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Experimental assessment on coconut shells as aggregate in concrete

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ABSTRACT: *The rising cost of construction materials in developing countries has necessitated research into the use of alternative materials civil engineering construction. In this study, a concrete mix of 1:2:4 was used as control, while coconut shells were used to replace crushed granite by volume. Seventy two cubes were produced and the densities and compressive strengths were evaluated at 7 days, 14 days, 21 days and 28 days. The density and compressive strength of concrete reduced as the percentage replacement increased. Concrete produced by 20%, 30%, 40% and 50% and 100% replacement attained 28-day compressive strengths of 19.7 Nmm^{-2}, 18.68 Nmm^{-2}, 17.57 Nmm^{-2}, 16.65 Nmm^{-2} and 9.29 Nmm^{-2}; corresponding to 94%, 89%,, 85%,79.6% and 44.4% of the compressive strength of the control concrete. The results of the study showed that concrete produced by replacing 18.5% of the crushed granite by coconut shells can be used in reinforced concrete construction. A potential exists for the use of coconut shells as replacement of conventional aggregate in both conventional reinforced concrete and lightweight reinforced concrete construction. The use of coconut shells as partial replacement for conventional aggregates should be encouraged as an environmental protection and construction cost reduction measure.*

Keywords: *concrete, coconut shells, compressive strength, coconut shell concrete*

I. INTRODUCTION

Concrete is the world's most used construction material. The consumption of concrete has been increasing at a higher rate due to the demand placed by the development of infrastructure in both developing and developed countries [1]. The negative consequences of increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance [2]. The possibility of a complete depletion of aggregate resources has rendered continued use of aggregates for construction unsustainable [3]. In view of this challenge, researchers throughout the world have been investigating ways of replacing aggregates to make construction sustainable and less expensive. Research addressing environmental and sustainability issues in construction has generated lot of interest in the world [4].

While wastes generated by industrial and agricultural processes have created disposal and management problems which pose serious challenges to efforts towards environmental conservation, their use contributes to resource conservation, environmental protection and the reduction of construction costs [5], since waste materials can be obtained at little or no cost, while making significant contribution to the conservation of natural resources and maintenance of ecological balance.

The potential of using agricultural wastes in civil engineering and building construction works have been investigated by various researchers [6], [7], [8] and [9]. In a study, [6] compared concrete made with coconut shells and palm kernel shells as replacement for coarse aggregates and concluded that coconut shells performed better than palm kernel shells as replacement for conventional aggregates in the of concrete. In an investigation to assess the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in the production of reinforced concrete slabs, [8] concluded that 25% sawdust and palm kernel substitution reduced the cost of concrete production by 7.45%. According to [9], 8% and 13% replacement of the volume and weight respectively of crushed granite by palm kernel shells in volume batched-concrete and weight-batched concrete can be used in reinforced concrete construction according to the requirements of [10].

Coconut shells are by-products of coconut oil production. Coconut shells are used in the production of activated carbon due to hardness and high carbon content [11]. Various researchers,[12], [13] and [14] have investigated the use of coconut shells and their derivatives in civil engineering construction

Cost reduction of 48% can be achieved if coconut shells are used to replace gravel in concrete [12]. 10-15% replacement of ordinary portland cement with coconut shell ash in both heavy weight and lightweight concrete construction has been recommended by [14].

This study was conducted to investigate the properties of concrete using coconut shells as replacement for crushed granite and to assess the potential use of coconut shell concrete as a structural material as well as contribute to knowledge on the use of waste materials in construction in Ghana.

II. MATERIALS AND METHODS

The materials used for concrete for this study were portland cement, sand, granite and coconut shells. Portland cement of class 32.5R, manufactured by Ghana Cement Works at Takoradi in the Western Region of Ghana and conforming to [15] was used. Crushed granite of nominal size 20mm was used as coarse aggregate. It was obtained from Sarobi quarry near Elmina in the Central Region of Ghana. The sand used was sourced from sand suppliers in Cape Coast. The average bulk density was 1550 kgm^{-3}, with a fineness modulus of 2.55. It was flushed with water to remove fines and dirt and sun dried before use. The coconut shells were obtained from Axim, a coconut producing area in the Western Region of Ghana. Ordinary potable tap water produced by Ghana Water Company was used in mixing the materials. It appeared clean and free from any visible impurities, conforming to the requirements of [16].

A concrete mix of ratio of 1:2:4 by volume, with a water cement ratio of 0.6 was used as control, to which the properties of all other mixes were compared. Coconut shells were used to replace 20%, 30% 40%, and 50% and 100% of the granite by volume. In an experimental investigation, [9] found out that replacement of granite with palm kernel shells by volume produced a better performance concrete than replacement by weight. Six different mixes were batched and 12 specimens of each mix were produced. Concrete was cast in pre-oiled cast iron moulds **(Fig. 1).**

Fig 1 Cast iron moulds

After casting, the moulds were covered with plastic sheets to prevent water loss through evaporation. After 24 hours, the cubes were demoulded and immersed in a curing tank to cure for strength gain. The curing process is beneficial to hydration of cement, while improving the physical and mechanical properties of concrete. On each day of testing, the specimens were removed from the tank and placed in the open air for about two hours. The compressive strength of the concrete specimen was determined by crushing after determination of density. The results for the density and compressive strengths are the average of three tests.

III. RESULTS AND DICUSSION

3.1 Strength

The results of the compressive strength tests are shown in Table 1.

Table 1 Compressive strength of coconut shell concrete (Nmm^{-2})

Age (days)	Replacement (%)					
	0	20	30	40	50	100
7	15.75	15.18	14.56	12.76	12.17	3.91
14	18.88	17.06	16.38	15.75	15.17	5.40
21	20.17	18.33	17.04	16.5	15.86	8.11
28	20.94	19.7	18.58	17.57	16.65	9.29

Fig. 2 shows the development of strength with age at various percentage replacements.

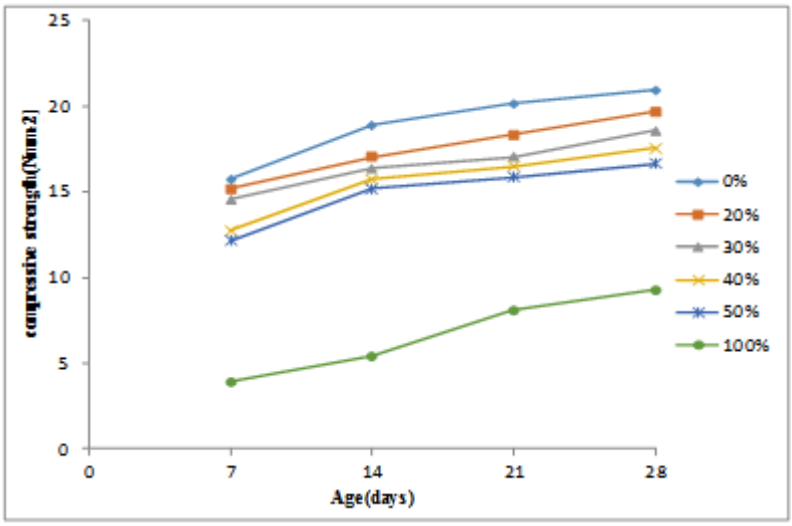

Fig 2 Development of strength with age

The maximum compressive strength of 20.9 Nmm^{-2} was attained at 0 % replacement (no coconut shells) while the minimum strength of 9.29 Nmm^{-2} was attained at 100% replacement (no granite). At 20% replacement, concrete attained a strength of 19.7 Nmm^{-2} marginally less than 20 Nmm^{-2}, the minimum recommended for use as structural concrete according to the requirements of [10]. The long-term compressive strength, however is likely to exceed 20 Nmm^{-2} ,considering the strength development trends shown in Fig 2.

At 18.5% replacement, the compressive strength is 20 Nmm^{-2}, equivalent to grade 20 concrete. Therefore 18.5 % replacement of granite by coconut shells in concrete can be used in reinforced concrete construction for dense aggregates according to the requirements of [10]. It can be seen that at all replacement levels, the strength of concrete increased as it aged. On each day of testing, the strength decreased as the percentage replacement of crushed granite increased. As the coconut shells increased the specific surface area increased, thus requiring more cement to bond with aggregates. Since the quantity of cement in each mix remained constant, no extra boding was developed to accommodate the increase in specific surface. Due to inadequacy of the bonding, the strength decreased. It can also be explained that, since granite is much stronger than coconut shells, reducing the quantity of granite and increasing the amount coconut shells in the mix resulted in reduced strength. It can be seen that concrete showed similar trends in strength development at various percentage replacement levels.

With the exception complete replacement, the compressive strength of concrete produced by 20%, 30%, 40%, and 50% replacement were higher than 15Nmm^{-2} ,the minimum recommended for use in reinforced lightweight concrete construction by [10].

3.2 Density

The results of density determination are shown in Table 2.

Table 2 Density of coconut shell concrete (kgm^{-3})

Age (days)	Replacement (%)					
	0	20	30	40	50	100
7	2320	2279	2223	2137	2115	1810
14	2349	2276	2220	2162	2136	1828
21	2388	2290	2224	2191	2145	1855
28	2418	2308	2241	2191	2161	1871

The variation of density of concrete at various replacement levels and ages are shown in Fig. 3.

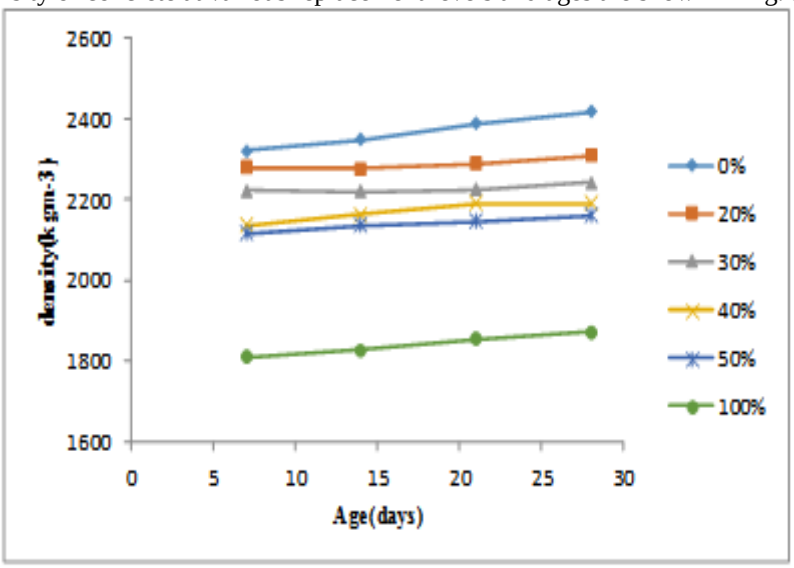

Fig 3 Variation of density with age

It is seen that the maximum density, 2418 kgm^{-3} was attained at 0% replacement while the minimum density, 1871 kgm^{-3} was attained at 100% replacement. With the exception of 100% replacement, the densities of concrete at 20%, 30%, 40% and 50% replacements were higher than 2000kgm^{-3}.It is also seen that the density of concrete reduced as the as the percentage replacement with coconut shells increased while it increased as concrete aged. As the percentage of coconut shells increased, the mass of the mix reduced since coconut shells are lighter than the granite they replaced. This reduction in mass led to the decrease in the density of concrete

IV. CONCLUSION AND RECOMMENDATIONS

In this study the density and strength characteristics of concrete produced by volume replacement of 20%, 30%, 40%, 50% and100% replacement of crushed granite with coconut shells were investigated. It is concluded that:

- Increase in percentage replacements by coconut shells reduced the strength and density of concrete.
- With the exception of complete replacement, 20%, 30%, 40%, and 50% replacement of crushed granite by coconut shells can be used in producing lightweight concrete.
- 18.5% replacement of crushed granite with coconut shells can be used to produce structural concrete per the requirements of [10].
- Coconut shells can be used as partial replacement of crushed granite or other conventional aggregates in reinforced concrete construction.

The following recommendations are made at the end of the study.

- Further studies should be carried out to ascertain the possibility of using coconut shell concrete as a structural material.
- Durability studies on coconut shell concrete should be carried out to assess its behaviour in aggressive environments.
- Developing countries like Ghana should encourage the use of agricultural wastes in construction as an environmental protection and cost reduction measure.

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