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Utilization of Bituminous Sand in the Production of Eco-friendly Sandcrete for Sustainable Construction

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Abstract. Sandcrete is a construction material composed of cement, fine aggregate, and water. The constituent materials are in great demand due to their use in various buildings. The increasing demand in turn has led to astronomical increases in the cost of procuring these materials thereby making it very difficult to meet the shelter provision requirement of the teeming population of a country such as Nigeria. There have been various attempts to address this issue by substituting different materials for river sand in the production of sandcrete, either entirely or in part, one such material which is used in this research is bituminous sand. Bituminous sands are composed of sands, heavy oil and clay that are rich in mineral and water. Ordinary Portland cement was mixed with both river sand (as control) and bituminous sand in 0, 10, 20, 30, 40 and 100% replacement levels. Seventy-two sandcrete cubes were cast in all for this study and tested for compressive strength. From the investigation, the samples compressive strengths increased with increase in curing age and decreased with increase in percentage replacement though at a different rate with the sample containing 0% bituminous sand and 100% river sand denoted SC0,100 gaining the highest strength of 8.59N/mm^2 at the 28th day of curing. The SC10,90, SC20,80, SC30,70 and SC40,60 attained 98.5%, 50%, 42.3% and 3.5% more strength compared to the design strength at 28th day of curing, respectively. While the SC100,0 attained 43.5% lower strength compared to the design strength at 28th day of curing. This research has revealed the possibility of using bituminous sand for developing eco-friendly sandcrete for construction purposes for up to 0-40% river sand replacement with bituminous sand.

Keywords: Sandcrete, Relative Density, Eco-friendly Production, Bituminous sand, Compressive Strength.

1. Introduction

The rapid advance of globalization and the growth in population has resulted in a growth in building construction that has consequently led to a high global demand for construction materials. Sandcrete is a construction material composed of Ordinary Portland Cement (OPC), fine aggregate and water. Sometimes an admixture is added. It is used to produce blocks which are walling unit system conventionally used in Nigeria for the erection of walls and partitions [1]. According to [2-6], about 90% of the homes in Nigeria are made with sandcrete blocks. These sandcrete blocks are used to partition rooms, foundation walls, fencing etc. in the building construction industry [7-9]. Natural river sand is one of the materials extensively used as fine aggregate in making sandcrete for building construction. Due to this extensive use and adoption of natural river sands for sandcrete production, it is no longer as abundant and inexpensive as it used to be, not to mention the negative impacts that the over exploitation of these river sands has caused to our environment. Some of these negative impacts are intrusion of salinity into rivers, lowering of the water table and increase in riverbed depth. This development has led engineers and researchers back to the drawing board to look for alternatives to natural river sand. As a result, materials like limestone and siliceous stone powder, fly-ash and quarry dust has now been used as natural river sand substitute in sandcrete production.

Bituminous sand (sometimes referred to as oil sand) is another form of sand which occurs naturally and could be used to replace river sand. Bituminous sand are sedimentary rocks consolidated or unconsolidated composed of sand, heavy oil and clay that are rich in mineral and water [10]. The heavy oil which is a sticky viscous black substance is bitumen and results in the name bituminous sand for the oil sand.

According to [11], several countries of the world like the former Soviet Union, Venezuela, Cuba, Indonesia, Brazil, Jordan, Madagascar, Trinidad, Colombia, Albania, Romania, Spain, Portugal, Argentina, and Nigeria boast of vast deposits of oil sands. Canada and Venezuela are believed to have larger quantities of reserve and production of bituminous sands [12], with Athabasca in Alberta Canada having the largest oil sand field beneath sections of boreal forest, Praire and Muskeg, followed by Cuba, Syria, and Albania [13]. [14] reported that on the African continent, some substantial amounts of bituminous sands exist in the eastern Dahomey basin. According to [15], the Dahomey basin stretches from southeastern Ghana through Togo and the Republic of Benin to south-western Nigeria with the northern basement complex and the Atlantic Ocean bounding the south-western Nigeria Dahomey basin section [14].

Nigeria is endowed with marked bituminous sands deposits [16,17]. Previous studies by [18,19] revealed that Nigeria's bituminous sand is among the largest deposit in the world. These sands occur within the Afowo formation and straddles across the southwest covering Lagos, Ogun, Edo, and Ondo states [20], having a belt of about 120km [21]. In their study, [22] observed bituminous sand on the surface of coastal plain in the Dahomey basin of Southwestern Nigeria particularly in Imakun-omi community which further showcased the availability of the sand for open surface mining.

The compressive strength of sandcrete is one of the core determinants for their use as a building construction material. Experiments by [23,24] in which they used raw bitumen to partially replace river sand to produce sandcrete, revealed slower rate of compressive strength development with the increase in bitumen content compared with the control sets. [25] concluded in their study that blocks containing 5% sand replacement with polyethylene terephthalate (PET) recycled wastes attained compressive strength comparable to conventional blocks. Previous research by [26] reported compressive strength of 5.48N/mm^2, 4.15N/mm^2 and 3.56N/mm^2 respectively for sandcrete at 28 days of curing using fine aggregates gotten from different locations. [27] reported sandcrete blocks compressive strength between 0.25N/mm^2 and 0.95N/mm^2 which did not meet the requirements of [28]. Also, in their studies [29-33] produced sandcrete using laterite, recycled waste papers, pulverized ceramics, and mineral wood fibers as river sand replacement.

Although studies have been conducted on the production of sandcrete using so many fine aggregates including those exposed to petroleum products and hydrocarbons, not much has been done on using naturally occurring bituminous sand to produce sandcrete. Also, despite the

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abundance of Nigeria’s bituminous sand deposits, interests have hardly been directed towards using them to make sandcrete for construction purpose. Hence, this research seeks to investigate the utilization of naturally occurring Nigerian bituminous sand to produce economically friendly sandcrete. The river sand will be replaced with bituminous sand at various percentages.

2. Material and Methods

2.1. Materials

The bituminous sand that was used for this investigation was gotten from Agbabu which falls within the local council area of Odigbo in Ondo state, southwestern Nigeria. Agbabu is located on geographical grid of latitude 6^0 35’ 16.3’’N and 6^0 37’ 13.9’’N and longitude 4^0 49’ 29.0’’E and 4^0 50’ 20.7’’E. Agbabu is bounded in the North by Ilubinrin village, in the South by Ojumode village, in the East by Sheba village and in the West by Lobuko village. The bituminous sand was dugged out from the outcrop using a pick and a shovel. The river sand used as the control for this research project was well-grained river sand obtained from a sand depot in Enugu, Nigeria. The obtained bituminous sand samples were in a solid compact form. As it was difficult to work with this sample in this form, the sample was crushed into sand sizes with the aid of a scoop and was sieved through 10mm mesh to increase the zone of the fine aggregate thus making it finer.

Bituminous sand was used to replace river sand at various percentages. The sandcrete samples were made using readily available ordinary Portland cement (OPC). The mixing and curing of the sandcrete were done with clean water devoid of impurities (pH = 6.8). A mix ratio of 1(cement):5.7(sand) was used to produce the sandcrete at a characteristic target design strength of $4N/mm^2$.

Figure 1: Bituminous sand and River sand used for the study

2.2. Methods

2.2.1. Batching and Mixing of Sandcrete

The experimental design included six mixtures of sandcrete cubes as displayed in table 1. The first sandcrete cube contained 0% bituminous sand and 100% river sand. This mixture was labelled as SC0,100. The river sand was partially replaced with 10%, 20% 30% 40% and 100%, by weight of bituminous sand, in the remaining five mixtures. These mixtures were labelled as SC10,90, SC20,80, SC30,70, SC40,60, and SC100,0, respectively. Batching of the sandcrete was by weight (see table 1) in accordance with the sandcrete mix ratio. Mixing occurred manually and the sequence of mixing was as follows: river sand was first spread on the hard clean floor of the laboratory, the cement then spread uniformly over the sand. The materials were thoroughly mixed with shovel until the mix appeared uniform. Water was then added gradually so that neither water by itself nor cement could escape. The mixing operation was then repeated as for the dry state until the mixture appeared uniform in color and consistency.

Table 1: Experimental Design

S/No	Sandcrete type	Cement [kg]	River sand [kg]	Bituminous sand [kg]	Water [kg]
1	SC 0,100	12.15	69.26	0.00	6.08
2	SC 10,90	12.15	62.33	6.93	6.08
3	SC 20,80	12.15	55.41	13.85	6.08
4	SC 30,70	12.15	48.48	20.78	6.08
5	SC 40,60	12.15	41.56	27.70	6.08
6	SC 100,0	12.15	0.00	69.26	6.08
Sum		72.90	277.04	138.52	36.48

SC0,100 means sandcrete cube containing 0% bituminous sand and 100% river sand, SC10,90 means sandcrete cube containing 10% bituminous sand and 90% river sand, SC20,80 means sandcrete cube containing 20% bituminous sand and 80% river sand and so on while SC100,0 means sandcrete cube containing 100% bituminous sand and 0% river sand.

2.2.2. Preparation of Specimen for Strength test

Various procedures, including oiling the inside of the 150mm x 150mm x 150mm molds with the help of a brush to lubricate the molds and allow for easy de-molding were carried out. Moulding, de-moulding, and curing were done during the process of preparing the sandcrete cubes for strength test of both the control and the bituminous sand sandcrete samples. The sample was cast into the oiled moulds in triplicate layers with a mason's trowel. The first, second and third layers were tamped with 25 blows each and were uniformly spread over the cross section of the mould in accordance with [34]. Each mold top was smoothened and levelled, and the outside surfaces cleaned. Seventy-two sandcrete cubes were made during this study. After twenty-four hours, the hardened sandcrete cubes were de-molded and put into curing tank containing water until the cubes were tested. The laboratory process also considered the precautions noted in [35,36].

2.2.3 Sandcrete Cube compressive strength test

The sandcrete samples of both hardened river sand and bituminous sand were tested under compression after curing the sandcrete samples for 7, 14, 21 and 28days. Triplicate samples of sandcrete cubes were used for the test. This was done for each of the days of curing in accordance with [37]. Seventy-two samples were crushed.

3. Results and Discussion

In this unit, the results of the testing of specimens have been discussed.

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3.1 Preliminary Test

Table 2 details the physical characteristics of the materials used for this study.

Table 2: Materials physical characteristics

Type of property	River sand	Bituminous sand
Physical appearance	White	Black
Relative density	2.62	2.24
Natural Moisture content (%)	0.70	0.45
Water absorption (%)	0.88	0.55
Bulk density (Kg/m^3)	1720	1350
Coefficient of gradation, C_c	0.75	0.84
Uniformity Coefficient, C_u	2.53	2.18
Fineness modulus	3.02	2.78

3.2 Compressive Strength of Sandcrete Cubes

The 7, 14, 21, and 28 -day compressive strength test results for all compositions are depicted in figure 2. These compressive strength values are obtained as the average of three specimens, meticulously cast from the same proportion and tested under identical conditions. The compressive strength for all the samples increased with time but at different rates. The increase in the sandcrete cubes compressive strength over time implies that as the hydration continues, more calcium silicate hydrate is formed which in turn increases the strength of the sandcrete.

The SC0,100 which is the 100% river sand sample recorded the highest compressive strength values over time with a compressive strength of 8.58N/mm^2 at 28th day of curing which is equivalent to 53.38% higher than its design characteristic strength. The SC10,90, SC20,80, SC30,70 and SC40,60 samples compressive strength values were 4.44N/mm^2, 4.0N/mm^2, 3.64N/mm^2 and 3.42N/mm^2 at 7th day of curing. On the 28th day of curing same samples had compressive strength values of 7.95N/mm^2, 6.00N/mm^2, 5.69N/mm^2 and 4.14N/mm^2 bringing about 44.15%, 33.33%, 36.01% and 17.40% increase respectively from the computed strength on the 7th day. This high strength recorded could also be attributed to the type of OPC used in the production of the sandcrete. The value for the SC100,0 that is 100% replacement of river sand with bituminous sand sample had the lowest compressive strength of 2.26N/mm^2 at 28th day of curing bringing about 73.7% reduction in strength compared to that obtained for SC 0,100 at 28th day of curing. This shows that the sandcrete cubes compressive strengths kept dropping as the percentage replacement of the river sand with bituminous sand increases.

This reduction in strength could be attributed to the bitumen present in the bituminous sand that formed part of the sandcrete matrix microstructure that have caused weakening of the cohesive forces in the sandcrete paste, gel expansion and increase in the internal hydraulic pressure because of the absorption of the bitumen. Hence, lower sandcrete cubes strength development. The SC10,90, SC20,80, SC30,70 and SC40,60 attained 98.5%, 50%, 42.3% and 3.5% more strength compared to the design strength at 28th day of curing, respectively. While SC100,0 (2.26N/mm^2) at 28th day of curing is observed to be approximately 43.5% lower compared to the design sandcrete strength. According to [28], sandcrete with strength of 4N/mm^2 is considered good for building construction. Thus, sandcrete made with 0 to 40% replacement level of river sand with bituminous sand can be used for construction purposes.

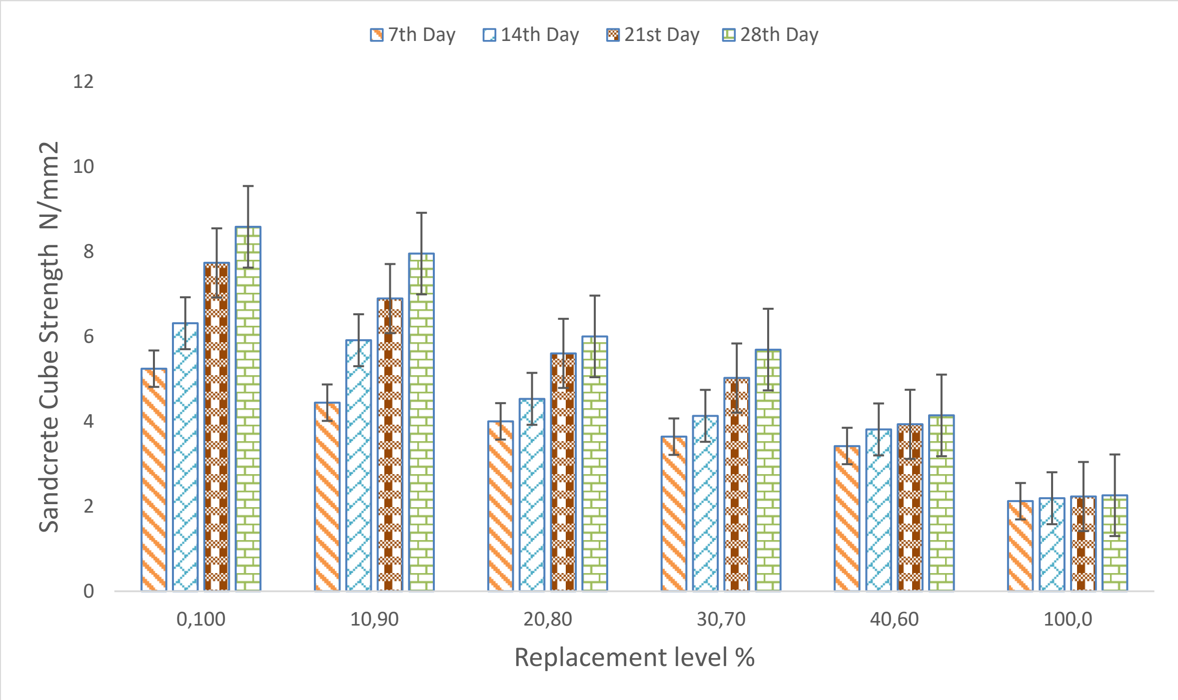

Figure 2: Average compressive strength of sandcrete cubes

4. Conclusion

This study considered the utilization of bituminous sand in the production of eco-friendly sandcrete for sustainable construction. Bituminous sand was used in place of river sand at various replacement levels as a fine aggregate material. Hence, the conclusions made are as follows:

- The compressive strength of bituminous sand sandcrete (BSS) increased as the curing age increases.
- As the replacement level of river sand with bituminous sand increases, compressive strength significantly decreases.
- At 0 - 40% percentage replacement levels average compressive strengths of the sandcrete cubes attained a value greater than the characteristic design strength of the sandcrete.
- Sandcrete made with up to 40% river sand replacement with bituminous sand can possibly be used to produce sandcrete which can be used for building construction.
- The measured compressive strength of SC100,0 sandcrete was 43.5% lower than the designed strength. This reduction could be attributed to the bitumen present in the bituminous sand that formed part of the sandcrete matrix microstructure that have

caused weakening of the cohesive forces in the sandcrete paste, gel expansion and increase in the internal hydraulic pressure because of the absorption of the bitumen.

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