ASSESSMENT OF PALM KERNEL SHELLS AS AGGREGATE IN CONCRETE AND LATERITE BLOCKS

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Abstract: Palm kernel shells were assessed as aggregate in concrete and laterite blocks. Results showed that laterite blocks reinforced with kernel shells at the optimum proportion of 1:4 (kernel shells:laterite) by volume were about 15% stronger than plain laterite blocks. The strength of laterite blocks reinforced with kernel shells also compared favorably with strength of sandcrete blocks which are popularly used as partitions in buildings. However, replacement of crushed stone aggregate with kernel shells in concrete blocks resulted in a strength reduction of about 50%. Therefore, palm kernel shells are not good substitutes for crushed stone aggregates in concrete.

Keywords: palm-kernel shells, laterite, concrete, strength

1. INTRODUCTION

Concrete is a construction material manufactured by mixing fine aggregate (e.g. sand), coarse aggregate (e.g. gravel, crushed stone), cement and water either in a designed or prescribed proportion. It is strong in compression and has good fire resisting properties, and when steel, which is strong in tension is incorporated into it, a strong and durable material which can withstand various forms of loading and can be formed into various shapes and sizes emerges. This accounts for its widespread use in civil engineering construction works such as buildings, bridges, dams, roads and so on. Similarly sandcrete blocks made by mixing cement, sand and water are popularly used as partitions in building due to their strength and water resisting capabilities.

However due to the exorbitant cost of steel, cement and crushed stone aggregate (which include energy and importation costs), the development and use of other materials available locally are now being emphasized. This would reduce the amount of foreign exchange spent on importation and thus bring down cost.

Materials that have been investigated include natural soil, particularly laterite and clay; naturally occurring aggregates (gravel, sand, pumice); shells, mining, industrial and agro wastes; timber; bamboo and natural fibers [1 ÷ 3]. Research has been carried out on the use of stabilized soil and sewage sludge [4] for masonry units and on replacing sand fines in concrete with laterite for structural use. It was discovered that cement/lime stabilized laterite blocks and burnt clay bricks could be used instead of sandcrete blocks since they proved structurally and aesthetically suitable [5]. Attempts have also been made at using coconut shells as aggregate in concrete [6 ÷ 8].

Partial replacement of sand with laterite has been considered in order to exploit the use of laterite (which is more readily obtained than sand) in concrete. It was found that ratio 1:1.5:3 (cement: fine aggregate: coarse aggregate) with a laterite/ sand ratio of less than 0.5 gave strengths comparable with that of normal concrete mixes thus reducing the quantity of sand used in the mix [1]. Laterite is also a good material for sub base and base courses

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of highways, and is also used for the construction of Silos for storage purposes. Recently, the need for cheap and durable construction materials has resulted in the use of laterite for making bricks. The clay and silt present serve as binders thus eliminating the use of cement. On mixing with water, laterite provides good friction, cohesion and proper interlock among soil particles. It could be moulded and shaped to form blocks which can be used for building partitions. The high tensile strength of bamboo (344 to 1793 kg/cm^2) coupled with its cheapness make it desirable for reinforcing laterite or low modulus concrete [9].

Of all the locally available materials that could be used for building construction, palm kernel shells appear least investigated hence this research is devoted to assessing its suitability as aggregate in concrete and laterite blocks. Palm kernel shells are available in large quantities [10] in palm oil producing areas of south western Nigeria They are underutilized [10] and are usually abandoned as waste materials or used in a small scale as fuel in furnaces and materials for filling potholes, so if found suitable for construction, their large supply could be harnessed to reduce construction cost without undermining the strength/integrity of structures.

2. EXPERIMENTAL WORK

2.1. Sample Collection and Preparation

Palm kernel shells from the Dura variety of oil palm were used for this study. The Dura variety is characterized by a large nut with a thick shell and thin mesocarp [11, 12].They were obtained from a plantation in Ondo state, Nigeria. The palm nuts were gathered, washed and then manually crushed to obtain the shells. Lateritic soil samples were also collected from a burrow pit in Ondo state and were air dried and thoroughly mixed to ensure homogeneity. Concrete was prepared using ordinary portland cement obtained from the local market and aggregates from a quarry.

2.2. Testing and Evaluation of Samples

2.2.1. Testing of Palm Kernel Shell and Crushed Stone

Sieve analysis was performed on samples of crushed stone aggregate and palm kernel shells to determine their grading. The palm kernel shells and crushed stone samples were shaken through a set of sieves of successively smaller openings and the mass of sample retained by each sieve was recorded. Thereafter, grain size distribution curves were drawn.

Specific gravity test was also carried out on samples of palm kernel shells. Specific gravity is the ratio of mass (or weight in air) of a unit volume of material to the mass of the same volume of water at a stated temperature. Samples of palm kernel shells were dried in an oven for 24 hours at 100^{0}C and the masses were determined. The mass of water occupying a volume equal to that of the solid including impermeable pores was determined for each sample by using a vessel, which could be accurately filled with water to a specified volume.

The apparent specific gravity $G's$ is then given by equation 1:

$$G's = \frac{D}{B - A + D} \tag{1}$$

where: A represented the mass of vessel with sample and topped up with water, B= mass of vessel full of water, D= mass of oven dried sample, B-A+D=the mass of water occupying the same volume as solid.

To determine the moisture content of each sample of palm kernel shells, an empty specimen can was weighed. Then the weight of can plus sample was determined. The can plus the sample was then oven dried and weighed.

The moisture content M_c was determined by equation 2:

$$M_c = \frac{B - C}{B - A} \times 100 \tag{2}$$

where: A= weight of empty can, B= weight of can plus sample, C= weight of can plus dry sample.

2.2.2. Testing of Laterite

Tests were conducted to determine the consistency property of laterite such as liquid limit, plastic limit and the plasticity index.

Compaction test was also conducted to determine the maximum dry density and the optimum moisture content that would give the best compaction when moulded into blocks and hence the maximum strength when tested on drying. The soil tests were conducted as specified in BS 1377 [13].

2.2.3. Determination of Compressive Strengths of Concrete Cubes

A prescribed mix of 1:2:4 (Cement: sand: coarse aggregate) by volume was used in making all concrete specimens. This prescribed mix was employed because it is the most commonly used for construction purposes in Nigeria. The prescribed mix constituents do not include the volume of water, it is therefore necessary to determine the water- cement ratio so as to estimate the quantity of water to be used such that the requirements of quality, workability, and economy could be balanced. Water/cement requirement is 28 liters of water to 1bag of cement for ordinary exposed structures (buildings) [14]. This results in a water- cement ratio of 0.56 which was adopted for this research.

After mixing the concrete, steel moulds with internal dimensions of 150mm x 150mm were used in casting the specimens for compressive strength tests. Casting, compaction and testing of concrete were done as specified in BS 1881 [15]. Some specimens were made with crushed stone as coarse aggregate while others were made with palm kernel shells. After 24 hours since casting, the moulds were stripped and the concrete specimens were taken to the curing stands. The two types of curing employed were soaking in water and wetting. The remaining samples were left uncured, thus giving three curing conditions.

Compressive strength tests were carried out on the specimens at 7, 14, 21 and 28 days since casting.

2.2.4. Determination of Compressive Strengths of Laterite Cubes

A measured quantity of laterite was mixed thoroughly with water as determined by the compaction test. The mix was then compacted into 150mm x 150mm moulds. On the third day since casting, the laterite cubes were demoulded and left to dry under atmospheric condition. The cubes were later tested for compressive strength on 7, 14, 21 and 28 days since casting as done for concrete specimens.

Other specimens were prepared with palm kernel shells as aggregates and tested like the plain laterite cubes. Trial mixes were made with varied proportion of kernel shells. The proportions of kernel shells used were 1:4, 1:3 and 1:2. Proportioning was by volume as done for concrete specimens. The variation of the proportion of kernel shells in the mix was to enhance the monitoring of the effect of the proportion of kernel shells on compressive strength of laterite cubes.

3. RESULTS AND DISCUSSION

3.1. Particle Size Distribution of Aggregates

The grading curves for palm kernel shells and crushed stone aggregates are shown in Figure 1. For crushed stone, the coefficient of uniformity was 6 while the coefficient of curvature was 1. This shows that the crushed stone aggregate used is well graded with sizes ranging from 0.4 mm to 30 mm. For kernel shells, the coefficient of uniformity was 2.3 and coefficient of curvature was 1.35, showing that the kernel shells used were gap graded with sizes ranging from 0.5 mm to 30 mm, falling within the medium/coarse sand fraction and the fine/medium gravel fraction.

3.2. Specific Gravity and Moisture Content of Palm Kernel Shells

The average specific gravity of samples of palm kernel shells tested was 1.028 which is less than 50% of the values for natural rock aggregate which ranges between 2.6 and 2.7 [16].

The average moisture content of samples of palm kernel shells tested was 11%. This value is considered high, suggesting high water absorption rate since the samples of palm kernel shells tested were air-dry.

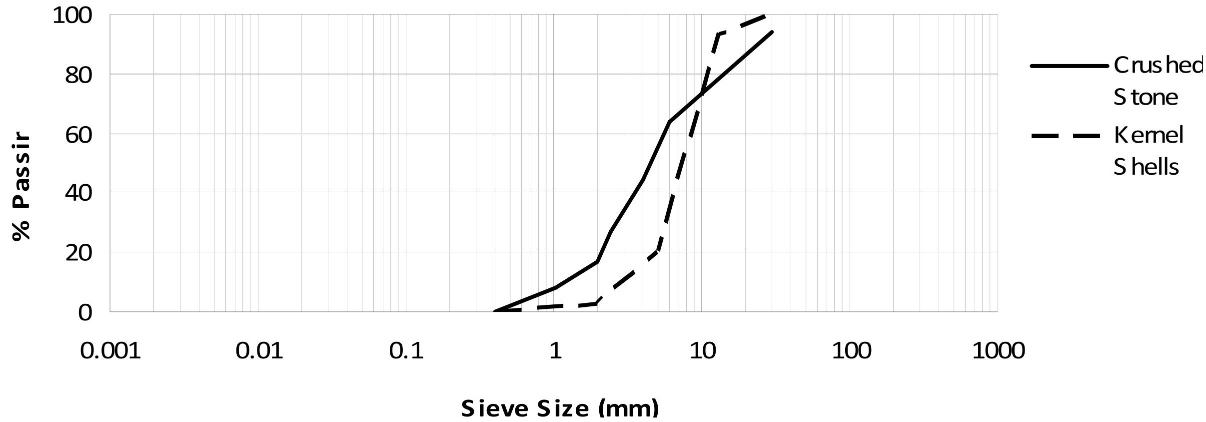

Fig. 1. Grading curves for crushed stone and palm kernel shells.

3.3. Atterberg Limits and Compaction Characteristics of Laterite

Results of Atterberg tests show that the liquid limit of laterite used was 35%, plastic limit was 24% and plasticity index was 11%. This indicates that the laterite used was not the clayey type and can be classified as an SC soil (according to the extended Casagrande classification system), which can be used as road base. The compaction test results show that the optimum moisture content was 13% and maximum dry density was 2280 kg/m^3. These results further revealed the fact that the laterite soil used was suitable for road construction as bases.

3.3. Compressive strength of concrete and Laterite Cubes

The relationship between the compressive strengths of concrete cubes (made with crushed stone and kernel shell aggregates) and age is shown in Figure 2, while Figure 3 illustrates the effect of the proportion of kernel shells in the mix on the compressive strength of laterite cubes. The relationship between compressive strength and age for plain laterite cubes and lateritic cubes reinforced with kernel shells is also shown in Figure 4.

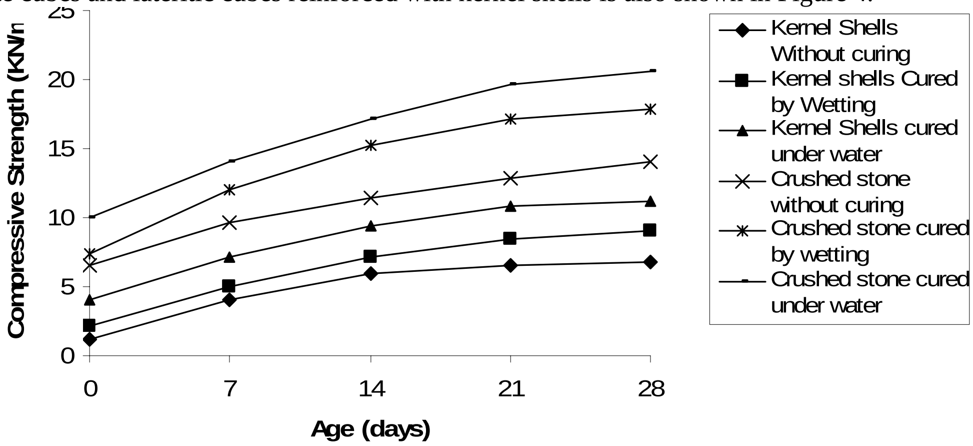

Fig. 2. Compressive strengths of concrete with crushed stones and palm kernel shells as coarse aggregate.

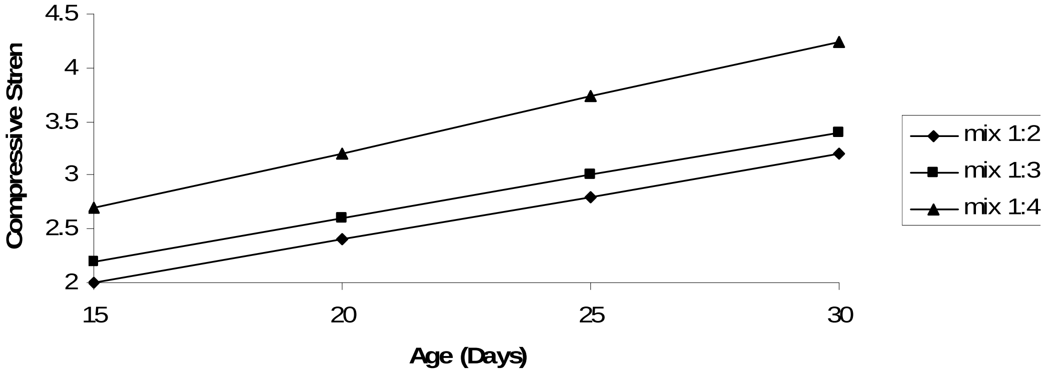

Fig. 3. Relationship between compressive strength and age for the trial test on laterite reinforced with kernel shells.

As could be observed, from Figure 3, proportion 1:4 (kernel shells:laterite) resulted in the maximum compressive strength of laterite cubes. From Figure 2, it could be observed that concrete with crushed stone as coarse aggregate generally had higher compressive strength than concrete with kernel shells as coarse aggregate. The application of kernel shells as aggregate in concrete led to about 50% reduction in the strength of concrete. The reduction in strength could be due to many factors such as the light weight, flaky shape or semi-porous nature of palm kernel shells. It is therefore obvious that palm kernel shells cannot substitute for crushed stone as aggregate in concrete except for aesthetic purposes. However, concrete with palm kernel shells as aggregate could be used for light weight construction work.

The strength of concrete specimens cured under water is greater than the strength of those cured by wetting, which is in turn greater than the strength of specimens which were left uncured. This shows that adequate wet curing during construction enhances the strength of concrete. From Figures 3 and 4, it could be observed that strength of laterite cubes increased linearly with age and that laterite cubes reinforced with kernel shells in appropriate proportion, 1:4 (kernel shells: laterite) had higher strength than plain laterite cubes (about 15% difference). Therefore the use of kernel shells as aggregate in laterite blocks should be encouraged.

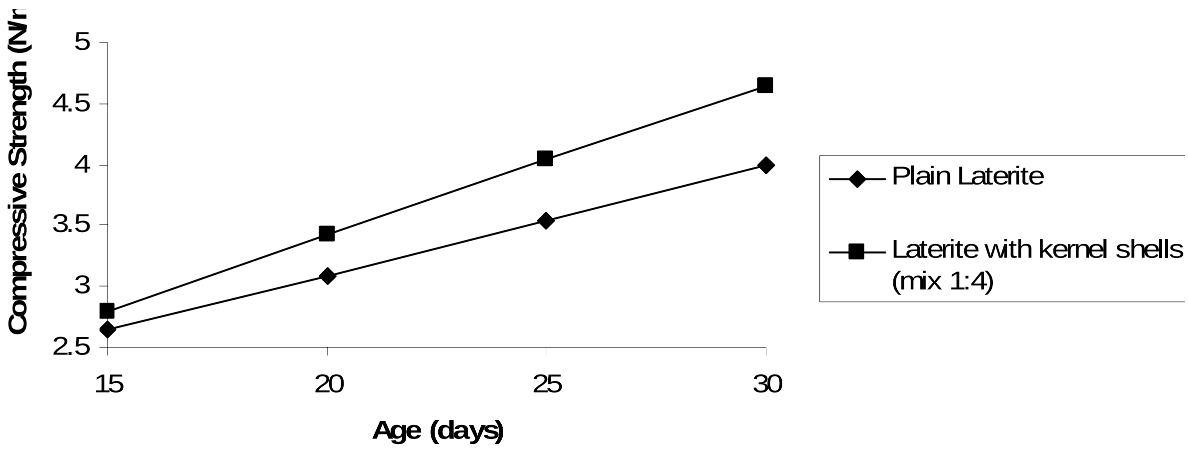

Fig. 4. Compressive strength of plain laterite and laterite reinforced with kernel shells.

Furthermore, the average 28-day strength of laterite cubes whether plain or reinforced with kernel shells, 4 N/mm^2 and 4.7 N/mm^2 respectively, compared favorably with the strength of class III mortar (sandcrete) blocks which is 4 N/mm^2 and is even much higher than the strength of class IV mortar (sandcrete) blocks which is 2 N/mm^2 [17]. Hence laterite blocks could be substituted for sandcrete blocks as partitions in buildings.

4. CONCLUSIONS

Tests on palm kernel shells revealed low specific gravity, high moisture content and water absorption rate.

Concrete with crushed stone as coarse aggregate has higher strength than concrete with palm kernel shells as aggregate. This shows that palm kernel shells cannot be substituted for crushed stones as coarse aggregate in concrete except for aesthetic purposes. However, concrete with palm kernel shells as aggregate could be used for lightweight construction work.

Laterite cubes reinforced with palm kernel shells are about 15% stronger than plain laterite cubes. However, it has been discovered that the proportion of kernel shells that would result in the maximum strength of laterite cubes is 25%, above which there could be a reduction in strength. This is because increase in quantity of kernel shells beyond the optimum value results in the reduction of the cohesive property of laterite.

The strength of laterite cubes (whether plain or reinforced with kernel shells) compare favorably with the strength of sandcrete blocks popularly used in day to day building construction work as partitions; so laterite blocks are good substitutes for sandcrete blocks.

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