The Effect of Concrete with Replacement of Oil Palm Shell as Course Aggregates

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Abstract. Concrete is one oldest construction. The production of concrete consumes a large amount of natural resources. As a step in ensuring the availability of resources for future generations, it is necessary to adopt engineering practices which focus on the conversation of non-renewable resources and energy such as oil palm shell. The government has indicated a growing concern for protecting the environment and the need to preserve natural resources using alternative materials, such as recycled or waste materials. Malaysia is the one of the largest palm oil producers and exporter in the world. The palm oil industry has created an environmental pollution due to the production of huge quantities of waste from the oil extraction process such as oil palm shell. To prevent this problem, oil palm shell has been used as replacement course aggregates in this study. The percentages of oil palm shell are used as replacement course aggregate by 0, 10, 20, 30 and 40% with water cement ratio 0.55 and 0.60. This study to investigate the effect on concrete by using oil palm shell as replacement course aggregates. The objectives of this study are to determine the wet properties, density and strength of the concrete. The tests were carried out by using slump test for wet properties and the compressive strength test was used to determine the mechanical properties of concrete. The result from this study, the wet properties of concrete was increases when the percentage of oil palm shell increases. The density of concrete was decreased steadily due to increasing of replacement oil palm shell. Next, the strength of concrete was decreases dramatically when oil palm shell uses increases. The conclusion from this study is oil palm shell as replacement course aggregates can be used as lightweight concrete by 10% of oil palm shell are used for both water cement ratio. Most of them cannot be used for concrete due to low strength requirement.

Introduction

Concrete is one of the oldest construction materials produced and it has been used extensively in construction of multi structures since ancient days. Many researcher and development of concrete has resulted in the production of many types of concrete. The production of concrete consumes a large amount of natural resources. As a step in ensuring the availability of resources for future generations, it is necessary to adopt engineering practices which focus on the conversation of non-renewable resources and energy [1].

The government has indicated a growing concern for protecting the environment and the need to preserve natural resources using alternative materials, such as recycled or waste materials. For example, currently aggregate demands for civil engineering field become serious concern due to increasing construction development in the developing country. Various types of aggregates are used in concrete and road construction materials. This lead to the rapid increase of the demands for aggregate for new construction and reconstruction of the buildings and road [2]. Thus, an alternatives method or material needs to be identified to minimize the decrease of natural aggregates in the country. To achieve this purpose, researchers have introduced industrial waste materials into concrete as aggregate replacement to preserve the natural resources and to find a safe method of depositing these waste materials instead of dumping them into the landfills.

Malaysia is the one of the largest palm oil producers and exporter in the world [3]. In 2008, Malaysia have been produced 17.7millions tons of palm oil on 4.5 million hectares of land [4]. Another years, Malaysia is accounting for 11 % of the world's oil and fat production and 27 % of export trade of oil and fat [5]. As a result, these industries generate a lot of waste product annually from 200 palm oil mills in Malaysia during palm oil processing and these waste products are simply disposed without any commercial return [3]. Besides that, the palm oil industry has created an environmental pollution due to the production of huge quantities of waste from the oil extraction process such as oil palm shell. There are many researches on oil palm shell used in concrete mixture as substitution of the aggregate [6]; [7]; [8].

For this study is more focus on concrete with water cement ratio of 0.55 and 0.60, and percentages of OPS of 0%, 10%, 20%, 30% and 40% as replacement course aggregates in concrete mixtures on strength, density and workability of concrete. Therefore the aim of this study is to investigation the effects on concrete by replacement oil palm shell as course aggregates. The objectives of this study are:

a) To determine the wet properties of concrete using oil palm shell.
b) To investigate the density of concrete using oil palm shell.
c) To investigate the strength of concrete using oil palm shell.

This study were conducted in the laboratory structures at D04, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Skudai, Johor which the experiment test involved are the slump test to test the workability while compressive strength test to test strength of concrete.

Previous Studies

Concrete by using palm oil shell as replacement course aggregates Palm oil shell is a one of the huge waste producing from oil palm extraction process (Figure 1). As a result, the oil palm shell (OPS) which have natural sized was ideal for substituting aggregates in concrete construction. Studies has found that oil palm shells was the organic aggregate which is better impact resistance compared to normal weight aggregate [9].

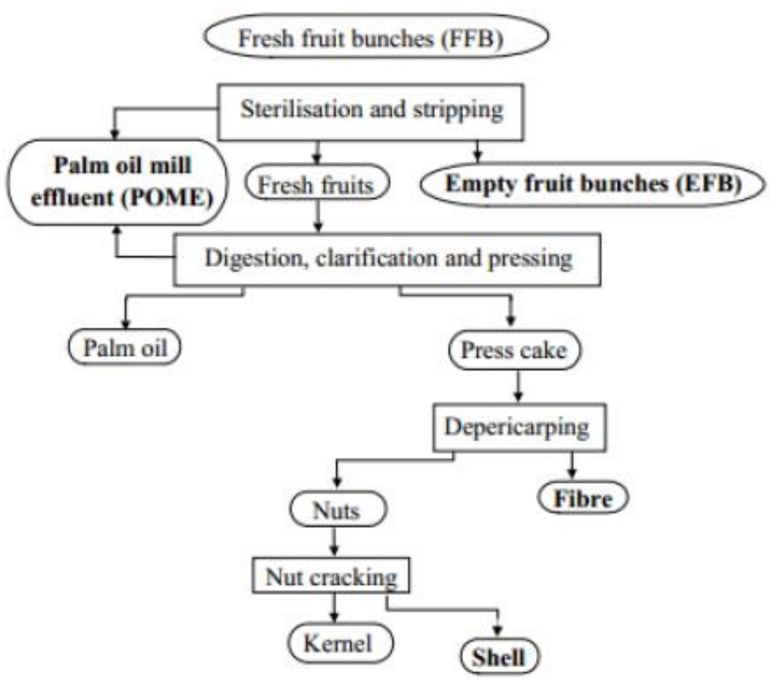

Figure 1: Simplified process flow diagram of an oil palm mill

Workability Previous study [10] has conducted experimental research on palm kernel shells as coarse aggregates in concrete. The workability of concrete will decrease due to increasing percentage of OPS. This happen because of increasing the specific surface as a result increases the quantity of palm kernel shell. When the oil palm shell is used by replacement of course aggregates the workability of concrete increases. This study also done as shown in Table 1 [8].

Table 1: Result of slump test

Concrete	**Slump test, mm**
Normal concrete	65
Oil palm kernel shell	105

Density The density of concrete decreases due to increasing the percentages of oil palm shell (OPS) in concrete mixture. The study by [11], the percentage of density reduced when granite is replacement by OPS as show in Figure 2. When the OPS were used 100% the densities was decrease by 8% from the normal weight concrete (NWA).

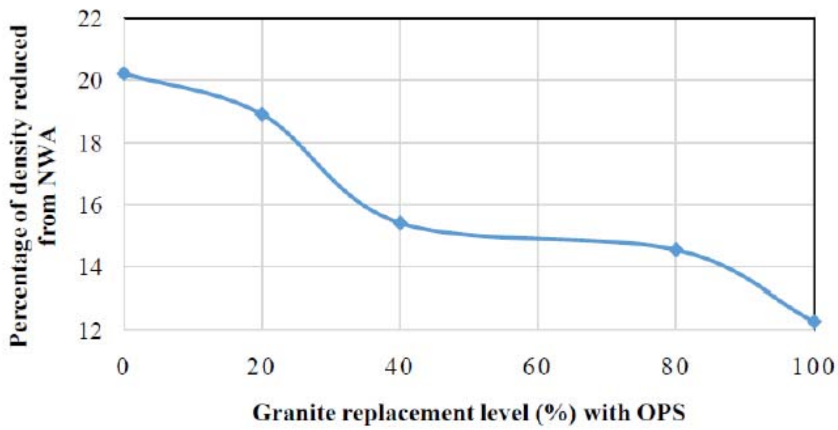

Figure 2: Pattern of change in the percentage of density reduced from NWA for the granite replacement level with OPS [11]

Compressive strength Generally, the development of compressive strength of concrete will increase with the age. The current study, the different amount of OPS is added to see the effects on the strength of the concrete either is increase or decrease the strength of concrete. Basically the strength of the concrete decreases when the percentage of OPS increases.

The compressive strength of the concrete specimens is affected to the percentage of OPS added. As the percentage of OPS increases, the compressive strength of the concrete decreases and vice versa [12]. This study also have done by [10], the Figure 3 below show the decreases strength of concrete as percentages of OPS increases.

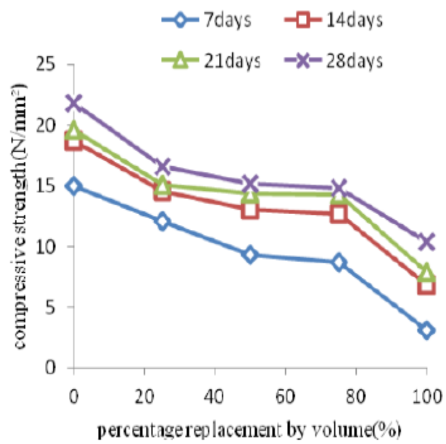

Figure 3: Variation of compressive strength with palm kernel shell content [10]

Methodology

This study involved two important stages as shown in Figure 4. The study began with the first stage, which determination strength, workability and density of oil palm shell as replacement aggregates in concrete mixture. The second stages of the study will conducted to investigate the relationship between water cement ratio with compressive strength of concrete.

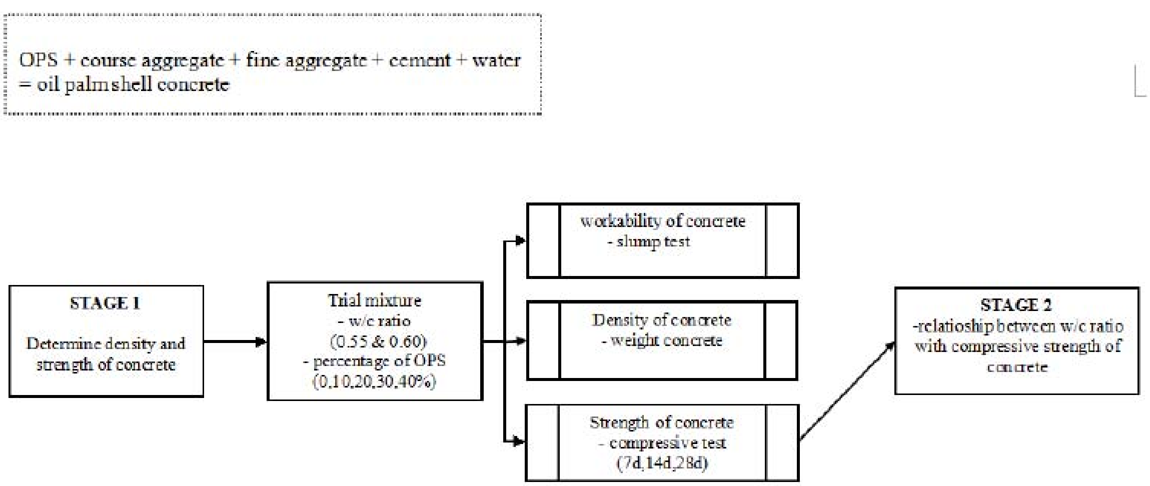

Figure 4: Study operation framework

Test Carried Out

*Workability***.** The workability of the concrete are measure by using slump test according to ASTM C143. This test to determine the concrete are true slump, shear or collapse. The control slump for this study are 20 – 30 mm.

Figure 5: Slump Test

Determination of compressive strength of concrete. In order to analyse the compressive strength of the concrete, several mix proportion of by the weight of ordinary Portland cement, sand, crushed aggregate, and oil palm shell as a substitution for coarse aggregate will be used to cast the specimens. In this test, size of OPS aggregates are used about 5 to 10 mm as show Figure 6

Figure 6: oil palm shell (5 - 10 mm)

The concrete mixer will be used to mix all the ingredient includes fine and coarse aggregate, OPS, water and cement. Malaysian ordinary Portland cement (ASTM Type 1) is used as the binding the fine aggregate (Figure 7), coarse aggregate (Figure 8) and oil palm shell. Meanwhile, the natural river sand with 60% percentage passing 600ųm sieve will be used as fine aggregate and the crushed stone with nominal size less than 10 mm as the coarse aggregate.

Figure 7: Fine Aggregate

Figure 8: Course Aggregate

The corresponding water/cement ration will be 0.55 and 0.60 respectively. In each mix proportion as mentioned, OPS is substituted for replace coarse aggregate in the gradation 0, 10, 20, 30, and 40 %. 0 % replacement will be used in this study for comparison. The mixtures will be casted in 100mm x 100mm x 100mm mould. The total sample for this study is ninety as show in Table 2 and 3.

Table 2: Samples for w/c ratio 0.55

BIL	W/c	0.55														
1	Duration	7-days					14-days					28-days				
2	% OPS	0	10	20	30	40	0	10	20	30	40	0	10	20	30	40
3	Casting	G1	G2	G3	G4	G5	H1	H2	H3	H4	H5	J1	J2	J3	J4	J5
		G1	G2	G3	G4	G5	H1	H2	H3	H4	H5	J1	J2	J3	J4	J5
		G1	G2	G3	G4	G5	H1	H2	H3	H4	H5	J1	J2	J3	J4	J5
4	Sample	G1	G2	G3	G4	G5	H1	H2	H3	H4	H5	J1	J2	J3	J4	J5

Table 3: Samples for w/c ratio 0.60

BIL	W/c	0.60														
1	Duration	7-days					14-days					28-days				
2	% OPS	0	10	20	30	40	0	10	20	30	40	0	10	20	30	40
3	Casting	K1	K2	K3	K4	K5	L1	L2	L3	L4	L5	M1	M2	M3	M4	M5
		K1	K2	K3	K4	K5	L1	L2	L3	L4	L5	M1	M2	M3	M4	M5
		K1	K2	K3	K4	K5	L1	L2	L3	L4	L5	M1	M2	M3	M4	M5
4	Sample	K1	K2	K3	K4	K5	L1	L2	L3	L4	L5	M1	M2	M3	M4	M5

Total casting per sample: 90
Total sample: 30 samples (after taking average of casting)
Example = (G1+G1+G1) / 3 = G1

Figure 9: mould (100mm x 100mm x 100mm)

Fresh concrete workability will be investigated immediately after the final mixing of the concrete using slump test. The cubes will be cast by filling each mould in three layers; each later will be compacted normally with 25 blows from steel rod. All specimens will be left in moulds for 24 hours to set under ambient temperature and will be removed from the mould and transferred into a curing that contained clean water. Figure 10 show the curing process.

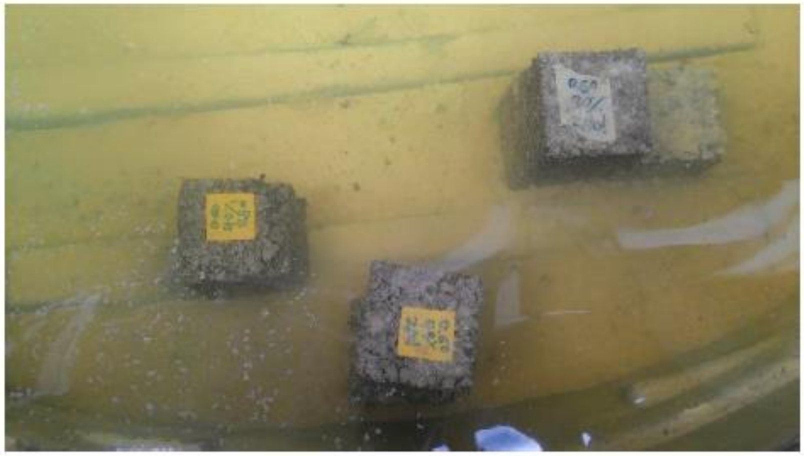

Figure 10: Curing process

Compressive strength test will be done at the age of 7-day, 14-day and 28-day on 100mm cube accordance to ASTM C39 as show in Figure 11.

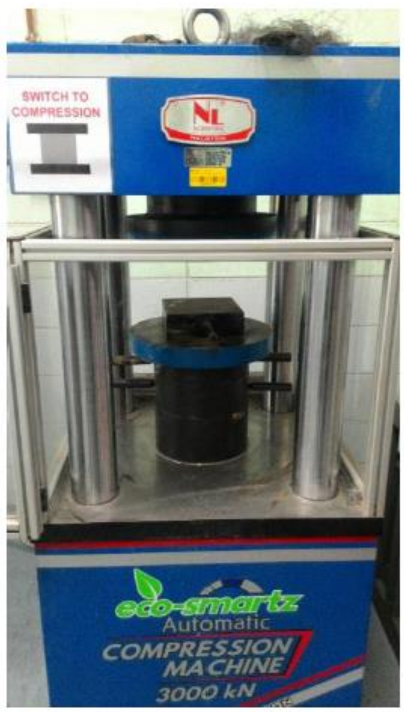

Figure 11: Compressive strength test

Data Analysis

Workability The results obtained from the slump test are presented in Table 4. It can be seen that, the mixes workability are increases as the of oil palm shell content increases.

The workability of both mixes increase with increase in the percentage replacement of course aggregate by Oil Palm Shell. From the result, it can be summarized that the workability is adversely affected by the incorporation of oil palm shell.

Table 4: Result of Slump Test for w/c ratio 0.55

Replacement	Height (cm)	Type of Slump
Control	8.50	True
10%	1.50	Zero
20%	2.00	Zero
30%	12.50	Shear
40%	13.50	Shear

Table 5: Result of Slump Test for w/c ratio 0.60 Replacement Height (cm) Type of Slump Control 14.50 Collapsed

Replacement	Height (cm)	Type of Slump
Control	14.50	Collapsed
10%	13.50	Shear
20%	14.00	Shear
30%	14.60	Collapsed
40%	15.50	Collapsed

Density The densities OPS for w/c ratio 0.55 and 0.60 are presented in Table 6 and Table 7 respectively. The variation of density of concrete with oil palm shell content is shown in Figure 12 and 13. It is seen that in both mixes, the density of concrete reduces as percentage content of oil palm shells increases. The densities of w/c ratio for 0.55 and 0.60 increase with age. The minimum densities occur at complete replacement of 40% OPS as course aggregates in concrete mixture.

Table 6: Density of OPS for w/c ratio 0.55

	Replacement	Weight (kg)	Volume (m3)	Density (kg/m3)
7	Control	2.415	0.001	2415
	10%	2.28	0.001	2280
	20%	2.010	0.001	2010
	30%	1.820	0.001	1820
	40%	1.650	0.001	1650
14	Control	2.480	0.001	2480
	10%	2.278	0.001	2278
	20%	2.043	0.001	2043
	30%	1.820	0.001	1820
	40%	1.628	0.001	1628
28	Control	2.430	0.001	2430
	10%	2.363	0.001	2363
	20%	2.070	0.001	2070
	30%	1.822	0.001	1822
	40%	1.765	0.001	1765

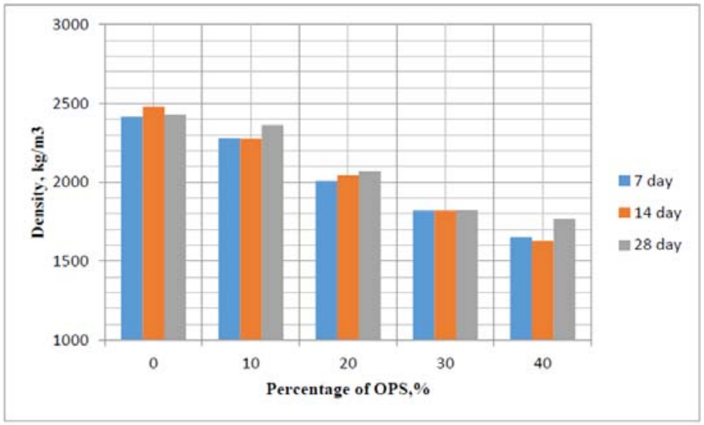

Figure 12: Variation of density with oil palm shell content (w/c ratio 0.55)

Table 7: The density of OPS for w/c ratio 0.60

Day	Replacement	Weight (kg)	Volume (m3)	Density (kg/m3)
7	Control	2.348	0.001	2348
	10%	2.297	0.001	2297
	20%	2.142	0.001	2142
	30%	1.792	0.001	1792
	40%	1.682	0.001	1682
14	Control	2.430	0.001	2430
	10%	2.305	0.001	2305
	20%	2.153	0.001	2153
	30%	1.848	0.001	1848
	40%	1.700	0.001	1700
28	Control	2.487	0.001	2487
	10%	2.317	0.001	2317
	20%	2.155	0.001	2155
	30%	1.843	0.001	1843
	40%	1.732	0.001	1732

The minimum 28-day densities of concrete of w/c ratio 0.55 and 0.60 are 1765 kg/m3 and 1732 kg/m3 respectively. The average densities of w/c ratio 0.55 are lower than 0.60, it is seen that densities decrease with increase in the w/c ratio of concrete mixtures.

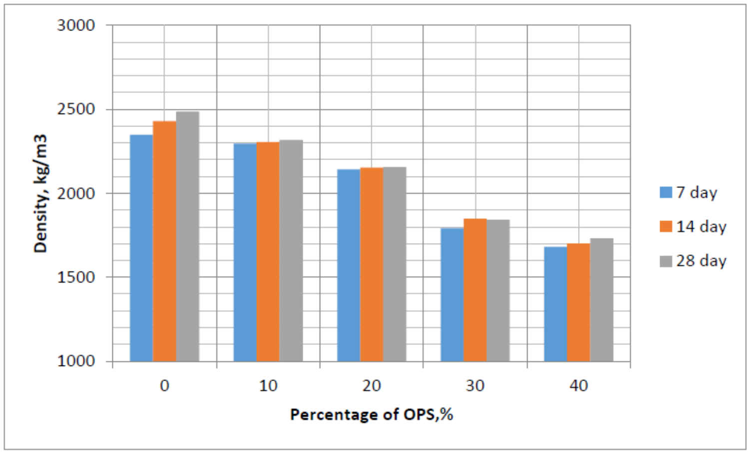

Figure 13: Variation of density with oil palm shell content (w/c ratio 0.60)

Compressive Strength Data obtained from the compressive strength test on cube (100mm) are presented in Table 8 and 9 where the compressive strengths at 0% (control), 10%, 20%, 30% and 40% of oil palm shell. The effects of replacement of course aggregate with oil palm shells on compressive strengths of the specimens are shown in Figure 14 respectively. It is seen that the compressive strength decreases the as oil palm shells content increases. The compressive strength is maximum at 0% replacement by OPS and minimum at 40% replacement.

As oil palm shell content increases due to different of weight between course aggregate and oil palm shell, then the specific area increases, thus requiring more cement paste to bond effectively with the shells. Since the cement content remains the same, the bonding is an inadequate. Strength depends to a large extent on good bonding between the cement paste and the aggregates. The compressive strength reduces as a consequence of the increase in percentage replacement of course aggregates.

Table 8: Compressive strength of OPS for w/c ratio 0.55

Day	Replacement	Strength (MPa)
7	Control	20.40
	10%	19.41
	20%	9.05
	30%	3.50
	40%	2.57
14	Control	26.77
	10%	19.72
	20%	9.62
	30%	4.16
	40%	2.55
28	Control	34.71
	10%	20.29
	20%	9.00
	30%	5.71
	40%	3.38

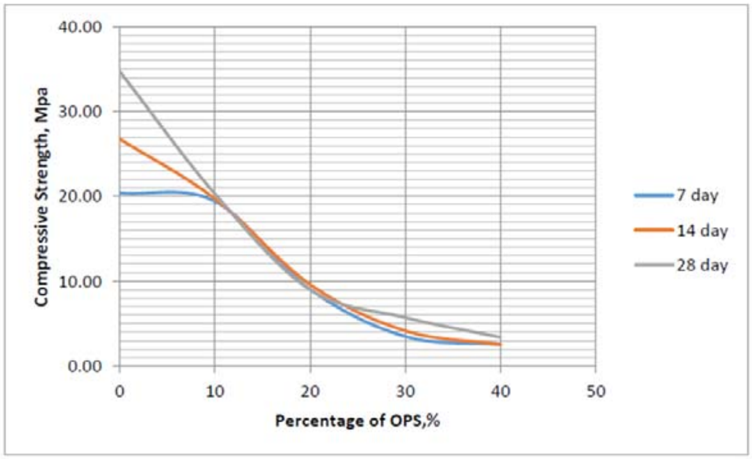

Figure 14: Variation of compressive strength with oil palm shell content (w/c ratio 0.55)

Table 9: Compressive strength of OPS for w/c ratio 0.60

Day	Replacement	Strenght (MPa)
7	Control	13.16
	10%	14.20
	20%	7.89
	30%	1.55
	40%	1.10
14	Control	17.26
	10%	20.08
	20%	12.20
	30%	2.84
	40%	1.79
28	Control	21.12
	10%	14.90
	20%	12.03
	30%	3.71
	40%	2.19

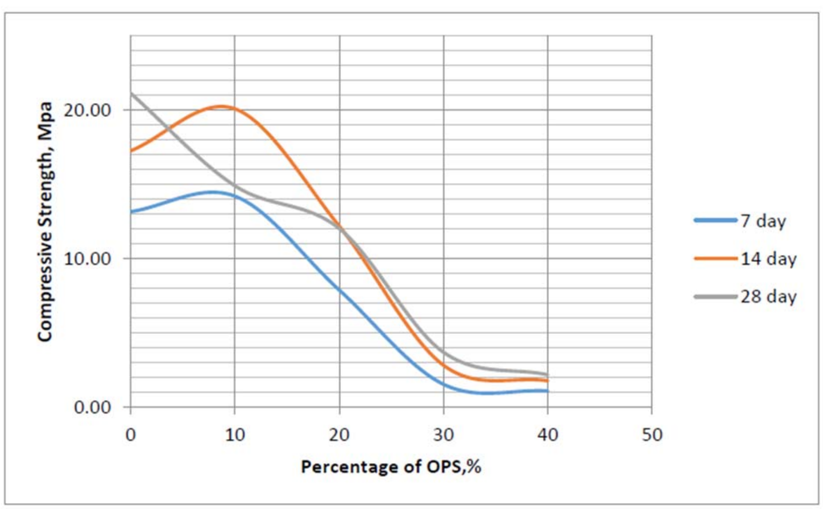

Figure 15: Variation of compressive strength with oil palm shell content (w/c ratio 0.55)

From the result, range for both w/c ratio was 5 to 20.29 Mpa, satisfying the criteria for classification as lightweight concrete. Besides that, reinforced concrete with dense aggregate also suitable for w/c ratio 0.55 with replacement of 10% of OPS about 20.29 Mpa.

Table 10: Recommended grades of concrete (BS 8110, 1997)

Grade	Characteristic strength	Concrete class
7	7.0	Plain concrete
10	10.0	
15	15.0	Reinforced concrete with Lightweight aggregate
20	20.0	Reinforced concrete with dense aggregate
25	25.0	
30	30.0	Concrete with post tensioned tendons
45	40.0	Concrete with pre tensioned
50	50.0	
60	60.0	

The different of compressive strength between w/c ratio 0.55 and 0.6 are not too big. At 28-day maximum compressive strength for w/c ratio 0.55 are 20.29 Mpa of 10% of replacement course aggregate while for w/c ratio 0.6 the maximum strength achieved are 14.90 Mpa. The strength of concrete are decreases when the w/c ratio is increases. The minimum strength for both w/c ratio when course aggregates at replacement of 40% of OPS are 3.38 Mpa (w/c 0.55) and 2.19 (w/c 0.60) as show at Figure 14 and 15.

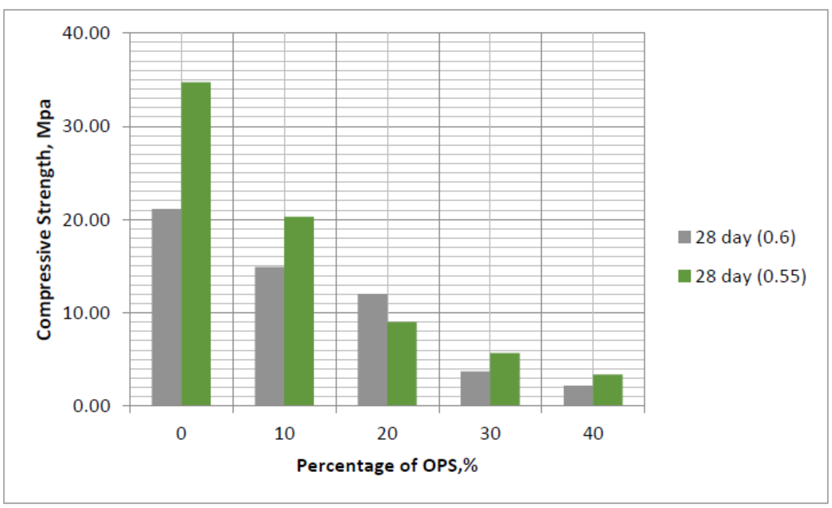

Figure 16: Different compressive strength between w/c ratio 0.55 and 0.60.

Conclusion

Conclusions can be drawn in this study are:

- Slump value is decreased as the percentage of replacement of oil palm shell increased. So decrease in workability.
- The density of concrete decrease as the percentage of replacement of oil palm shell increased and water cement ratio increased.

- The compressive strength is decreased as the percentage of replacement increased, but oil palm shell (w/c 0.55) concrete developed higher compressive strength than oil palm shell with w/c ratio 0.60.
- Decrease of bonding between oil palm shell and cement due to increase the percentage of replacement of oil palm shell in concrete mixtures.
- There exists a high potential for the use of oil palm shells as aggregates in the manufacture of lightly reinforced concrete.

Recommendations for further study are:-

- Further research should be conducted tensile strength test either it suitable for tensile structural.
- The replacement of OPS as course aggregates in concrete mixture are suitable for lightweight concrete such as wall barrier. Then, acoustic performance should be conducted for oil palm shell either it good for noise barrier wall.

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