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INFLUENCE OF OIL PALM SHELL ON WORKABILITY AND COMPRESSIVE STRENGTH OF HIGH STRENGTH CONCRETE

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ABSTRACT: This paper illustrates a quantitative study on workability and strength properties of concrete which is produced by Oil Palm Shell (OPS) as coarse aggregate. A set of laboratory tests including Slump, Compaction Factor, Density, Compressive Strength and Schmidt Hammer test was conducted on concrete made by natural aggregate as control sample and concrete produced by different percentage of OPS i.e. 10%,20%,30%,40% and 50% of dry weight of coarse aggregate. All samples were submerged for 3, 7, 14 and 28 days as curing age. The results demonstrate that the rate of workability for OPS samples shows a relatively medium to high workability ranging from 28 to 50mm for slump height and 0.93 to 0.95 for compaction factor. The general strength of OPS concrete samples produced high strength concrete with compressive strength reaching up to 52.2N/mm^2 for 28 days. 50% is sufficient for lightweight concrete however, 30% is the optimum percent to produce high strength with partially lightweight concrete. The results of this study can be contributed to produce high strength concrete as well as lightweight concrete particularly in construction of high rise buildings.
KEYWORDS: Workability, Compressive Strength, Oil Palm Shell, Lightweight Concrete, High Strength Concrete

INTRODUCTION

The high demand for concrete in construction industry has resulted to a rapid decrease in natural stone deposit such as the Gravel and Granit. As a result of escalating environments problem which comes as a result of excessive usage of natural stone deposit, thereby causing ecological imbalance, the need to find and explore an alternative material that could be used as a replacement to the conventional aggregate has become necessary.

According to [3], between 70 to 80 per cent out of the total volume of concrete is occupied by aggregate. With this large proportion of the concrete occupied by aggregate, it is expected for aggregate to have a profound influence on the concrete properties and its general performance. Aggregates are essential in making concrete into an engineering material. They tend to give concrete its volumetric stability; they also have a unanimous influence on reducing moistures related to deformation like shrinkage of concrete.

Furthermore, in developed countries, the construction industries have identified the use of waste natural material as the potential alternative to conventional aggregates by reducing the size of structural members. This has brought immense change in the development of high rise structures using Light Weight Concrete (LWC). However, in Asia the construction industry is yet to utilize the advantage of LWC in the construction of high rise structures [1and 6].

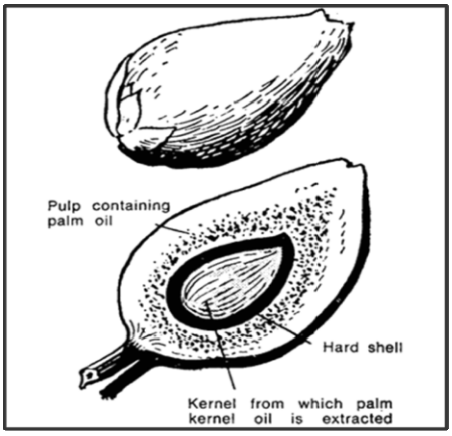

Figure 1.Oil Palm Fruit

Oil palm shell is the end product of oil palm manufacturing process. Oil palm is a fruit of a Palm Tree. The Palm tree grows in a region where the temperature is very hot and rains a lot such as Malaysia and Nigeria. Oil Palm fruit consists of two major parts: Pulp that is a yellow fruit and when crushed, produces palm oil and Kernel which is bounded in the shell of the seed when kernel is crushed, it produces palm kernel oil.

Malaysia is the second largest palm oil producing country in the world and it produces more than half of world's palm oil. The requirement of vegetable oil is constantly increasing and more cultivation of palm oil is forecast in the near future. However, one significant problem in the processing of palm oil is the large amounts of by products such as Empty Fruit Bunches (EFB), Palm Kernel Shells (PKS) or Oil Palm Shells (OPS) and Palm Oil Mill Effluent (POME). Furthermore, these are one of the main contributors to the nation pollution problem. These waste materials are stockpiled and dumped, such have caused storage problem in the vicinity of the factories as large quantities of these wastes are produced every day [3].

❖ BACKGROUND OF STUDY

According to [5] OPS aggregates can produce concrete with compressive strengths of more than 25MPa. Apart from the environmental gains in the utilization of oil palm shell, there is also an economical achievement from the production of low cost houses. A model low-cost house of 58.68m^2 area which was built in Sarawak-Malaysia using 'OPS hollow blocks' for walls and 'OPS concrete' for footings, lintels and beams was performing well and has no structural problems at all [5].

The effects of OPS will undergo under different curing conditions for a period of 56 days on workability, density, and compressive strength of a concrete when used as coarse aggregate [4]. It was noted that fly ash used as cement replacement for OPS concrete has a negative effects on the compressive strength of the concrete with a reduction of up to 29%. It was also revealed that compressive strength of OPS concrete was within the range for structural LWC, which was about 50% less than the ordinary concrete, and that OPS concrete attained the highest strength within a 56 days water curing period.

According to [7, 8 and 10] established methods such as ACI method for formal weight concrete and other similar methods could not be applied as mix design for OPS concrete. Based on [7], a trial mix design for concrete with OPS aggregate as coarse aggregate resulted to compressive strength of 24N/mm^2 for 28days of age. Fly ash as mineral admixture and calcium chloride as an accelerator were used to study improvement in strength of the concrete.

Meanwhile, High Strength Concrete based on [11] is to achieve 6000psi (40Mpa) compressive Strength of 28 days curing age however, it should be considered that it depends on geographical bases and condition of concreting.

❖ MATERIALS AND METHODS

The materials used in this study are portable de-air water, Ordinary Portland Cement of ASTM type 1, coarse aggregate with particle size distribution between 5 to 14mm, OPS were obtained in sufficient quantities from Sime Darby Sepang Estate Oil Mill Company which is located in Negeri Sembilan-Malaysia. Impurities such as oil remains and dirt were removed from OPS by applying thermal process and leave in temperature room for 24 hours.

A set of laboratory works were conducted to investigate the effects of OPS on workability and compressive strength of concrete, when used as coarse aggregates. These tests were included slump test based on B.S. 1882 part II, compaction factor test according to B.S. 1881:1970 part II, which tests the workability of concrete, compressive strength test BS 1881 Part 116 and Schmidt hammer or Surface Hardness-rebound test based on BS 1881 Part 202 to determine the strength of concrete. The tests were conducted at different ages of 3,7,14 and 28 days under full water curing and cube samples have been totally submerged in water container [9].

A mix proportion for LWC is quite different from the mix proportion of high strength concrete or normal strength concrete. For the LWC, which is to be produced from using OPS as aggregate requires an average cement/water ratio [8]. Hence cement/ water ratio of 0.5 was used in this research with mixing ration of 1:2:4. Cast iron mould of 150 x 150 x 150 mm^3 was used for casting. For each batch of mixing in OPS concrete, the quantity of cement, water aggregates are shown below:

- □ Weight of cement = 1.157 kg
- □ Weight of river sand = 2.314 kg
- □ Weight of crush aggregates = 4.63kg

Table 1.Amounts of ingredients used in each batch of mix (kg).

Sampl	%OPS	Cemen	Sand	Aggreg	OPS	Total
P_0	0%	1.157	2.314	4.63	0.0	8.101
P_1	10%	1.157	2.314	4.17	0.43	8.101
P_2	20%	1.157	2.314	3.70	0.93	8.101
P_3	30%	1.157	2.314	3.24	1.39	8.101
P_4	40%	1.157	2.314	1.39	3.24	8.101
P_5	50%	1.157	2.314	2.32	2.32	8.101
Total	----	6.942	13.884	19.45	8.31	48.61

RESULTS AND DISCUSSIONS. SLUMP TEST

Consequently, after conducting laboratory tests based on particular standard methods, the results below were obtained.

The workability of concrete batches for different percentages of OPS using slump test is shown in Figure 2. The mix samples with constant w/c ration of 0.5 exhibited medium to high workability. It is obvious that workability of concrete reduces as the amount percentage of OPS increases except for 10% OPS where it shows a spike in workability, to which from that point, as the percentage of OPS increases, the workability of the concrete reduces. This can be attributed to the fact that since the control aggregate is denser than the OPS aggregate, and the replacement is by weight, the specific surface increases as the OPS content increases. This implies that more cement paste is required for the lubrication of the aggregate, hence reducing the entire fluidity of the mix, thereby reducing the height of the slump.

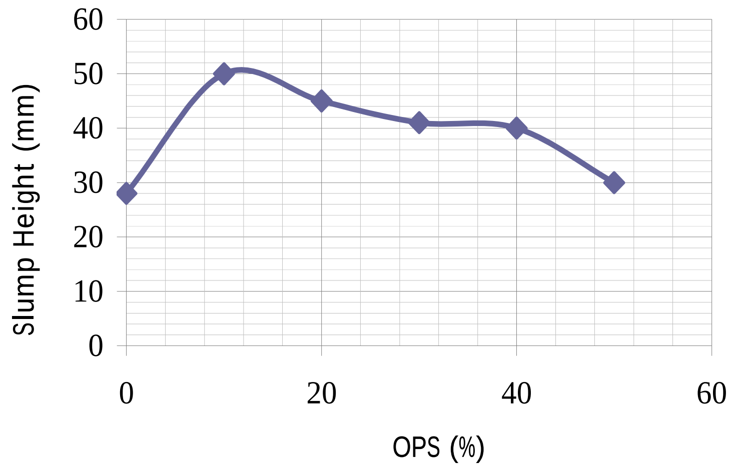

Figure 2. Slump Heights for Different Percentages of OPS

Similarly, the decrease of slump height in 20%,30%,40% and 50% OPS as percentage of OPS aggregate was increased was equally be attributed to w/c ratio. With w/c ratio of 0.5 used for all the mixes, the hydrated cement paste became more watery and less viscous. This process permits the penetration of cement into the OPS aggregate; furthermore, it reduces the amount of cement paste available for lubrication and hydration. This procurement leads to a decrease in the free movement of cement paste in the mix and consistently leads to a decrease in slump.

A similar test was conducted by [2] using Palm Kernel Shells (PKS) as the replacement of control aggregate as also experienced the same behaviour showed by OPS aggregate. As the percentage PKS of increases, the workability of the concrete reduces, hence reducing the height of slump.

COMPACTION FACTOR TEST

Figure 3 shows the compaction factor of concrete mixes for different percentages of OPS as a replacement of coarse aggregate in mixes. Compaction Factor Test is conducted to check the workability of the concrete mixes. Although similar test has been conducted to check the workability of the concrete by Slump Test, Compaction Factor Test is held to check the accuracy of the results.

From the compaction factor test results, it is indicated that 10% OPS sample with 0.95 had the highest compaction factor, which is same to the slump test. Also from the figure, it can be noted that similar to slump test, from the highest compaction factor sample which is 10% OPS, the figure started to decrease. The decrease in the compaction factor value after a steep rise from 0%, 10% and 20% OPS maybe as a result of human factor, as all workability tests are operator sensitive, which will tend to inherit errors in experimental measurements.

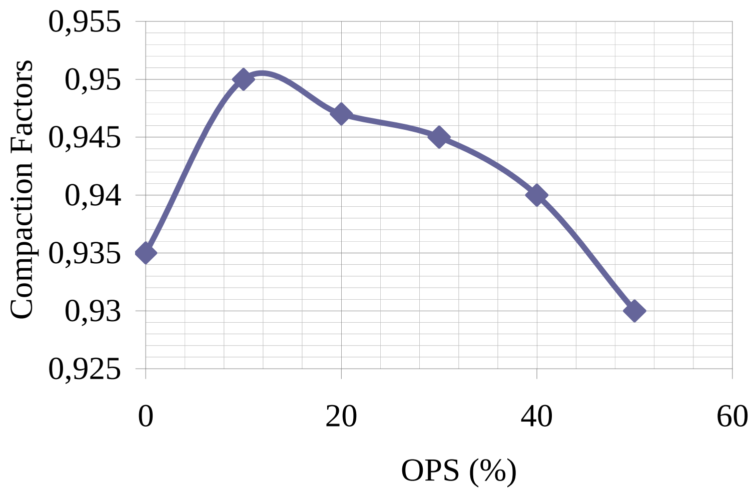

Figure 3.Compaction Factors for Different Percentages of OPS

Finally, all the compaction factors for the entire mixes sample are within the satisfactory range from medium to high workability. The result of the compaction factor test can be correlated to the slump test, although the relationship is not monaural.

❖ DENSITY OF SPECIMENS

The densities of all samples were determined to find the possibility of structural LWC component. Densities of three samples were determined to which the average is taken to determine the actual density of each sample. The density is determined using the scale balance. The Table 2 illustrates the density of samples with different percentage of OPS as replacement of coarse aggregate.

Table 2.Density of Specimens (Kg/m^3)

Days	0% OPS	10% OPS	20% OPS	30% OPS	40% OPS	50% OPS
3	2409	2253	2110	2077	1983	1889
7	2449	2268	2132	2084	1996	1908
14	2455	2270	2177	2123	1999	1910
28	2476	2292	2194	2129	2056	1925

Figure 4 shows that density reduces as percentage inclusion of OPS increases vice versa. The range of densities for OPS concrete for 28days was between 2230 – 1925 kg/m^3, while in contrast, 0% OPS concrete (control concrete) has a density of 2476 kg/m^3. The highest density was recorded for 0% OPS of 2476 kg/m^3, while the least density was recorded for 50% OPS with 1925 kg/m^3.

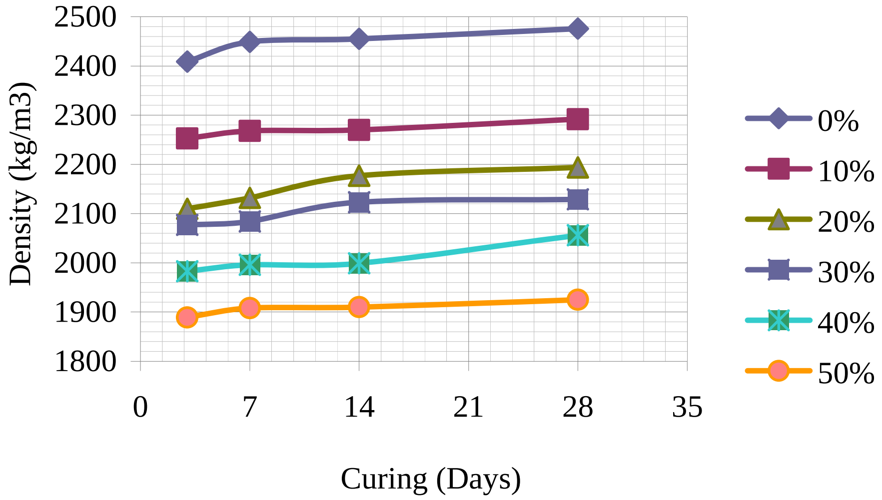

Figure 4. Densities of Cubes for Different Percentages of OPS

From the hypothesis of this study, it was known that concrete strength will be reduced as the amount of OPS increases. This can be contributed to the generally light weight nature of OPS aggregates having a unit weight of less than 2000 kg/m^3, which is approximately 60% lighter compared to the conventional crushed stone aggregate [5 and 10]. This consequently results to the production of LWC. With LWC normally having a density of less than 2000 kg/m^3, 40% and 50% OPS aggregate samples are considered as LWC samples 2056 kg/m^3 and 1925 kg/m^3 respectively. An expected weight for control aggregate concrete is within the region of 2400 kg/m^3, thus implying that 0% OPS sample concrete is considered as a normal weight concrete. The reason behind 40% and 50% OPS being lightweight concrete is because for 10%, 20%, and 30% OPS, the ratio of coarse aggregate to OPS aggregate is greater than OPS aggregate. This implies that coarse aggregate has a larger volume in the mix than OPS aggregate, and since coarse aggregate is heavier in weight than OPS aggregate, causes to a heavier density concrete.

Furthermore, LWC maybe have been produced as a result of amount of w/c ratio that was used. An increase in w/c ratio results to a decrease in cement content and increase in water content; this reduces the overall weight of the concrete. Another possibility resulting to production of LWC is the actual weight of both coarse and OPS aggregate that were used. As shown from the table and figure above, an increase in OPS aggregate ratio leads to a decrease in the air and dry density of the concrete. However since OPS aggregate is lighter in weight than coarse aggregate, as coarse aggregate is been replaced at different percentages, resulting to a lesser amount of coarse aggregate in the mix, absorption of cement paste is greatly reduced as OPS aggregate do not properly bond with cement, this reduces the overall density of concrete, thus leading to the making of LWC.

❖ COMPRESSIVE STRENGTH TEST

Figure 5 and Table 3 show the development of compressive strength of concrete with age. It indicates the different amount of OPS that were added, as it affects the strength of the concrete. The rate of strength gained was substantial as the curing day's increases, while on the other hand, the strength of the concrete decreases as the percentage of OPS increases. The compressive strength of the concrete specimens is reciprocal to the percentage of OPS added. As the percentage of OPS increases, the compressive strength of the concrete decreases, vice versa.

As it is clear, 0% OPS attained the maximum strength, as OPS gradually replaces the coarse aggregate, so the concrete strength is gradually dropped. These phenomena could be explained from the fact that OPS are organic materials that happen to be lighter and less strong than the usual coarse aggregate. Furthermore, the reduction in strength of concrete strength as a result of increment in the added percentage of OPS aggregate could be attributed as a result of the highly irregular shapes of the OPS, which prevent full compaction with usual coarse aggregate, there by affecting the strength of the concrete. More also, the bonds between OPS and cement paste were not as strong as that of control concrete because of the smoothness of the sample [7].

Table 3 Compressive Strength Test Results (N/mm^2)

Days	0% OPS	10% OPS	20% OPS	30% OPS	40% OPS	50% OPS
3	29.5	24.49	21.73	16.17	13.2	9.51
7	48.73	41.24	36.76	25.12	19.82	15.05
14	52.6	44.26	39.74	34.92	27.19	23.56
28	59.8	52.2	43.63	39.24	33.3	29.51

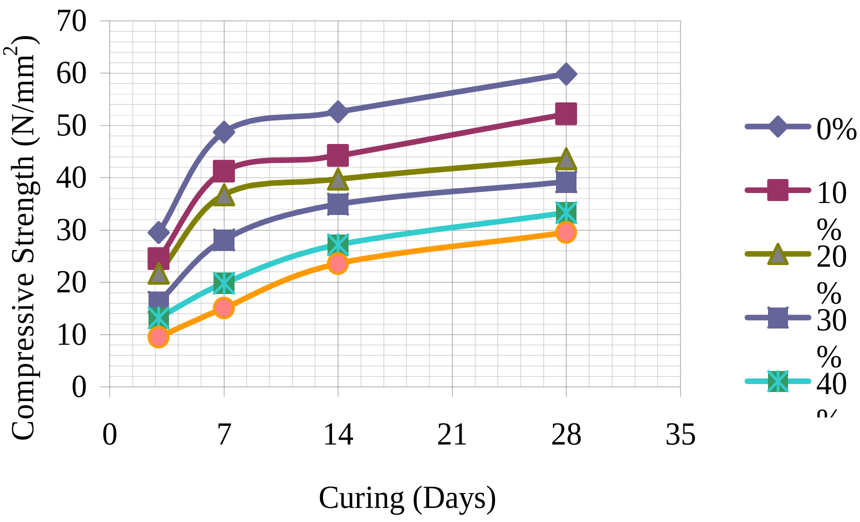

Figure5. Compressive Strengths of Different Percentages of OPS versus Curing Days

However, in regard to the general strength of all samples, it can be noted that all samples are high strength concrete. A high strength concrete is a high performing concrete generally with specific compressive strength of 6,000psi (40mpa) and above [11]. Taking 28 days as the reference curing day, 0%, 10%, 20% certified the condition of high strength concrete. Even at least curing days of 3, 7days, when concrete strength is at its least, some samples attained a very high strength. The compressive strength developed for 50% OPS in 28 days, which has the most amount of OPS is quite above the range of 20.10 – 24.20 N/mm^2 requirement for structural LWC components.

❖ SCHMIDT HAMMER TEST

The Schmidt Hammer Test is conducted to determine the strength of samples by measuring the hardness of concrete surface. Figure 6 shows the Schmidt Hammer test results for OPS concrete samples as the strength of the samples increases with age.

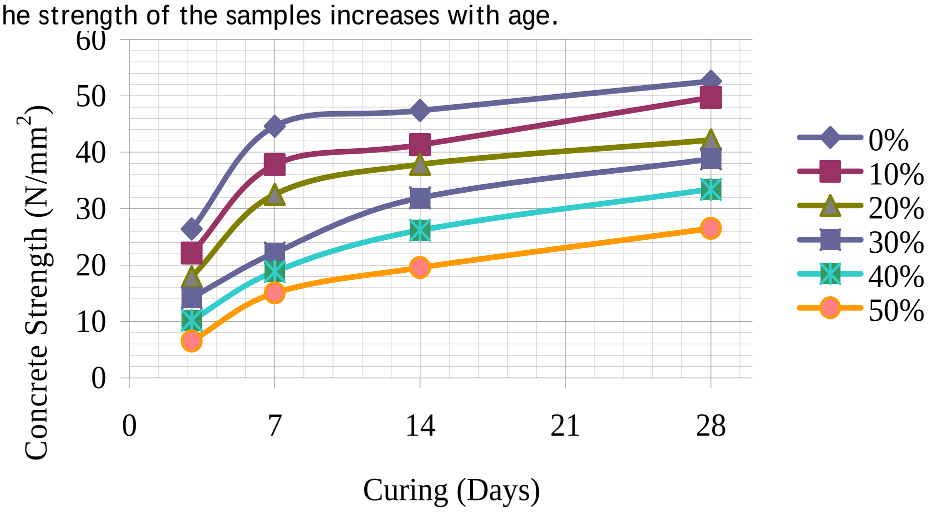

Figure 6. Schmidt Hammer Strengths in Different Curing Days

Similar to the compressive strength test, the Schmidt Hammer test results also indicated a substantial increase in concrete strength as the curing days increase and as the amounts of OPS in each sample reduce, with 0% OPS having the maximum strength and 50% OPS having the least concrete strength. However, in the case of the Rebound Hammer test results, the concrete strength appeared to have depreciated when compared to the compressive strength test results. The difference in results maybe as a result of concrete surface area which is been affected by the roughness of the concrete surface resulted by the presence of OPS in the sample. Other factors that may have affected the rebound hammer reading, which affected the strength of the concrete maybe related to the Schmidt Hammer, or the angle of inclination.

From the results above, it is clear that both Schmidt hammer and compressive strength test have resemblance, the reason behind 0% OPS having a high strength and 50% OPS maybe for the same reason, that OPS are organic materials that happen to be lighter and less strong than the usual coarse aggregate.

CONCLUSION

In general, OPS aggregate was founded to be a good replacer of coarse aggregate in concrete production from strength and workability point of view and according to recycle of waste material. Based on this study, the following conclusions can be drawn.

- The general strength of 10%, 20% and 30% OPS concrete samples produced high strength concrete with compressive strength reaching up to 52.2N/mm^2 for 28 days, which satisfies the requirement for high strength concrete.
- Concrete with 10% OPS and 50% OPS had the highest and least compressive strength respectively, which indicates that the compressive strength of OPS concrete samples is dependent on the amount of OPS aggregate in the sample. However, even though the strength of the samples have been dependant on those two variables, i.e. amount of OPS and curing period, the least desirable structural requirement for light weight concrete was achieved.
- The rate of workability for OPS samples shows a relatively medium to high workability ranging from 28 to 50mm for slump height and 0.93 to 0.95 for compaction factor.
- Not all OPS concrete samples air dry fully satisfied the structural light weight concrete requirement, with only 28 days 50% OPS concrete sample been within the density limit of 2000 kg/m^3 for structural lightweight concrete, even though 10%, 20%, 30% and 40% OPS samples could be considered as partial lightweight concrete, but not fully light weight concrete.
- Finally, 30% OPS is the ideal percentage of OPS which is in the boundary limit of the production of high strength concrete, however it is considered as partial lightweight concrete. In addition further more study, it can be recommended to use of additional admixtures and to look through influence of aging in long term study.

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