

Strength Properties of Hydraulic Cement Concrete Pavement Incorporating Coconut Shell as Coarse Aggregate

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Coconut shell being a hard and not easily degradable material if crushed to size of coarse aggregate can be a potential material to replace coarse aggregate in concrete. In this study the characteristics of the coarse aggregate and the coconut shell were evaluated. Properties of fresh and hardened concrete with partial replacement of coarse aggregate with coconut shell were also studied. Concrete specimens with 0%, 5%, 10%, 15% and 20% by weight of coarse aggregate replacement with coconut shell were made at 1:2:4 mix ratio. The compressive strength for all the concrete specimens was evaluated at 7, 14, 21 and 28 days and constant water cement ratio of 0.5 was maintained for all the concrete specimens. The aggregate crushing value of the coarse aggregate and the coconut shell were 23.47% and 28.25% respectively and the aggregate impact value of the coarse aggregate and the coconut shell were 17.44% and 20.2% respectively. The slump values, densities and compressive strength of concrete decreased as the percentage replacement with coconut shell increased. Concrete produced with 0%, 5%, 10%, 15% and 20% replacement attained 28 days compressive strength of 38.17, 35.11, 32.14, 31.18, and 29.14 N/mm² respectively. The results obtained in this study showed that coconut shell satisfied the requirements for coarse aggregate and can be used as partial replacement of coarse aggregate (up to 20%) in concrete pavement production.

KEYWORDS: Coarse aggregate, Coconut shell, Concrete pavement, cement, Strength properties.

There are many research works conducted to improve the engineering properties of concrete by partial or full replacement of coarse aggregate, fine aggregate or cement paste (ACI 318/318R-08, 2009, Gunasekaran et al, 2011, and Olanipekun, 2006). Cement mortar and concrete are the most widely used construction material. It is difficult to point out another material of construction which is versatile as concrete. It is the material of choice where strength, permanence, durability, impermeability, fire resistance and abrasion resistance are required. It is also closely associated with every human activity that it touches every human being in his day to day living (Shetty, 2013).

Infrastructure development across the world created demand for construction materials. Concrete manufacturing involve consumption of ingredients like cement, aggregates, water and admixtures (Amarnath, and Ramachandrudu, 2012, Parag, and Sandhya, 2014, and Shetty, 2013). Among all

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Introduction



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the ingredients, aggregates form the major part (Amarnath, and Ramachandrudu, 2012). It is incredibly versatile and is used in almost all major construction projects (Amarnath, and Ramachandrudu, 2012, Parag, and Sandhya, 2014, and Shetty, 2013). Aggregates typically consist of 60% - 70% of the volume of a concrete mixture (Shetty, 2013). Use of natural aggregates in such a rate leads to question about the preservation of natural aggregates sources (Amarnath, and Ramachandrudu, 2012). In addition, operations associated with aggregate extraction and processing are the principal cause of environmental concerns (Osei, 2013, and Shetty, 2013). The negative consequences of increasing demand of aggregates include depletion of aggregate deposits, environmental degradation and ecological imbalance (Osei 2013). The possibility of a complete depletion of aggregate resources has rendered continued use of aggregates in construction works unsustainable (Naik, 2008).

Research addressing environmental and sustainability issues in construction has generated lots of interest in the world (Akshay, et al 2014, Gunasekaran, et al 2011, and Olanipekun, et al 2006). The use of waste materials saves natural resources and dumping spaces, and helps to maintain a clean environment, (Parag, and Sandhya, 2014).

Coconut shell being a hard and not easily degradable material if crushed to size of coarse aggregate can be a potential material to substitute coarse aggregate in concrete (Akshay et al, 2014, Gunasekaran, et al 2011, and Olanipekun, et al 2006). According to Olanipekun, et al (2006) and Gunasekaran, et al (2011), limited research has been conducted on mechanical properties of concrete with coconut shell as aggregate replacement. Coconut shells are agricultural waste produced as by products of coconut oil production (Osei, 2013). The potential of using agricultural wastes in civil engineering works have been investigated by various researchers. In a study, Olanipekun et al, (2006) compared concrete made with coconut shells and palm kernel shells as replacement for natural coarse aggregates and concluded that coconut shells performed better than palm kernel shells as replacement for conventional aggregates in concrete pavement. In an experimental assessment on coconut shell as aggregate in concrete, Osei, (2013) concluded that 18.5% replacement by volume of crushed granite with coconut shell can be used to produce structural concrete in line with BS 8110.

The coconut shell aggregate has higher water absorption because of higher porosity in its shell structure (Gunasekaran et al, 2011, Kakade, and Dhawale, 2015, and Olanipekun et al, 2006). The aggregate impact value of coconut shell aggregate is much lower compared to crushed aggregate which indicates that this aggregate have good absorbance to shock (Kakade, and Dhawale, 2015). In a study Parag, and Sandhya, (2014) concluded that the coconut shell has potential as light weight aggregate in concrete and using the coconut shell as aggregate in concrete can reduce the material cost in construction because of the low cost of abundant agricultural waste. They suggested that Coconut shell concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional crushed aggregates are costly. In a study Akshay et al, (2014) concluded that coconut shell aggregate concrete satisfied the requirements of ASTM C330/C330M-14 (2014). They have it that to increase the speed of construction, enhance green construction environment, we can use lightweight concrete. The possibility exists for the partial replacement of coarse aggregate with coconut shell to produce light weight concrete.

This research work is aimed at assessing the strength properties of hydraulic cement concrete pavement incorporating coconut shell as coarse aggregate. The major objectives of this work are: to examine the properties of concrete pavement produced by partial replacement of coarse aggregate (crushed granites) with coconut shell at different percentages and to enlighten the relevant agencies, professional bodies, consultancy and construction firms on the potential use of coconut shell in concrete production.

Cement

The hydraulic cement used in this study conform with the specifications of ASTM C150/ C150-16 e1 (2016) ASTM C1157/C1157M-11 and AASHTO M85 (2016).

Aggregates

Aggregates were selected in accordance with AASHTO (2013, 2015), ASTM 127-15 (2015), ASTM D448 (2012), ASTM C33/C33M (2013), ASTM C29/C29M (2016), ASTM C330/C330M-14 (2014), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013). Crushed granites passing through sieve 25mm but retained in sieves 19 mm, 12.5mm, 10mm and 4.75mm was used as coarse aggregate. Coconut shell was obtained locally and crushed into smaller sizes passing through sieve 25mm but retained on sieve 19 mm, 12.5mm, 10mm and 4.75mm. The coconut shell aggregate were air dried for 21 days. Fibre and husk on dried shells were carefully removed.

Mix Design

Table 1 shows the design mix used for this study. The concrete specimens were prepared at the mix ratio of 1:2:4 by weight and marked as shown in Table 1. The control mix (G1) with 0% coconut shell was prepared. Subsequently samples G2, G3, G4 and G5 were prepared with 5%, 10%, 15% and 20% replacement by weight of coarse aggregates with coconut shell.

Concrete specimen mark	Percentage replacement with coconut shell (%)	Cement content (kg/m ³)	fine aggregate content (kg/m ³)	Coarse aggregate content		Water cement ratio (%)
				Crushed granite (kg/m ³)	Coconut shell (kg/m ³)	
G1	0	357	714	1428	0	0.5
G2	5	357	714	1356.6	71.4	0.5
G3	10	357	714	1285.2	142.8	0.5
G4	15	357	714	1213.8	214.2	0.5
G5	20	357	714	1142.4	285.6	0.5

Table 1

Design mix for the concrete specimens

Sieve Analysis

Combined sieve analysis was conducted for fine aggregate, coarse aggregate and coconut shell in accordance with AASHTO (2013, 2015), ASTM C136/C136M-14 (2014), ASTM D6913-04 (2009), ASTM D448 (2012), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013). The sieve analysis involves the passing of original samples through a stack of sieves arranged in descending order of the openings of the sieves, with larger sieves on the top. The materials retained on each sieve after shaking, represents the fraction of the aggregates coarser than the sieve in question and finer than the sieve above.

Aggregate Impact Value (AIV) Test

The aggregate impact value test gives relative measure of the resistance of an aggregate to sudden shock or impact (Udoeyo, and Dashibil, 2002). The aggregate impact value (AIV) was conducted for the coarse aggregate and the coconut shell in accordance with AASHTO (2013, 2015), ASTM D5874-02 (2007), ASTM C131/C131M-14 (2006), WSDOT M46-01.15 (2013), and WSDOT M46-01.24 (2016).

Aggregate Crushing Value (ACV) Test

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load (Shetty 2013). The aggregate crushing value test

was conducted for both coarse aggregate and coconut shell in accordance with ASTM D5874 – 02 (2007), ASTM C131/C131M -14 (2006), ASTM C192/ 192M -15 (2015), and WSDOT M46-01.24 (2016).

Slump Test

According to AASHTO (2013), AASHTO (2015), BSEN 12350-02 (2009), BSEN 206-1(2006)], the slump test is a measure of the consistency of the concrete and a change in the slump test indicates that something in the manufacturing of the concrete has changed. Slump test was conducted on the fresh concrete in accordance with [AASHTO (2013, 2015), ASTM C143/C143M -15 (2015), ASTM C1611 (2015), WSDOT M46-01.15 (2013), and WSDOT M46-01.24 (2016)].

Compressive Strength Test

Compressive strength test was performed on the hardened concrete in accordance with AASHTO (2013, 2015), ACI 318/318R, ASTM C495/C495M (2012), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013). The test specimens were of the size 150 mm x 150 mm x 150 mm. The filling of the moulds was in three layers of 50mm each. The concrete cubes were compacted manually using 16mm diameter rod at 40 evenly distributed strokes per layer. The samples were marked and cured in clean fresh tap water and were maintained at a room temperature. Three specimens from each of the five different mixes were crushed at 7, 14, 21 and 28 days age respectively and the average compressive strength were recorded.

Results and discussion

Table 2

Combined aggregate gradation (fine aggregate, coarse aggregate and coconut shell)

Sieve size (mm)	Percentage retained (%)	Cumulative percentage Retained (%)	Percentage passing /finer (%)
25	0.00	0.00	100.00
19	4.18	4.18	95.82
12.5	17.84	22.02	77.98
9.5	15.11	37.13	62.87
4.75	12.81	49.94	50.06
2.36	8.88	58.82	41.18
1.18	9.78	68.60	31.40
0.6	1.16	80.76	19.24
0.3	7.48	88.24	11.76
0.15	5.20	93.44	6.56
0.075	4.26	97.70	2.30

Table 3

Physical and mechanical properties of fine aggregate, coarse aggregate and coconut shell

Properties	Fine aggregate	Coarse aggregate	Coconut shell
Specific gravity	2.6	2.70	1.63
Water absorption (%)	1.11	2.1	4.48
Aggregate crushing value (%)	-	23.47	28.25
Aggregate impact value (%)	-	17.44	20.20

Aggregates characteristics

The results of the combined gradation of coarse aggregate, coconut shell, and fine aggregate are shown in **Table 2**. The results of the physical and mechanical properties of the coarse aggregate, fine aggregate and coconut shell are shown in **Table 3**. These properties conform to the requirements of coarse aggregate for concrete pavement in accordance with ASTM D5874 – 02 (2007), ASTM C131/C131M -14 (2006), ASTM 127 -15 (2015), ASTM D448 (2012), ASTM C33/C33M (2013), ASTM C330/C330M-14 (2014).

Properties of concrete incorporating coconut shell

Table 4, shows the slump, density and compressive strength values of concrete at different percentage replacement of coarse aggregate with coconut shell. The slump decreased with increase in coconut shell percentage. The control mix with 0% coconut shell showed higher compressive strength. Furthermore, the compressive strength decreased with coconut shell percentage increase. Fig. 1 shows the relationship between 28 day and 56 day compressive strength with percentage replacement of coarse aggregate with coconut shell. Fig. 2 shows the relationship

Specimen mark	Percentage replacement of coarse aggregate with coconut shell (%)	Slump (mm)	Density (kg/m ³)	Average compressive strength (N/mm ²)				
				7 day	14 day	21 day	28 day	56 day
M1	0	83	2490	26.84	31.87	35.11	38.17	42.22
M2	5	77	2467	23.67	28.01	33.08	35.11	41.54
M3	10	63	2348	21.01	25.04	29.78	32.14	38.65
M4	15	60	2380	19.18	23.66	25.11	31.18	35.23
M5	20	57	2336	17.11	21.17	23.18	29.14	33.06

Table 4

Properties of concrete incorporating coconut shell as partial replacement of coarse aggregate

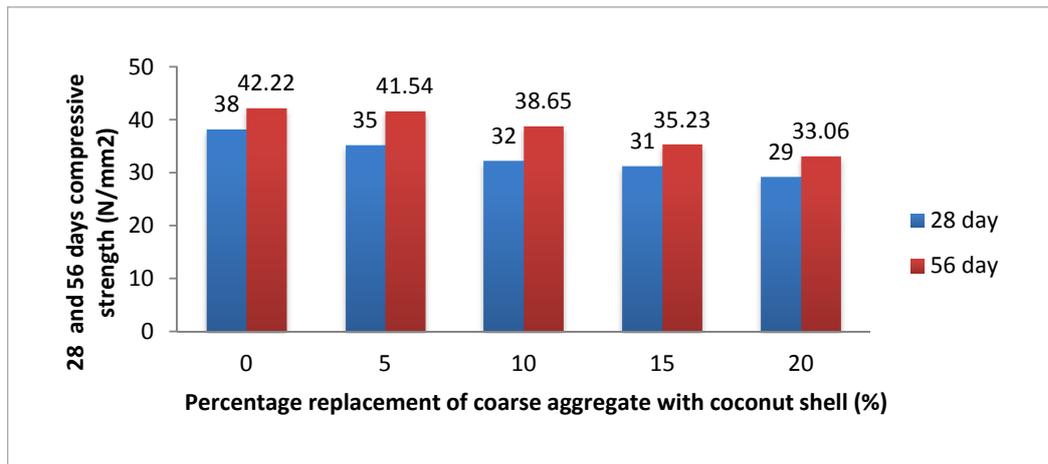


Fig. 1

Relationship between 28 day and 56 day compressive strength and percentage replacement with coconut shell

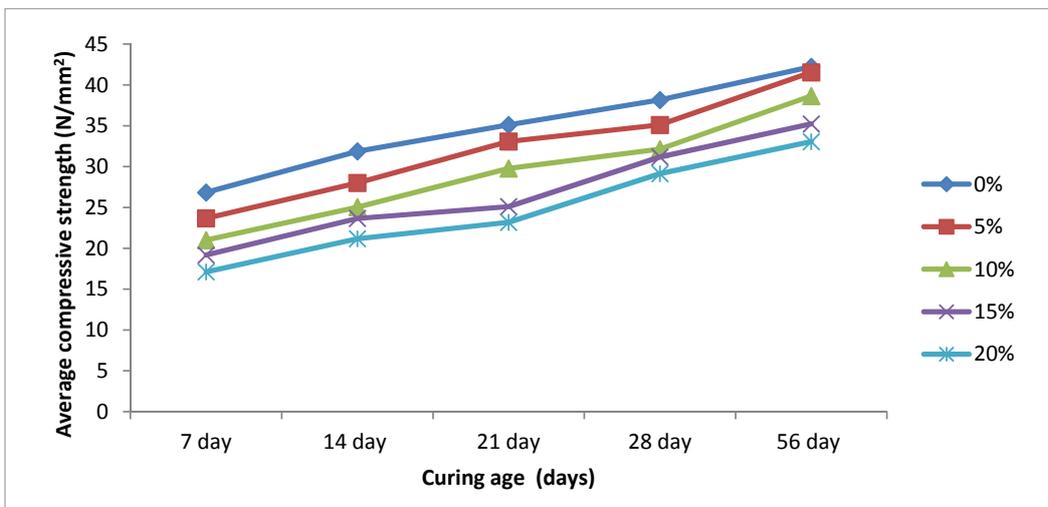


Fig. 2

Relationship between the average compressive strength with curing age

between compressive strength and age of the concrete specimens. There were good relationships between these variables. The results conformed to the specifications of AASHTO (2013, 2015), ACI 318/318R, ASTM C495/C495M (2012), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013).

Conclusion and recommendations

Based on the results and discussions presented in this research, the following conclusions were drawn;

- 1 The use of coconut shell in concrete pavement production will contribute to resource conservation of natural aggregate, environmental protection and reduction in the cost of construction since this agricultural waste can be obtained at little or no cost.
- 2 Coconut shell characteristics satisfied the requirement for concrete coarse aggregate and can be used as partial replacement of coarse aggregate in concrete production in accordance with ASTM D5874-02 (2007), ASTM C131/C131M -14 (2006), ASTM 127-15 (2015), ASTM D448 (2012), ASTM C33/C33M (2013), ASTM C330/C330M -14 (2014), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013).
- 3 The properties of concrete incorporating up to 20% coconut shell aggregate satisfied the minimum requirement of 28 N/mm² for 28 days compressive strength for standard concrete pavement as specified by ASTM D5874-02 (2007), ASTM C131/C131M -14 (2006), ASTM 127-15 (2015), ASTM D448 (2012), ASTM C33/C33M (2013), ASTM C330/C330M -14 (2014), WSDOT M46-01.15 (2013), WSDOT M46-01.24 (2016), and WSDOT M41-10 (2013).
- 4 Percentage increase in coconut shell replacement reduces the compressive strength, density and slump values of concrete.
- 5 Developing counties should encourage the use concrete pavement and structural concrete incorporating coconut shell up to 15% by weight of coarse aggregate as a construction cost reduction measure and an environmental friendly Construction.
- 6 Performance of coconut shell concrete in heavy traffic pavements should be carried out by future researchers.
- 7 Standard concrete pavement produced at 1: 2: 4 mix ratios satisfied the minimum cementitious content of 215 kg/m³ which is a function of durability as specified in PCA IS415.

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