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Assessment of Manufactured Sand in Concrete Produced with Palm Kernel Shells as Coarse Aggregate

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Abstract: ***This article reports on a research carried out to assess the effects of manufactured sand in concrete, produced with palm kernel shells as coarse aggregate; on the strength, weight in air and workability. The concrete was designed using British Building Research (BRE) method, and a total of 54 cubes were made of 150mm by 150mm by 150mm. Two concrete classes were designed and produced, namely Lightweight Concrete (LC) class 22 and 38, then cured for 28 and 90 days. The specified design slump was between 30mm-60mm. Natural sand was replaced by manufactured sand (Msand) at 25% intervals, batched by volume till it got to 100% fine aggregate usage. The coarse aggregate portion was solely PKS, batched by volume. The maximum compressive strength for LC 22 was 16.1N/mm^2 and 18.22 N/mm^2, at 28 and 90 days respectively. While LC 38 was 19N/mm^2 and 20.3N/mm^2, in same order. Msand replacement portion applicable to both LC22 and LC38 was 32%. Compressive strength gained with time by samples, were not directly proportional to the densities developed with respect to time. The strength differences were 26.8% and 48.7% for LC22 and LC38 respectively, when compared with the expected characteristic strengths.***

Keywords: coarse aggregate; compressive strength; concrete; manufactured sand; palm kernel shells; workability

1. Introduction

Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its versatility and relative economy in meeting wide range of needs has made it a very competitive building material. Both natural and artificial aggregates are used in the production of concrete in the construction industry. Fine and coarse aggregates which generally occupy 60% to 75% of concrete volume strongly influence concrete's freshly mixed and hardened properties as well as its mix proportions and economy [1], [2], [3].

Concrete is a widely used construction material in civil engineering projects throughout the world for the following reasons: It has excellent resistance to water, structural concrete elements can be formed into a variety of shapes and sizes and it is usually the cheapest and most readily available material for the job [4].

According to [5], the high cost of building materials in the developing countries of the world can be reduced to a minimum by the use of alternative materials that are cheap, locally available in most countries and which bring about a reduction in the overall deadweight of the building. Some industrial and agricultural by-products that have little or no economic benefit could gainfully be used as building materials. One such material is palm kernel shell (PKS). PKS consists of small size particles, medium size particles and large size particles in the range 0-5mm, 5-10mm and 10-15mm [6].

Utilization of such seemingly agricultural waste, like PKS, would help in providing an alternative to making concrete. Instead of too much dependence on crushed stones, thus reducing the rate of depletion of this natural resource. It will contribute further in establishing another acceptable ecological friendly and biodegradable engineering material, therefore, creating a cost effective construction alternative to existing conventional ones.

Fine aggregate used in making concrete might be river sand or mining sand, otherwise both known as natural sand. Natural sand are cheap source of sands but with varying distances and haulage to site, it could become uneconomical for use; at this point, manufactured sand might become the best alternative.

Manufactured sand (Msand) by virtue of production are more angular and flaky, by virtue of production [7], while natural sand have particles that are well-rounded or nearly rounded. The angular shapes of Msand may contribute to higher strength because of this unique property. The synergy derived from these unique particulate properties of these various types of fine aggregate may be good enough to improve strength, to the point of crossing strength barrier into better industrial acceptance of concrete with PKS.

[8]carried out a research on PKS in light weight concrete using it as coarse aggregate. He found out that for grade 25 and below, the material was found to compare favorably with conversional crushed granite. [9] did an experimental study on palm kernel shell as coarse aggregate in concrete. Crushed granite were used, replaced by volume and weight by palm kernel shells. Various tests were done in relation to ages. The study identified possible cost reduction in replacing granite with palm kernel shells, with as much as 13% savings, on the premise that PKS was got free of charge. [10] had research done on palm kernel shell as aggregate in the production of structural lightweight concrete, but with the use of erosion sand as fine aggregate. They assessed the erosion sand to be within zone 3. [11] conducted on the physical properties of palm kernel shell used as a coarse aggregate and their effect on the strength properties of palm kernel shell concrete. They

replaced crushed granite by palm kernel shell to see its effect on the compressive strength and density of palm kernel shell concrete. Like other researchers, they also acknowledged the great potentials of using oil palm shell, also known as palm kernel shell (PKS) as replacement to crushed stones, with the benefits that accrue.

1.1 Statement of problem

To find out the effect of manufactured sand in palm kernel shell integrated lightweight concrete, it became necessary to see; what is the maximum compressive strength attainable at 28 and 90 days? What percentage of manufactured sand in replacement would give best performance in compressive strength and workability? With the use of manufactured sand in mixes, does density increase or decrease in same sequence as compressive strength?

2. Materials and Methods

Materials

The manufactured sand (Msand) was obtained from local distributors in Benin City. The quarries where they normally get consignment is prevalent at Estako area of Edo state, Nigeria. The natural sand and Portland cement were gotten from distributor's within the Benin metropolis. The palm kernel shells were obtained from a mill around the University of Benin (Isihor quarters), Benin City. The palm kernel shells were soaked for 24 hours and air-dried in the laboratory before use. Before the soaking, the PKS were washed with water and sieved with 5mm sieves to removed fine impurities that may have adverse effect on the research. Various tests were conducted on the aggregates and binder to ascertain and establish their physical and mechanical properties, in accordance with the relevant standards.

Specimen preparation and testing

Two concrete classes were designedin accordance with British Building Research (BRE) method as listed by [12]. The produced Lightweight Concrete (LC)classes were LC 22 and 38, which were supposed to have characteristic strengths of 22N/mm^2 and 38N/mm^{2}respectively; according to [13].The specified slump was between 30mm-60mm. Concrete mixes and cubes were made in accordance to requirements of [14] then cured for 28 and 90 days.

Natural sand was replaced by Msand at 25% intervals, batched by volume; till 100% fine aggregate usage was reached. The coarse aggregate portion was solely PKS, batched by volume in relation to the designed expected coarse aggregate portion.

Before the putting the specimens in the various moulds, workability was investigated using slump test method, in accordance with [15]. A total of 54 cubes of 150mm by 150mm by 150mm were made and the various compressive strengths were determined using machines available in the laboratory of the Civil Engineering Department of the University of Benin, Benin City; where attempts to crush the cube samples till failures resulted were made. The values of maximum load at failures were noted and analyzed.

Plate 1: Compressive strength test setup

Plate 2: A heap of crushed palm kernel shells at the mill

3. Results and Conclusion

Table 1: Some physical properties of the fine aggregates

Physical Property	Natural sand	Msand
Fineness modulus	2.00	3.1
Specific gravity	2.62	2.77
Bulk density	1480 kg/m^3	1650 kg/m^3

Looking at the physical properties enumerated in table 1, it indicates that the natural sand is fine sand, because it fineness modulus is 2.00. But the manufactured sand is rather coarse sand due to a 3.1 value of fines modulus. With high bulk density of the Msand as compared with other aggregate, it is sure to impart a level of influence on the concrete matrix.

Table 2: Some physical properties of the coarse aggregate

Physical Property	PKS
Fineness modulus	1.4
Specific gravity	1.37
Bulk density	707kg/m^3
Dry density	1250kg/m^3
Water absorption	19.7%

From table 2, it is observable that the water absorption for PKS was over 10%.Therefore the aggregates had to be soaked before use, as proven by several researches. Since that water absorption is that high, paste demand for concrete made with PKS would be high than those made with conventional pure granite as coarse aggregate portion. The low bulk density as compared to the specific gravity, indicated existence of large voids in the PKS sample, requiring greater need to be filled by finer particles. The low bulk density of PKS in the concrete matrix influences the relative density of the combined aggregates, thus producing predominantly lightweight concrete.

Table 3: Workability of concrete and weight of cured concrete

LC 22			
Percentage of Msand	Slump (mm)	Weight in air (kg) 28days	Weight in air (kg) 90days
0	55	6.24	6.36
25	64	6.32	6.29
50	60	6.27	6.43
75	20	6.40	6.39
100	31	6.36	6.38

The weight in air of the samples increased with curing time as seen in table 3, except when the Msand replacements were 25% and 75%. It can also be observed that their respective slumps test values did not fall within the 30-60mm design specification. An indication that poor workability would be a main cause of this reduction in weight, which also resulted in lower densities of these affected samples.

Table 4: Workability of concrete LC 38 and weight of cured concrete

Percentage of Msand	Slump (mm)	Weight in air (kg) 28days	Weight in air (kg) 90days
0	15	6.47	6.52
50	6	6.65	6.60
75	47	6.70	6.77
100	8	6.50	6.57

Unlike low strength concrete (LC22), the reduction of weight in air of the concrete sample is not predominantly controlled by the workability in medium strength concrete, like LC38;because at a low slump value of 8mm, the weight still increased from 6.5kg in day 28 to 6.57kg in day 90. That means physical and mechanical properties of Msand, other than just cement and water contents, have a large influence on the performance of this form of lightweight concrete. Table 4 showcases these. When then Msand replacement portion was just 50%, the weight reduced with time as the workability was poor. This reduction arises, among other things, from shrinkage within the concrete. The shrinkage was stimulated by the presence of honeycomb, low water content and less content of Msand, whose particulate nature could have helped in taking up the shrinkage strains. One can clearly notice that for a 100% fine aggregate content of Msand, shrinkage was minimal, because the weight in air of the sample and eventual density actually increased with time.

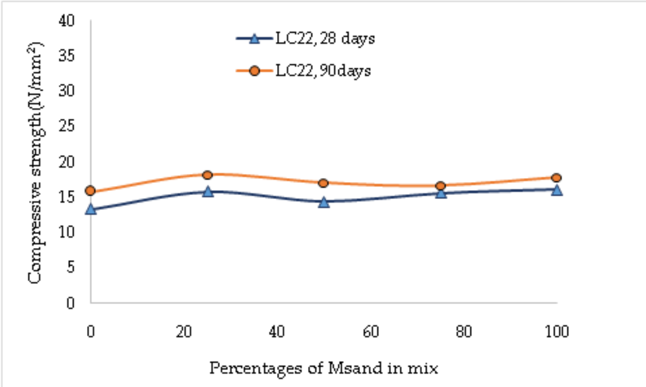

Figure 1: Compressive strength of Lightweight concrete of class 22 at 28 and 90 days.

From figure 1, an average of 10.4% compressive strength increase can be noticed after 28days. This gives a pass that the combination of PKS and Msand guarantees compressive strength gains, for low strength lightweight concrete production. The highest compressive strength attained at 90 days was 18.22N/mm^2 at 25% Msand fine aggregate replacement content, the closest to this being at 100% Msand content, giving 17.85N/mm^2 at 90 days.

Compared with the expected characteristic strength of 22N/mm^2, the strength differencewas26.8%, which resulted at 100%Msand fine aggregate usage.

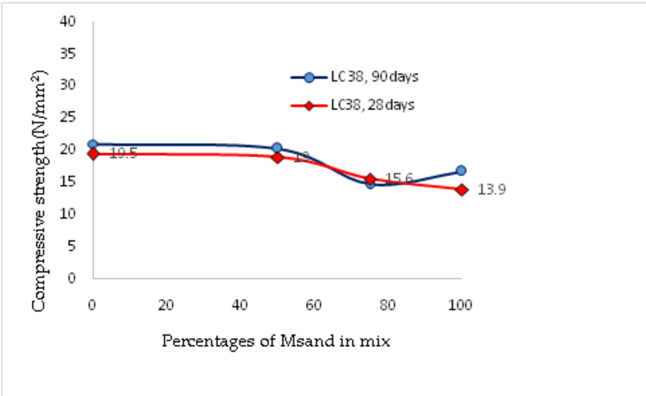

Figure 2: Compressive strength of Lightweight concrete of class 38 at 28 and 90 days.

In figure 2, it is observable that the compressive strength also increased with time, but only at 75% Msand replacement. Juxtaposing this position with table 4, it goes to show that at this portion of Msand content, increase in density may be sure, but compressive strength increase do not occur or retained for medium strength lightweight concrete; like LC38.

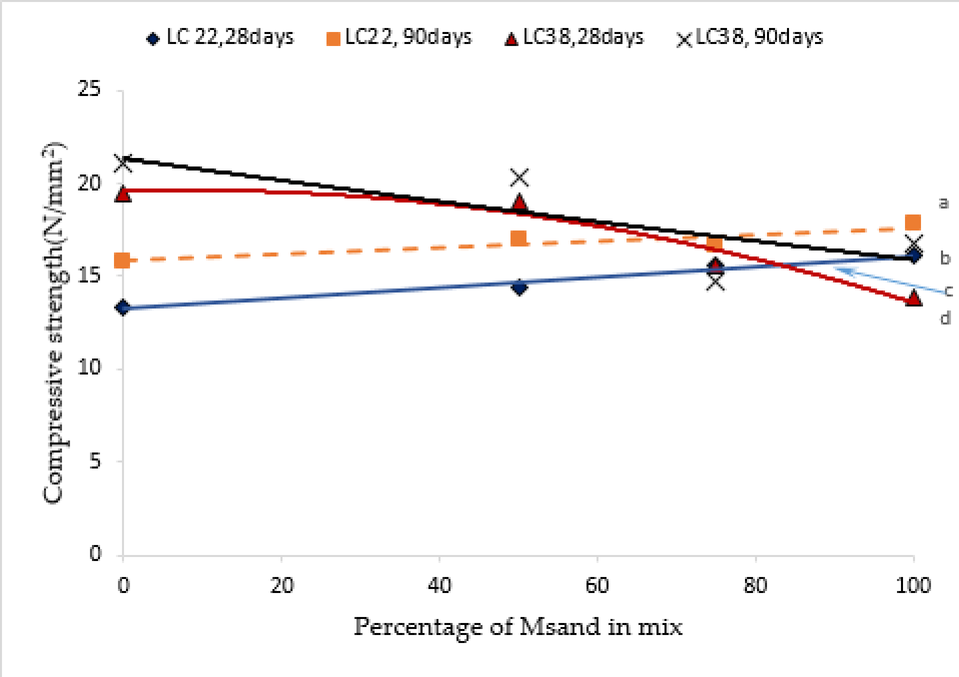

Figure 3: Comparison of the compressive strengths of the concrete classes, with respect to time and Msand content in the mixes.

The mathematical models for the compressive strengths in figure 3 are as follows;

(a): $y = 0.0177x + 15.854$ (1)
(b): $y = 5E\text{-}05x^2 - 0.0599x + 21.342$ (2)
(c): $y = 0.029x + 13.217$ (3)
(d): $y = -0.0007x^2 + 0.0111x + 19.604$ (4)

Reflected in the models created in figure 3, three distinct paths are shown. First, that for lightweight concrete of class 38, best compressive strength performance happens at nonuse of Msand as fine aggregate. Secondly, lightweight concrete of class 22, attained highest compressive strength performance at 100% use of Msand, as fine aggregate. Thirdly, regardless of the concrete class, the safe percentage replacement applicable for both LC22 and LC38 is 32%.

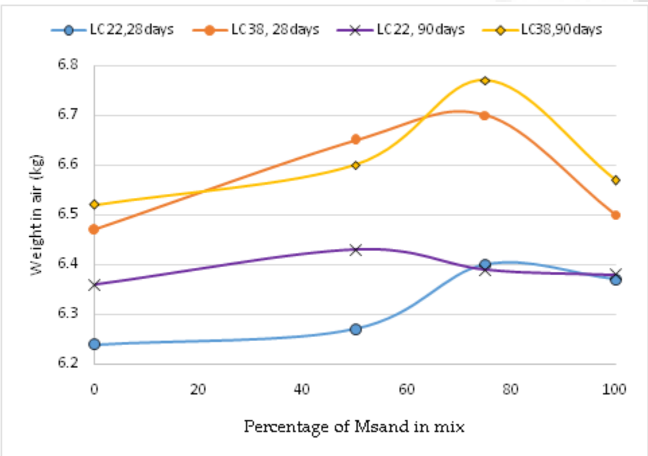

Figure 4: Weight in air in relation with Msand content in concrete.

Interestingly, in figure 4, weight in air, that is directly proportionate to the samples densities, spikes up and reaches peaks between 50-85% Msand replacements. From the compressive strength results and models developed, it is evident that best compressive strength performance did not occur at 50-85% of Msand contents in the mixes. Following from these facts, it indicates that compressive strength gained with time by lightweight concrete (produced with such aggregate as PKS and Msand), is not directly proportional to the weight or densities developed with time.

$$f_{LC} \neq \rho \quad (5)$$

Where f_{LC}, characteristic cube strength of lightweight concrete and ρ is density developed with time.

4. Conclusion

In view of the findings from this research, it is fitting to say that maximum compressive strength of Lightweight concrete (LC) 22, produced with PKS and Ms and as coarse and fine aggregates portions is 16.1N/mm² at 28 days and 18.22 N/mm² at 90 days. While LC 38 is 19N/mm² and 20.3N/mm² for 28 and 90 days respectively. Use of PKS and Msand to produce low strength lightweight concrete, guarantees best compressive performance at Msand fine aggregate use of 100%. The singular Msand use, applicable to both low and medium strength lightweight concrete is 32% as fine aggregate replacement; or else Msand use is not appropriate on Medium strength lightweight concrete, for best compressive strength performance. Compressive strength gained with time by lightweight concrete is not directly proportional to the densities developed with time. Use of Msand, generally has negative effect on the workability of medium strength lightweight concrete, but negligible on low strength lightweight concrete. The strength difference is 26.8% and 48.7% for LC22 and LC38 respectively, in relation with their respective characteristic strengths.

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