figure 2. The slump test for determination of workability is conducted in accordance to BSEN 12350-2 [23]. The specimens were water cured until the testing age. Compressive strength test was conducted on the specimens at the age of 7, 14 and 28 days using compressive strength machine. Compressive strength was conducted following the procedure stated in BSEN 12390-3 [24].

Figure 2 Plastic mould for preparing (150x150x150mm) cubes

3. Result and Discussion

3.1. Workability

Slump test is conducted to measure the consistency of plastic concrete. Figure 3 shows the result of slump test for four different types of specimens namely control mix, S1, S2 and S3 respectively. Evidently, percentage of palm oil clinker and fine laterite aggregate added in the mix influence the workability of concrete. Control mix specimen, S1 which produced using 100% river sand recorded 12 mm of slump. Whereas the S3 which consist of 100% FL recorded 18 mm of slump which indicates the highest slump value compare to the other specimens. This presumably owing to the different physical properties of these aggregate determined by its formation process. Past researcher, Muthusamy et. al [25] has pointed out that the presence of voids on the surface texture of laterite aggregate and its capability of absorbing water in concrete mix. When laterite aggregate is used in large amount as a partial sand replacement, it absorbs high amount of mixing water causing the adhesion between laterite particles become weaker. As a result, when slump cone is removed, the mix slide down as it failed to stick between each other. Figure 4 illustrates the SEM image of dense river sand particle free of voids. Past researcher Saffuan et. al [26], has reported similar observation when palm oil fuel ash which is a porous material was used as partial sand replacement beyond the limit in concrete mix.

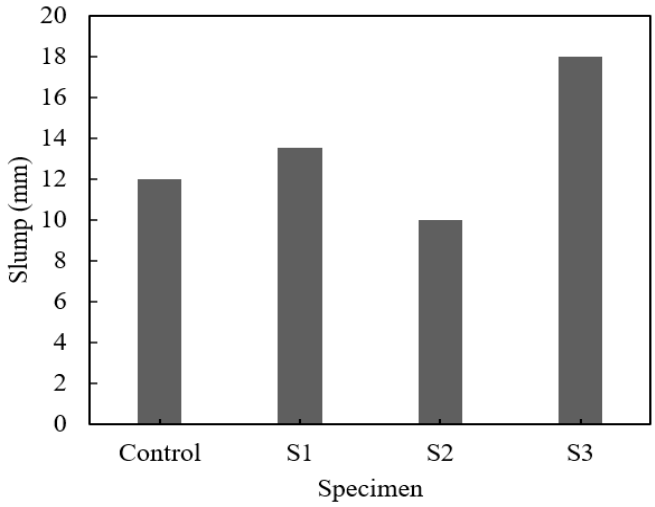

Figure 3 Slump test result of concrete mixes

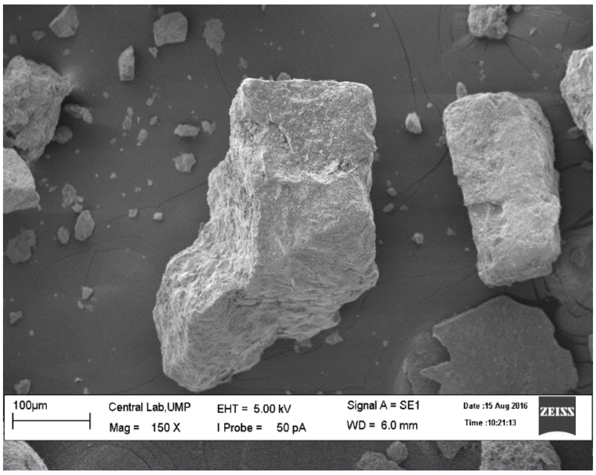

Figure 4 SEM image of river sand

Later, the t-test was applied to determine whether the population means differ between the two variables. Table 3 shows a summary of t-test result for control mix and S1 (25% FL + 25% FPOC + 50% river sand). As can be seen from the result, it was shown that with 95% confident level, it failed to reject the null hypothesis. Therefore, the evidence suggests that there is no significant different in workability between control mix and S1. It appears that, the workability for both control mix and S3 are considerably acceptable.

3.2. Compressive Strength

As mentioned previously in Introduction, the main purpose of this study was to investigate the performance of concrete containing various ratio of natural river sand combined with fine palm oil clinker and laterite aggregate. Figure 5 shows the result of compressive strength for all four mixes tested at age of 7, 14 and 28 days. As can be seen in the figure, all specimens exhibited continuous strength increment throughout the curing age. This increment of strength is generally following the general concrete where concrete get strength overtime. The concrete will be near-optimal strength and is unlikely to change much more after 28 days of curing. However, the S1 specimen recorded higher compressive strength compared to control specimen as early as day 7 of the cast. This is most probably due to the FPOC that was added in the mix and the suitable proportion between FPOC and FL that improve early strength compared to other specimens.

Table 3 t-test: Two sample assuming unequal variance

Parameters	**t- Test on Control Mix and S1**	
	Control mix	**S1**
Mean	5.52	24.78333
Variance	33.2352	970.1658
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-1.05331	
P(T<=t) one-tail	0.201336	
t Critical one-tail	2.919986	
P(T<=t) two-tail	0.402672	
t Critical two-tail	4.302653	

Application of continuous water curing promotes undisturbed hydration process resulting in formation larger amount of C-S-H gel which is responsible for concrete strength development. It is interesting to note that inclusion of fine aggregate from difference sources namely fine palm oil clinker, fine laterite and river sand influence the compressive strength performance of concrete. Incorporation of fine laterite aggregate able to increases the concrete strength as compared to plain specimen. However, an exclusive combination of these three different types of fine aggregate at certain ratio would be a synergy towards enhancement of concrete strength. This can be observed from the compressive strength for specimen S1 produced using 25% FPOC + 25% FL + 50% river sand which recorded the highest value of compressive strength throughout the testing age. This is possibly due to proper proportion and the properties of FPOC itself where the FPOC produce irregular shape that could fill up the space between other materials which could lead to higher strength.

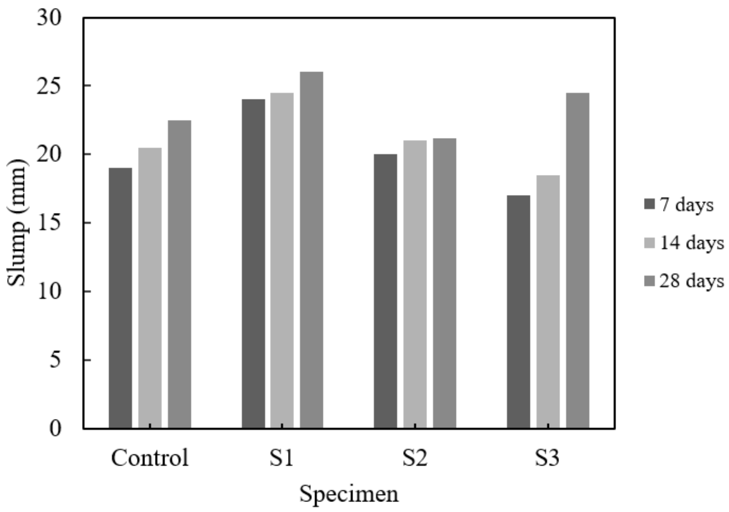

Figure 5 Compressive strength test result of concrete mixes.

The t-test was applied for compressive strength test to determine whether the population means differ between the two variables. To test the hypotheses that control mix were associated with statically significant different mean compressive strength, an independent samples t-test was performed. The independent samples t-test was associated with statically significant effect, t(3)= 3.277, P= 0.015. Thus, the control sample were associated with statically significant smaller mean compressive strength than sample S1.

Table 4. Average compressive strength for control mix and specimen S1

Days	**Average Compressive Strength**	
	Control mix	**Specimen S1**
7	19	23.87
14	20.37	24.25
28	22.422	26.64

Table 5. T-test: Two sample assuming unequal variance

Parameters	**t- Test on Control Mix and S1**	
	Control mix	**S1**
Mean	20.597	24.92
Variance	2.966	2.255
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-3.277	
P(T<=t) one-tail	0.015	
t Critical one-tail	2.132	

Table 6 shows the average compressive strength between control mix and specimen S2 which contains 50% FL + 50% river sand. Table 7 shows the summary of t-test result. To test the hypotheses that control mix was associated with statically significant different mean compressive strength, an independent samples t-test was performed. The independent samples t-test was associated with statically significant effect, t(3)= 0.144, P= 0.449. Thus, the evidence suggested that at 95% confidence level, there was no significant difference between control mix and specimen S2 which contain 50% FL + 50% river sand.

Table 6. Average compressive strength for control mix and specimen S2

Days	**Average Compressive Strength**	
	Control mix	**Specimen S2**
7	19	19.88
14	20.37	20.84
28	22.422	20.98

Table 7. T-test: Two sample assuming unequal variance

Parameters	**t- Test on Control Mix and S2**	
	Control mix	**S2**
Mean	20.597	20.447
Variance	2.966	0.303
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	0.144	
P(T<=t) one-tail	0.449	
t Critical one-tail	2.920	

Table 8 shows the average compressive strength between control mix and specimen S3 which contains 100% fine laterite. The t-test was applied by assuming unequal variances with alpha equal to 0.05. Table 9 shows the summary of t-test result. Since the null hypothesis stated that there was no statistically significant different between two groups, the analysis result failed to reject the null hypothesis as indicated t(3)= 0.125, P= 0.454. Therefore, the evidence suggested that at 95% confidence level, there was no significant difference between control mix and specimen S3 which contain 100% laterite as the alternative source material to replace natural aggregate (sand).

Table 8. Average compressive strength for control mix and specimen S3

Days	**Average Compressive Strength**	
	Control mix	**Specimen S3**
7	19	17.24
14	20.37	19.03
28	22.422	24.61

Table 9. t-test: Two sample assuming unequal variance

Parameters	**t- Test on Control Mix and S3**	
	Control mix	***S3***
Mean	20.597	20.293
Variance	2.966	14.776
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	0.125	
P(T<=t) one-tail	0.454	
t Critical one-tail	2.353	

4. Conclusion

Based on the result obtained from this study, the following conclusion can be drawn:

- The suitable integration of laterite stone and palm oil clinker portion as partial sand replacement would enhance the compressive strength of concrete shown by S1 mix.
- The statistical analysis on compressive strength between control mix and S2 and S3 has shown that there is no significant different in term of strength of concrete. Thus, crushed laterite can be used as the alternative source material to replace river sand.
- Inclusion of palm oil clinker as partial sand replacement in the concrete mix would reduce amount of clinker disposed as solid waste by palm oil industry thus promoting towards green environment.
- The use of crushed laterite stone and palm oil clinker as partial sand replacement would reduce the high dependency of concrete industry on river sand supply.

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