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OPTIMIZING COMPRESSIVE STRENGTH CHARACTERISTICS OF HOLLOW BUILDING BLOCKS FROM GRANITE QUARRY DUST AND SAND

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ABSTRACT

As a result of the overdependence on river-sand for construction activities, there is need to source for a readily available material with comparable strength when used for certain purposes (in this case, sandcrete hollow blocks). This paper evaluates the compressive strength of sandcrete hollow building blocks when its sand fraction is partially replaced with quarry dust. A range of 0%, 10%, 15%, 20% and 25% sand replacement with quarry dust was used in the cement: sand mix ratios of 1:6 and 1:8 for molding the blocks of size 450mm x 225mm x 225mm.These blocks were produced by machine compaction under a pressure of 3N/mm². Results indicate that for mix ratio of 1:6 at 28 days when 10% quarry dust partial replacement was applied, the compressive strength of the blocks was about 7% greater than that of blocks without partial replacement. Also, for the mix ratio of 1:8 at 28 days and 10% partial replacement with quarry dust, the compressive strength of the blocks was about 46% higher than that without partial replacement of the sand fraction. The strength of the blocks increases with increase in quarry dust partial replacement of sand. However, for the mix ratios employed, it is noted that 15% partial replacement of sand with quarry dust gave an optimum compressive strength of 3.8N/mm² and 4N/mm² for the two mix ratios respectively. It is suggested therefore, that the optimum replacement of sand with granite quarry dust as fine aggregates should be 15% of the sand fraction in hollow building blocks of the size and mix ratio adopted herein.

Keywords: *hollow building Blocks, granite dust, sand, partial replacement, compressive strength*

1. INTRODUCTION

According to Seeley [1], sandcrete blocks are walling materials that are made of coarse natural sand or crushed rock dust mixed in proportion with cement and water and is compacted to shapes. NIS 87 [2] defines sandcrete blocks as composite materials made up of cement, sand and water and molded into different shapes and sizes. Sandcrete hollow blocks generally in construction are defined as structural walling units dimensionally larger than bricks and have one or more large holes or cavities passing through it. The solid materials are 50% to 75% of the total volume of the block calculated from the overall dimension [3]. It broadly has porous rough surface and silver grey colour. This makes it attain adequate strength to be used as walling materials. Sandcrete hollow block shave featured for a very long time in building construction works in Nigeria. Seeley [1] grouped sandcrete blocks into two main classes viz: light weight and dense sandcrete blocks. Light weight blocks are non- load bearing and are not suitable to be used in substructure or below the damp proof course. They are intended for use in non -load bearing walls and partitions. Dense blocks are load bearing, and are suitable in substructure and are durable even when exposed to extreme climate. The physical properties of sandcrete blocks among others include strength, durability, fire resistance, thermal insulation etc. In engineering practice, the strength of sandcrete blocks at a given age and cured at a reasonable temperature usually 25^{o}C is assumed to depend primarily on the water-cement ration and degree of compaction [4]. Compressive strength of blocks is a measure of the blocks resistance to axial load application. The recommended strength by BS 2028, [5] is: Mean strength, 3.45N/mm²; Lowest individual strength, 2.59N/mm².From specification, it implies that the least compressive strength of individual block must be at least 75% of the mean value. The Federal Ministry of Works and Housing (1979) in Nigeria [6], recommends a compressive mean strength of 2.1N/mm² and lowest individual strength of 1.7N/mm². NIS 87 [2] specifies

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that the lowest crushing strength of individual load bearing blocks shall not be less than 2.5N/mm^2 for machine compacted and 2.0 N/mm^2 for hand compacted blocks.

2. GRANITE DUST PRODUCTION AND ITS ASSOCIATED USES IN CONCRETE BLOCKS

Crushing granite rock aggregates in quarries generates considerable volumes of quarry fines, often termed "quarry dust". The finer fraction is usually smaller than 5mm in size [7]. The use of quarry dust in concrete according to Chattering et al [8], is desirable because of the benefits such as useful disposal of a by-product, reduction of river sand consumption and increase in strength. Quarry dust has rough, sharp and angular particles, and as such causes a gain in strength due to better interlocking. Quarry dust has been identified as possible replacement for sharp sand in concrete works. Jayewardene et al [9, 10] in their paper "Use of quarry dust instead of river sand for future constructions in Sri Lanka" identified quartz, feldspar, biotite mica, hornblende and hypersthenes as the major minerals present in fresh rock which show mica percentages between 5% and 20%. They added that mica percentages in charnocktic gneiss and granitic gneiss are always less than 5%, similar to sand and therefore suitable for use in civil engineering construction. They reported that sand mining had been banned in some areas of major rivers in Sri Lanka because of its negative environmental impact. Granite rock is abundant in Nigeria giving rise to many quarry sites with large heaps of quarry dust. Hence, quarry dust can be reasonably used as alternative to river sand. Also, Shahul et al [11] observed that natural sand is usually not graded properly and has excessive silt, while quarry rock dust does not contain silt or organic impurities and can be produced to meet desired gradation and fineness as per requirement. This consequently contributes to improving the strength of sandcrete blocks. Agbede et al[12] described quarry dust as a cohesionless sandy material acquired either naturally (which is rare) or artificially by the mechanical disturbance of parents rocks (blasting of rocks) for construction purposes, composed largely of particles with a diameter range of 0.05mm to 5.00mm. They found in their study on "suitability of quarry dust as partial replacement for sand in hollow block production" that quarry dust is cheaper than River Benue sand during rainy season. Sridharan et al [13] conducted shear strength studies on soil-quarry dust mixtures and observed that 20-25% of the total production in each crusher unit in India is left out as waste-quarry dust. This waste problem may be avoided as it could be converted into useful application in concrete production.

The construction industry in Nigeria should expect a serious shortage of sand in the near future due to over exploitation of river sand. The increase in demand for sand has placed immense pressure on sand resources. Therefore, the extraction of this aggregate is bound to have considerable negative effect on the place where they occur [14].Erosion and failure of river banks, lowering of river beds, damage to the bridge foundation sand other structures situated closer to the rivers, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining [9]. This over dependence on river-sand could have a crippling effect on the construction industry as well as the economy of Nigeria, if there is no close-substitute. Near-shore marine sand, dune sand and quarry waste (crushed rocks) are the other alternative sources available for concrete production in Nigeria. Manufactured sand or quarry fine is increasingly becoming more accepted as an alternative to natural sand where the traditional sources are becoming less available due to resources being depleted and the need to make use of ever-growing stockpiles of quarry fines [15].Manufactured sand is produced by the crushing of rock, typically in locations where there is a shortage of natural sand. It is also referred to as "crushed rock sand", "stone sand", "crusher sand" and "crushed fine aggregate" [16]. There is no consistent definition for quarry fines used throughout the quarrying sector or construction industry. This leads to confusion of definitions in the published literature. The phrases quarry fines, quarry dusts and quarry wastes are used interchangeably, and are used to refer to materials which are of different particle size ranges. It may, or may not be produced intentionally, and may not be waste materials at all[15]. Quarry fines are generated by processes related to blasting, processing, handling and transportation. Particle shape, grading and fines content are a function not only of the crushing process but also of the mineral composition and texture of the parent rock [7]. As a rule of thumb, a coarse-grained rock will generate fewer fines than affine-grained rock. Also, minerals with low abrasion resistance (i.e. softer materials) will breakdown more readily than harder materials and produce more fines. In many quarry locations, the term 'fines' refers to undersized material from crushing plant that is given no further processing and accumulates overtime. The production of aggregates from crushed rock generates a proportion of fines as a normal consequence of variable responses of the rock material to the crushing process. A number of strategies have been developed to make use of fines, in accordance with the needs of local markets, regulation and legislation [7]. Crushed rock aggregate quarrying generates considerable volumes of quarry fines, often termed 'quarry dust'. Such manufactured sands are currently produced from hard rock quarries in several areas of Nigeria.

The use of quarry dust also called manufactured sand has been accepted as a building material in the industrially advanced countries of the western world for the past decades [17]. As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of quarry rock dust in the industrialized nations like Australia, France, Germany and the UK has reached more than 60% of its total production.

Radhikesh et al [18] carried out an experimental study to investigate the suitability of quarry dust as fine aggregate for producing blocks. Test results revealed that the replacement of fine aggregate by quarry dust up to 50% has a negligible effect on the reduction of physical and mechanical properties while there is a saving of up to 56% of money and the percentage of saving would be more for mass production of blocks.

Manasseh [19] investigated the suitability of crushed granite fines to replace river sand in concrete production for rigid pavement. It concluded that, based on economic analysis and strength test results, 20% replacement of river sand by quarry dust is recommended for production of concrete for rigid pavement.

3. MATERIALS AND METHODS

The materials used for this work are sand, quarry dust, cement and water. The sand is passed through 3.35mm British Standard test sieve[4]and is free from deleterious substances (clay, loam, dirt and any organic or chemical matters).The sand has a specific gravity of 2.66, an average moisture content of 0.7 and a coefficient of uniformity of 2.95. The fine aggregates used are well graded and these are represented in Figures 1 and 2.

The quarry dust used was collected from Reynolds Construction Company's quarry site at Ofosu, Edo state. It was sieved appropriately and has a specific gravity of 2.7, an average moisture content of 0.35 while its coefficient of uniformity is 10.7.

The permeability of the block was determined using Darcy's law for fluid flow in a permeable medium. To get the water absorption coefficient, the block sample was partially immersed in water and was allowed to rise by capillary action. After some time, moisture begins to diffuse through the boundary surface and would change its weight overtime. To obtain the porosity, the block was fully immersed in water after which the volume of void was obtained. The porosity was measured as the ratio of the volume of voids to the initial volume.

The results obtained from carrying out the hydrothermal test are recorded in Tables 7 and 8.

The brand of cement used is the Ordinary Portland Cement (OPC), conforming to BS 12 [20]and produced by Dangote Industries PLC. Potable tap water from the Civil Engineering laboratory of the University of Benin was used throughout the research experiments. Water is important in starting the reaction between cement and other constituent materials. The binding property of cement cannot take effect without water.

3.1. Experimental Procedure

A total number of 90 sandcrete hollow blocks were moulded comprising of an equal number of 450 x 225x225mm. 45 blocks each using mix ratio of 1:6 and 1:8 (one part fine aggregate) with a fine aggregate constituent variation of sand and quarry dust replacement proportions of 0%, 10%, 15%, 20% and25%. The blocks were cured for 7, 14, and 28 days. They were crushed after each curing period. The materials were divided into batches using the two mix proportions. Each batch was thoroughly mixed with a shovel to produce uniform and consistent colour. The machine moulds of 450x225x225mm was filled with each mix ratio and vibrated for about 60 seconds. The compacted block was demoulded and kept in a dry place for curing. The demoulded blocks were first kept in a damp place for the first 24hours to prevent rapid drying after which they were cured daily with two sprays of water in the morning and evening daily until just before the compressive test was carried out. The 45 blocks each, for the mix proportions being considered are separated into 5 parts (9 blocks per part)for the varying percentages of0%,10%,15%,20% and 25% sand replacement with quarry dust were tested. The nine blocks are in turn separated into three parts of which their average(s) determine the compressive strength values of 7, 14 and 28 days curing under the two mix proportions.

4. RESULTS AND DISCUSSIONS

The properties of materials used for this work were determined and the results of the compressive strength of hollow blocks made with partial replacement of sand with quarry dust are presented in Tables 1 to 6 for the various mix ratios employed. It is observed from the mix ratios, that the addition of quarry dust enhanced the compressive strength of the sandcrete blocks. It was seen for mix ratio,1:6,at 28 days when 10% granite fines was added to 90% sand , that the strength obtained is about 7% greater than that of 0% granite fines to 100% sand mix of the same size and proportion (Table 3). Also for mix ratio 1:8, at 28days when 10% granite fines is added to 90% sand, the strength obtained is about 46% greater than that of 0% granite fines to 100% sand mix of the same size and proportion (Table 6). For both mix ratios, it is noted that the compressive strength attains a maximum value or peak value at 15% (Tables 1 to 6) sand replacement for the various ages of the blocks, after which it depreciated. From the results of porosity, permeability, water absorption coefficient of the sandcrete hollow blocks against quarry dust content as shown in Tables 7 and 8; it is seen that these properties decreases with increase in sand replacement by quarry dust. Remarkably at 25% sand replacement with granite quarry dust, these properties reduced drastically to insignificant levels (Tables 7 and 8).

Table 1: Compressive Strength results of Sandcrete Blocks (1:6 mix ratio) for7 Days.

S/N	Quarry Dust (%)	Dry Weight(kg)	Dry Density(kg/m^3)	Average Crushing Strength (n/mm^2)
1	0	26.00	1154.50	2.96
2	10	26.00	1150.10	3.05
3	15	27.00	1233.50	3.29
4	20	27.20	1194.00	2.53
5	25	27.50	1207.10	2.26

Table 2: Compressive Strength results of Sandcrete Blocks (1:6 mix ratio) for14 Days.

S/N	Quarry Dust (%)	Dry Weight (kg)	Dry weight(kg/m^3)	Average Crushing Strength (n/mm^3)
1	0	25.70	1128.10	3.01
2	10	28.00	1229.10	3.22
3	15	27.70	1216.00	3.27
4	20	28.00	1229.10	3.13
5	25	27.00	185.2	3.01

Table 3: Compressive Strength results of Sandcrete Blocks (1:6 mix ratios) for 28 Days.

S/N	Quarry Dust (%)	Dry weight(kg)	Dry Density(kg/m^3)	Average Crushing Strength(n/mm^2)
1	0	27.70	1216.00	3.50
2	10	27.70	1216.00	3.73
3	15	26.30	1154.50	4.00
4	20	27.10	1189.60	3.45
5	25	26.20	1150.10	3.33

Table 4: Compressive Strength results of Sandcrete Blocks (1:8 mix ratios) for7 Days.

S/N	Quarry dust (%)	Dry Weight(kg)	Dry density(kg/m^3)	Average Crushing Strength (n/mm^2)
1	0	25.90	1130.90	1.30
2	10	26.70	1152.00	2.56
3	15	25.40	1112.00	2.80
4	20	25.70	1128.10	2.47
5	25	25.40	1115.00	2.27

Table 5: Compressive Strength results of Sandcrete Blocks (1:8 mix ratio) for14 Days.

S/N	Quarry Dust (%)	Dry Weight(kg)	Dry Density(kg/m^3)	Average Crushing Strength (N/mm^2)
1	0	26.00	1168.60	1.83
2	10	26.20	1150.10	2.93
3	15	26.60	1167.60	3.05
4	20	26.90	1180.80	2.49
5	25	26.40	1158.80	3.00

Table 6: *Compressive Strength results of Sandcrete Blocks (1:6 mix ratio) for 28 Days.*

S/N	QUARRY Dust (%)	Dry Weight(Kg)	Dry Density(Kg/m^3)	Average Crushing Strength (N/mm^2)
1	0	26.20	1150.10	2.05
2	10	26.90	1180.80	3.00
3	15	26.70	1172.00	3.80
4	20	26.20	1150.10	3.62
5	25	26.50	1163.20	3.36

Table 7: Hygrothermal result of sandcrete blocks after 28 days for 1:6 cement:sand mix ratio

S/N	Quarry Dust (%)	Porosity (%)	Permeability (%)	Water Absorption coefficient(%)
1	0	12.50	0.057	0.080
2	5	10.30	0.049	0.060
3	10	8.200	0.022	0.040
4	15	6.000	0.015	0.020
5	20	5.000	0.001	0.010
6	25	3.000	-	-

Table 8: Hygrothermal result of sandcrete blocks after 28 days for 1:8 cement:sand mix ratio

S/N	Quarry DuST(%)	Porosity (%)	Permeability (%)	Water Absorption coefficient(%)
1	0	12.562	0.059	0.089
2	5	10.514	0.053	0.067
3	10	8.274	0.027	0.043
4	15	6.126	0.018	0.025
5	20	5.158	0.001	0.010
6	25	3.125	-	-

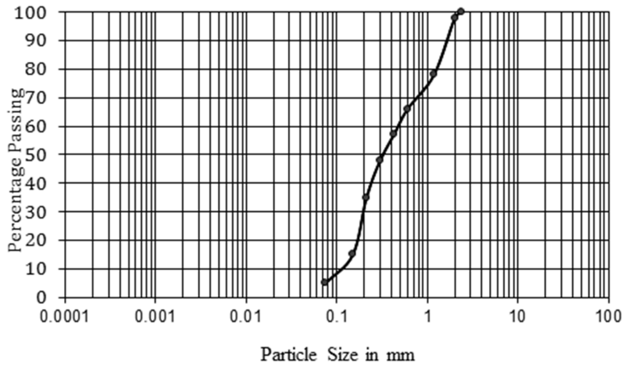

Figure 1: Grading curve for fine aggregate (sand)

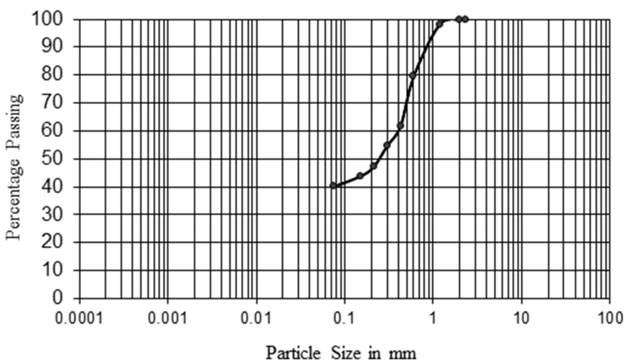

Figure 2: Grading curve for fine aggregate (Quarry Dust)

5. CONCLUSION AND RECOMMENDATION

In summary, the following deductions were drawn from the tests carried out on the sandcrete hollow blocks with varying quarry dust at different ages and mix ratios.

i. 15% granite quarry dust by volume of the fine aggregate is appropriate in sandcrete block mixture for best compressive strength. It can also be seen that the compressive strength value at 15% sand replacement with granite quarry dust, conforms to the NIS block standard (NIS 87:2000); which prescribes an average value of 2.5N/mm^2 and 1.72N/mm^{2}for load bearing and non-load bearing blocks respectively (Compare with data in Tables 1 to 6).

The result obtained is also greater than the mean value prescribed by the British Standards in BS 2028 (1985) and that by The Federal Ministry of Works and Housing in Nigeria.

ii. From Tables 1 to 6, it can be seen that as the percentage content of quarry dust increases, there is no gainful effect on the compressive strength.

iii. There is a considerable increase in the strength with age of the sandcrete hollow block made with quarry dust (granite fines) inclusion.

iv The hydrothermal property of the block unit in terms of the porosity, permeability and water absorption coefficient reduced steadily as the percentage of granite fine increased.

v. Due to the better particle packing and consequent reduction in the volume of voids, there would be an increase in strength of wall compartment of buildings built with such blocks.

vi. Further, the addition of granite fines improves the grading of the fine aggregate content thereby improving the workability of the mix and enhancing the compressive strength.

vi. Block made with quarry dust would be able to withstand high temperature in case of theevent of fire accidents.

vii. It could also be used in waterlogged environment without any fear of dilapidation of the structure in which it had been used to build.

viii. The appearance of the blocks is better in the sense that it has a brighter colour compared with the blocks with no quarry dust in them. It has a course texture on the surface, therefore screening (plastering) is made easier.

ix. Blocks made with granite quarry dust can be used in the construction of erosion structure.

As with most engineering concerns and civil Engineering construction in particular, the strength, quality, durability and most importantly safety of structures are of utmost consideration in any circumstance. Therefore utilizing the findings from this work is suggested. It is advised that the manufacturer of blocks should adopt the method suggested in this paper, as using 15% quarry dust replacement gives the desired qualities of strength, durability and safety in structures.

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