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Prognostication of Concrete Characteristics with Coconut Shell as Coarse Aggregate Partial Percentile Replacement

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ABSTRACT

In this constructed environment, the rising cost of building construction materials is the issue of great concern. The prices of building materials are rising day by day. The coarse aggregates are the main ingredients of concrete. In this paper, the utilization of coconut shell as a replacement for coarse aggregate has been discussed based on the results obtained from comprehensive experimental results. The construction industry totally relies on cement, sand and aggregates for the production of concrete. Properties of concrete with coconut shells (CS) as aggregate partial percentile replacement were studied. Control concrete with normal aggregate and CS concrete with 10 - 50% coarse aggregate replacement were prepared with constant water – binder ratio of 0.45. For all mixes, workability, density, water absorption, compressive strength flexural strength and tensile strength were determined at 7, 14 and 28 days. The results showed a steady decline in the workability. The density results for concrete cube and beam specimens shows general decrease in physical property due to CS replacement. The water absorption tests showed that the percentage water absorption increases with increase in the percentage replacement level of coarse aggregate with CS. The compressive, flexural and tensile strength of CS concrete were found to be lower than normal concrete
Keywords: Coconut Shell (CS), Partial, Percentile, Aggregates, Water-Binder Ratio, Concrete

I. INTRODUCTION

Infrastructure development across the world created demand for construction materials. Concrete is the premier civil engineering construction material. Concrete manufacturing involve consumption of ingredients like cement, aggregates, water and admixture(s). Among all the ingredients, aggregates form the major part. Two billion tons of aggregate are produced each year in the United States. Production is expected to increase to more than 2.5 billion tons per year by the year 2020 [1]. Similarly, the consumption of the primary aggregate was 110 million tonnes in the UK in year 1960 [2] and reached nearly 275 million tonnes by 2006 [3]. Utilization of natural aggregate in such a rate leads to a question about the preservation of natural aggregates sources. In addition, operations associated with aggregate extraction and processing are the principal causes of environmental concerns [4]. In light of this, in the contemporary civil engineering construction, using alternative materials in place of natural aggregate in concrete production makes concrete as sustainable and environmentally friendly construction material.

Diverse alternative waste materials and industrial by products such as fly ash, bottom ash, recycled aggregates, foundry sand, china clay sand, crumb rubber, glass were replaced with natural aggregate and were investigated for the properties of concretes [5-10]. Apart from above mentioned waste materials and industrial by products, few studies identified that coconut shells, the agricultural by product can also be used as aggregate in concrete [11,12].

The use of coconut shell as coarse aggregate in concrete has never been a usual practice among the average citizens, particularly in areas where light weight concrete is required for non-load bearing walls, non-structural floors, and strip footings. It is evident that the coarse aggregate usually take about 50% of the overall self weight of concrete. The cost of materials for construction is increasing every day because of intense demand, scarcity of raw materials, and paying high bills for energy. From the viewpoint of energy saving and conservation of natural resources, the exploitation of alternative construction materials is now a global concern.

II. METHODS AND MATERIAL

Experimental Procedure

2.1 Material Used

Concrete specimens

The cube size of 150x150x150mm will be used to conduct the compressive strength test. On the other hand, a beam of 330x100x100mm will be used to conduct the flexural strength test. A sample of specimen which contains 0% Coconut shell is also used as control sample. A total of 108 specimens will be prepared.

Cement

Ordinary Portland Cement (OPC) from a single source will be used throughout. Portland cement can be defined as hydraulic cement that hardens by the interaction between its properties and that of water which forms a water resisting compound when it receives its final set.

Coarse aggregate

Aggregate has a significant influence on the compressive strength of concrete, crushed coarse aggregate produces a concrete with higher strength than one with uncrushed coarse aggregate (smooth and rounded aggregate). Crushed gravel of 10mm size will be used as coarse aggregate with a density, relative density and absorption value of 2375kg/m^3, 2.7 and 0.5% respectively.

Fine aggregate

Fine aggregate refers to aggregate particles lower than 4.75mm but larger 75mm. Fine aggregate act as filler in concrete, fine aggregate is usually known as sand and it most complies with coarse, medium or fine grading requirement. The fine aggregate will be air dried to obtain saturated surface dry condition to avoid compromising water cement ratio. In this research, river sand is used and sieve analysis will is conducted to prior to obtain fine aggregate passing through 600 µm sieve.

Water

The chemical reaction between water and cement is very significant to achieve a cementing property. Hydration is the chemical reaction between the compounds of cement and water yield products that achieve the cementing property after hardening. Therefore it is necessary to that the water used is not polluted or contain any substance that may affect the reaction between the two components, so tap water will be used in this study.

Coconut Shell (CS)

For the purpose of this research, the Coconut shells were obtained from a local coconut field located in Seremban, Malaysia. They were sun dried for 1 month before being crushed manually. The crushed materials were later being transported to the laboratory where they are washed and allowed to dry under ambient temperature for another 1 month. The particle sizes of the coconut shell range from 10 to 14 mm.

2.2 Mixed Design

Almost all the available mix design methods are based on experimental relationships, charts and graphs developed from a wide experimental investigation. Basically, they understand the same assumptions communicated in the previous section and only minor differences exist in different mix design methods in the process of selecting the mix proportions. The conditions of concrete mix design are generally influenced by the usual experience with regards to the structural design conditions, durability and placing conditions.

The mix design method in this research is comprehended based on the Department of Environmental (DOE) United Kingdom. Selecting the best proportions of cement, fine and coarse aggregate and water to produce concrete having specified properties is a primary problem in designing concrete mix. Hence, the design mix is very essential in achieving the design characteristic strength. Table 1 shows the mix proportions and Figure 1, shows the process of DOE mix design method.

Table 1: Mix Proportions

Quantity	Cement (kg/m^3)	Water (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Coconut shell (kg)
Per m^3	511.11	230	653.7	980.34	-
Control 0.00338m^3	1.73	0.78	2.21	3.31	-
10% CCS	1.73	0.78	2.21	2.98	0.331
20%CCS	1.73	0.78	2.21	2.65	0.662
30%CCS	1.73	0.78	2.21	2.32	0.993
40%CCS	1.73	0.78	2.21	1.99	1.324
50%CCS	1.73	0.78	2.21	1.655	1.655

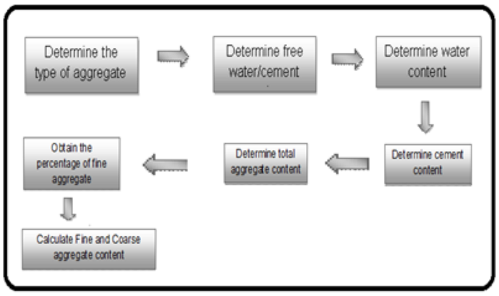

Figure 1: Processes for DOE method

III. RESULTS AND DISCUSSION

3.1 Slump Test

Fresh concrete is define as workable when the concrete can be transported, placed, compacted and finished easily and without segregation, slump tests were conducted for concrete with granite aggregate and 10%, 20%, 30%, 40% and 50% coconut shell aggregate replaced in granite-concrete to determine the comparable workability. In this study, 3 batches of all concrete types were tested on the workability before the fresh concrete specimens were casted in the moulds. Table 2 presents the test results for the average slump of control granite-concrete and all coconut shell concrete.

Table 2: Slump test

Concrete Class	Composition with CCS replacement	Batch N0	Slump (mm)	Average slump (mm)
1	0%	A	67	66
		B	65	
		C	66	
2	10%	A	52	52
		B	53	
		C	52	
3	20%	A	48	47
		B	46	
		C	47	
4	30%	A	41	40
		B	39	
		C	40	
5	40%	A	35	36
		B	37	
		C	36	
6	50%	A	29	29
		B	28	
		C	30	

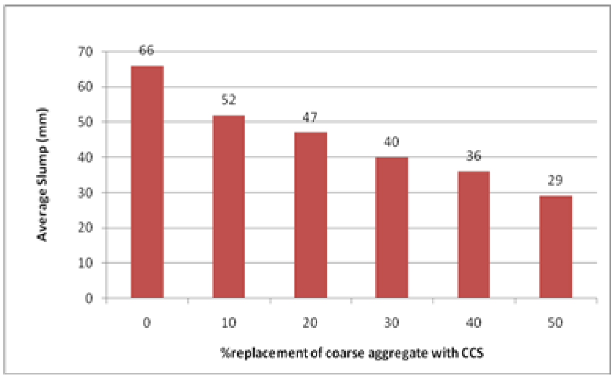

Figure 2: Results of Slump Test

Figure 2 shows average results for coconut shell concrete percentage from the slump test, the design slump was 30 to 60mm. in this investigation, the results shows that as the percentage of the shell increases the workability of the concrete reduces, this may be due to the water absorption capacity of coconut shell. Although, the decrease in slump with coconut shell replacement did not exceed the acceptable designed slump. This is consistent with results reported by Olanipekun et al., (2006).

3.2 Compaction Factor Test

The compacting factor is proposed in BS 1881: Part 103: 1993 and ACI 211. 3-75 (Revised 1987). The compacting factor test results are shown in table 3 below.

Table 3 Compacting Factor test results

%Replacement with CCS	Compacting Factor
0%	0.95
10%	0.92
20%	0.872
30%	0.869
40%	0.791
50%	0.78

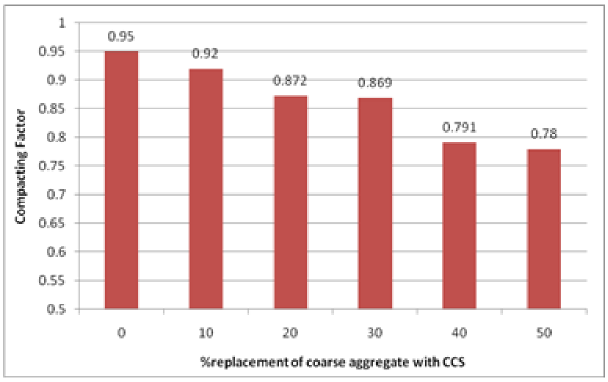

Figure 3: Compacting factor test results

3.3 Density Test

The density test was performed on cubes and rectangular beam specimens at 28 curing days of curing. The measured mass of moist concrete types showed variation of mass in respect with CS percentages replacement in granite-concrete. However, the moist concretes were dried in the oven and re-weighed. In this study, one sample of concrete type was used to calculate the densities of each specimen. The density results for cube and beam specimens are shown in the table 4 below respectively.

Table 4: Density result for concrete cubes & beams

Density result for concrete cubes

CCS	Weight	Volume	Density	AVR-Density
(%)	(kg)	(m^3)	(kg/m^3)	(kg/m^3)
0	8.60	0.0034	2550	2550
	8.70		2580	
	8.55		2533	
10	7.75	0.0034	2300	2250
	7.3		2200	
	7.55		2240	
20	6.80	0.0034	2000	2000.2
	6.75		2014.7	
	6.85		1985.3	
30	6.43	0.0034	1891.2	1857
	6.13		1802.9	
	6.10		1823.5	
40	5.50	0.0034	1671.6	1602.9
	5.31		1561.8	
	5.54		1629.4	
50	4.80	0.0034	1411.8	1445.1
	4.92		1447.1	
	5.02		1476.5	

Density result for concrete beams

CCS	Weight	Volume	Density	AVR-Density
(%)	(kg)	(m^3)	(kg/m^3)	(kg/m^3)
0	7.2	0.004	1800	1811.7
	7.33		1832.5	
	7.21		1802.5	
10	6.9	0.004	1725	1734.2
	7.06		1765	
	6.85		1712.5	
20	6.76	0.004	1690	1680.8
	6.68		1670	
	6.73		1682.5	
30	6.5	0.004	1625	1602.5
	6.32		1580	
	6.41		1602.5	
40	7	0.004	1530	1530
	6.03		1507.5	
	6.21		1552.5	
50	5.8	0.004	1450	1465.8
	5.77		1442.5	
	6.02		1505	

Table 4, shows the average densities for the 28 days-cured specimens prepared for cubes and beams for compressive strength and flexural strength testing. From the table it can be seen that density reduces by the addition of CS aggregates. The minimum densities are found in the 40% and 50% of CS replacement. It is evident that all values falls well within the range of lightweight concrete.

3.4 Water Absorption Test

The cubic samples were tested for water absorption capacity at 28 days of curing. In the first place, the dry masses of concrete samples were saturated in the water basin for the period of 28 days specified in the methodology. After, the saturated concrete samples were again reweighed. Subsequently, the saturated mass was subtracted from dry mass of samples to determine the mass of water absorption and thus, percentage of water absorption relative to dry mass. Table 5 shows the percentages of water absorption by sample of cubic specimen.

Table 5: Water absorption test results on cube concrete samples

Concrete	Composition with	Dry mass	Saturated mass	Mass of Absorbed	% of absorbed water
Class	CCS percentage	of sample (g)	of sample (g)	water (g)	relative to dry mass
A	0%	6460	6530	70	1%
B	10%	6460	6620	160	3%
C	20%	4670	4950	280	6%
D	30%	4420	4780	360	8%
E	40%	4180	4680	500	12%
F	50%	5250	6150	900	17%

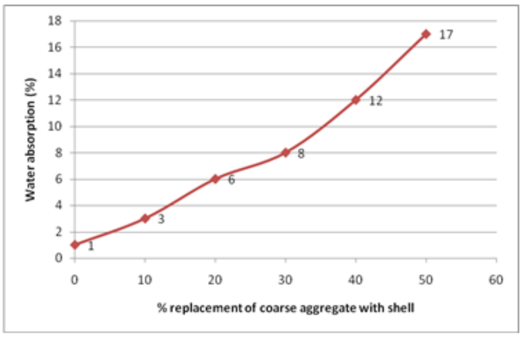

Figure 4: Water absorption amount with CS replacement

Figure 4 shows the water absorption amount for different percentage of CS replacement. The water absorption tests showed that the percentage water absorption increases with increase in the percentage replacement level of coarse aggregate with CS. 50% of CS replacement shows the highest water absorption followed by 40%, 30%, 20% and lastly 10% of CS. This is because the higher percentage of CS applied in each mixture increases the total voids in the concrete mix. This will result to higher water absorption capacity since samples are capable of absorbing more water when more voids are distributed. According to figure 4, 50% of CS exhibit 17% of water absorption while 40%, 30%, 20%, 10% and 0% gives the amount of 12%, 8%, 6%, 3% and 1% of water absorption respectively.

3.5 Compressive Strength

The most valuable property in concrete is the concrete compressive strength because it gives the overall definition of the quality concrete strength that relates to the hydrated cement paste. Basically, the specimens were being tests for three selected curing periods namely: 7, 14, 28 days, detail test results are shown in table 6.

Table 6: Compressive strength of concrete specimens at 7, 14, and 28 days of curing

Concrete Class	Composition with CS replacement	Average compressive strength (MPa)		
		7days	14days	28days
A	0%	24.15	30	39
B	10%	21	25.2	33
C	20%	18.22	22.5	28.22
D	30%	15.20	19	24.52
E	40%	13.18	17.03	21
F	50%	11.4	15	18.4

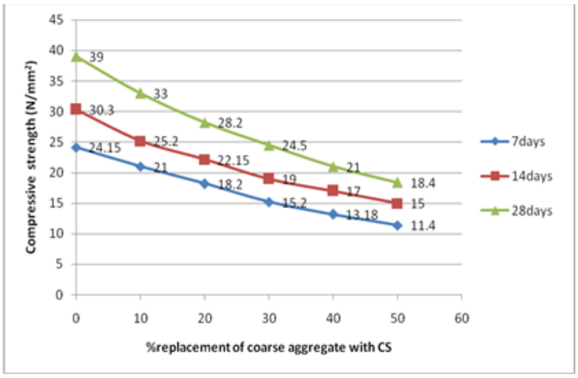

Figure 5: Compressive strength of CS concrete

The average test results of the compressive strength in their specified curing periods of 7, 14 and 28 days and percentage replacement of CS were summarized as shown in Table 6. Similarly, the results were also presented in graphical form in Figure 5. The results showed that the compressive strength of the concrete decreased as the percentage of the shells increased in the mix ratio (Figure 5). It was observed that the concrete compressive strength of the cube specimens increases with increasing age. The results further showed that grades 20 and 15 lightweight concretes can be obtained if the percentage replacement levels of the conventional coarse aggregate with CS do not exceed and 50%.

3.6 Flexural Strength

Flexural strength can be described as the capacity of a beam or even a slab of concrete to resist failure due to bending. This flexural strength is also known as Modulus of Rupture. The effect of concrete with various percentage of coconut shell (CS) on flexural strength is shown on table 7. The flexural strength was tested on 7, 14 and 28 days of curing. The results showed that the flexural strength of the concrete decreased as the percentage of the CS increased in the mix ratio. It was observed that the concrete flexural strength of the beam specimens increases with increasing age.

Table 7: Flexural strength of concrete specimens at 7, 14, and 28 days of curing

Concrete Class	Composition with CCS replacement	Average flexural strength (N/mm^2)		
		7days	14days	28days
A	0%	6.23	7.12	8.19
B	10%	6.11	7.03	7.89
C	20%	5.86	6.75	7.66
D	30%	5.68	6.63	7.46
E	40%	5.60	6.45	7.30
F	50%	5.46	6.20	7.14

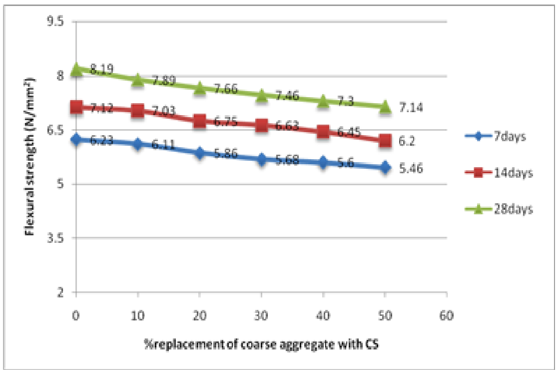

Figure 6: Flexural strengths of CS concrete

Figure 6, shows a graphical representation of reduction in flexural strength for different CS percentage. The results showed that the flexural strength of the concrete decreased as the percentage of the CS increased in the mix ratio. It was observed that the concrete flexural strength of the beam specimens increases with increasing age.

3.6 Tensile Strength

The split tensile strength of the concrete specimens was determined at 7, 14 and 28 days following BS EN 12390 part 6 2009.

Table 8: Tensile strength of concrete specimens at 7, 14, and 28 days of curing

Concrete Class	Composition with CCS replacement	Average tensile strength (N/mm^2)		
		7 days	14 days	28 days
A	0%	2.24	3.05	3.98
B	10%	2.22	2.55	3.35
C	20%	2.04	2.24	2.8
D	30%	1.73	1.96	2.45
E	40%	1.42	1.73	2.15
F	50%	1.22	1.54	1.86

The average test results of the split tensile strength in their specified curing periods of 7, 14 and 28 days and percentage replacement of CS were summarized as shown in Table 8.

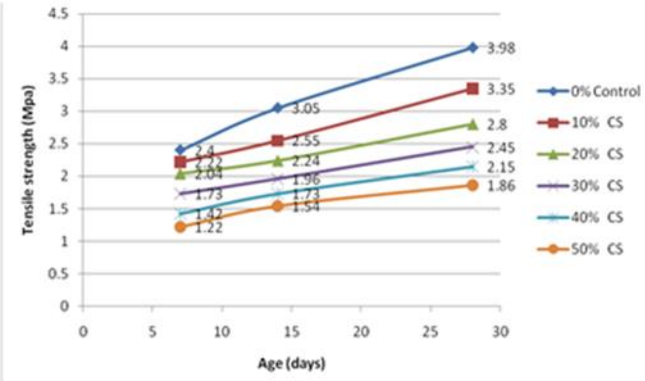

Figure 7: Tensile strengths variation with different percentages of CS

Similarly, the results were also presented in graphical form shown in Figure 7. The results showed that the tensile strength of the concrete decreased as the percentage of the CS increased in the mixes. It was observed that the concrete tensile strength of the cylindrical specimens increases with increasing age.

IV. CONCLUSION

Extensive research was carried out on control concrete with normal aggregate and CS partial percentile replacement on aggregate for concrete with 10 - 50% coarse aggregate replacement were prepared with constant water – binder ratio of 0.45. For all mixes, workability, density, water absorption, compressive strength flexural strength and tensile strength were determined at 7, 14 and 28 days. The following conclusions can be derived from the present investigation:

The results showed a steady decline in the workability. The 0.45, water cement ratio which was kept constant all through the mix made the workability lower. The workability actually reduces as there is an increase in the amount of CS added to the mix. Due to the absence of super plasticizers the workability of the concrete was on the lower side.

The density results for concrete cube and beam specimens shows general decrease in physical property due to CS replacement. Though, the reduction was not equal for cube and beam samples for same percentage of CS replacement of coconut shell in concrete.

The water absorption tests showed that the percentage water absorption increases with increase in the percentage replacement level of coarse aggregate with CS. 50% of CS replacement shows the highest water absorption followed by 40%, 30%, 20% and lastly 10% of CS.

The compressive strengths of CS concrete were found to be lower than normal concrete by 5–55% after 7 days, 9-50% after 14 days and by 12–52% after 28 days, depending on the curing environment. Their values were within the normal range for structural lightweight concrete

Flexural strength of concrete specimens decreases with increase in the percentage replacements of coarse aggregate with CS for all curing days. 10% CS level was identified as the optimum replacement percentage because its exhibits the highest flexural strength

The tensile test results show less performance in tensile strength with CS proportional replacements in concrete. For the extent of strength achieved proved that normal concrete were much better than the CS concrete. Here, the decrease in tensile strength is directly proportional to the percentage replacement of granite with CS.

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