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Effects of Granite Fines on the Structural and Hygrothermal Properties of Sandcrete Blocks

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Abstract: Sandcrete block as a building component has been in use in Nigeria and many other nations for a very long time. However, the high and increasing cost of the constituent materials has contributed to the non-realization of adequate housing for both urban and rural dwellers in many African countries. Therefore, any material that can complement sand or cement thereby reducing the production cost will be of great interest. But, blocks, like any typical building component, have properties that are used for their classification, quality-determination and hence, their application. Each block has its unique set of properties based on its constituent mix, presence of admixtures and manufacturing process. In this study, tests were performed on hollow sandcrete blocks containing cement, sharp sand and granite fines in varying proportions to determine their structural and hygrothermal properties. The percentage of granite fines by volume of the total fine aggregate was varied in steps of 5% to a maximum of 30%. Results of the tests show that the inclusion of granite fines in the sand-cement matrix has a very significant effect on the compressive strength of sandcrete blocks. It was also, observed that for both mix proportions, 15% granite fines content is the optimum for improved structural performance. The hygrothermal properties of the block with 15% granite fines content indicate it as the most compact.

Key words: Effects, granite fines, engineering properties, sandcrete blocks

INTRODUCTION

Blocks made from a mixture of sand, cement and water are called 'sandcrete' blocks. They are used extensively in virtually all African countries including Nigeria. For a long time until perhaps a few years ago, these blocks were manufactured in many parts of Nigeria without any reference to any specification either to suit local building requirements or for good quality work. It is comforting to observe that the situation has since changed as the standards organisation of Nigeria now has a document in place giving the specifications both for the manufacture and use of standard sandcrete blocks. However, the high and increasing cost of the constituent materials has contributed to the non-realization of adequate housing for both urban and rural dwellers in the country. Consequently, manufacturers resorted to sharp practices in mix proportion and unacceptable substitutes for sand or cement. Therefore, any material that can complement sand or cement thereby reducing the production cost will be of great interest. Alternatives to cement or sand as a material for construction are very desirable stimulants for socio-economic development of the country.

The presence of mineral admixtures to building products has been observed to impart significant improvement on its strength, durability and workability. Mental (1994), investigated structural effects of admixtures in concrete. It was reported by Falade (1997) that the 28 days compressive and flexural strength values increased when cement was partially replaced with powdered glass in concrete manufacture. Okpala (1993) investigated the effects on some engineering properties of sandcrete blocks when cement was partially replaced with Rice Husk Ash (RHA). The compressive strength of the blocks was reported to decrease with increasing RHA content. Cisse and Laquerbe (2000) observed that the mechanical resistance of sandcrete blocks obtained when raw ash was added increased in performance over the classic mortar blocks.

In order to enhance, the compressive strength of sandcrete blocks, granite fines are sometimes used as a partial replacement of the sand content in the sand cement matrix (Falade 1993, 1999). Granite fines are readily available at limestone quarries in Nigeria where limestone rocks are blasted to produce granite chippings. These chippings are now extensively used in Nigeria as coarse aggregate in the manufacturing of concrete. There is

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however, no document in place, to the best knowledge of the authors, giving specifications for the use of the granite fines in the manufacture of sandcrete blocks. Therefore, the main thrust of this study is to determine the optimum percentage by volume of the granite fines that should be used as a partial replacement for the sand in the sand-cement matrix for improved structural performance.

Blocks, like any typical building components, have properties that are used for their classification, quality determination and hence, their application. Due to their porous nature, sandcrete blocks generally take in fluid when exposed to moist conditions. The need to ascertain both structural and hygrothermal properties of sandcrete blocks as useful guides to their application cannot be overemphasized. This study, therefore, investigates the structural and hygrothermal properties of sandcrete blocks produced with varying proportions of sand, cement and granite fines. Hygrothermal properties are fluid-related properties governing the flow of liquids, gases and ions across the membranes of a porous medium under certain thermal conditions. Roels *et al*. (2004) carried out similar experimental studies on some building materials. The hygrothermal properties considered in this study are porosity, permeability, water absorption coefficient and sorptivity.

MATERIALS AND METHODS

The material constituents, their mix, presence of admixtures and manufacturing process are important factors that determine the properties of sandcrete blocks. The materials used and method of manufacture employed in this investigation are thus, presented.

Materials of sandcrete blocks: The sandcrete blocks are made of sand, cement and varying proportions of granite fines and water.

Sand: The sand used was clean, sharp river sand that was free of clay, loam, dirt and any organic or chemical matter. It was sand passing through 4.70 mm zone of British standard test sieves. The sand had a specific gravity of 2.66 and an average moisture content of 0.90%. The coefficient of uniformity of the sand was 2.95.

Cement: The cement used was ordinary Portland cement from the West African Portland cement company, Ewekoro in Ogun State of Nigeria.

Water: The water used was fresh, colourless, odourless and tasteless potable water that was free from organic matter of any type.

Granite fines: The granite fines were obtained from the limestone quarry in Ogun state of Nigeria. The specific gravity of the granite fines was 2.7 and the average moisture content was 0.32%. The coefficient of uniformity of the granite fines was 10.7.

Grading of aggregates: The grading of an aggregate defines the properties of different sizes in the aggregate. This grading has a considerable effect on the workability and stability of the mix. Wet sieving analysis, which is in accordance with international standard was used. The particle size analysis of the sand used in this study is shown in Fig. 1 and that of the granite fines is shown in Fig. 2.

Manufacture of sandcrete blocks: The blocks (all hollow) were manufactured with the use of a vibrating machine. The blocks were all 450×225×225 mm in size. The standard mix proportion is 1:6 that is one part by volume of cement to 6 parts by volume of coarse sand but a mix proportion of 1:8 is used by many commercial sandcrete block manufacturers. In this research effort, both mix

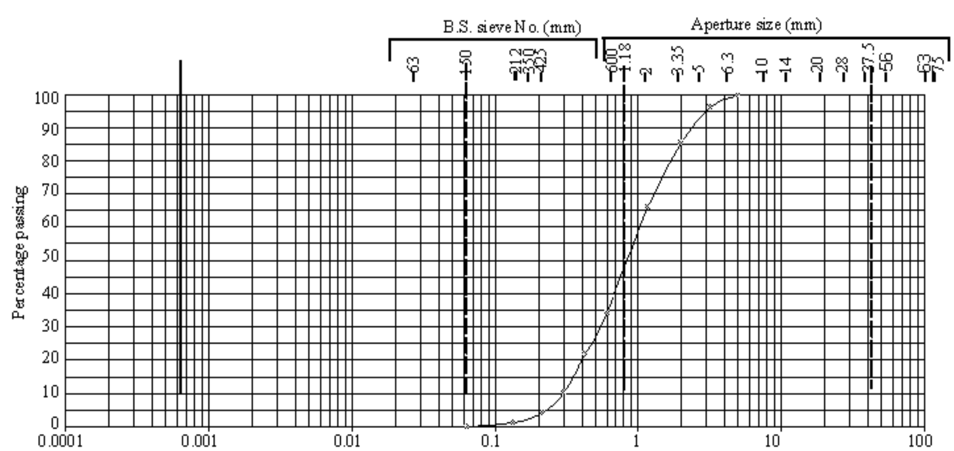

Fig. 1: Particle size distribution curve of sand

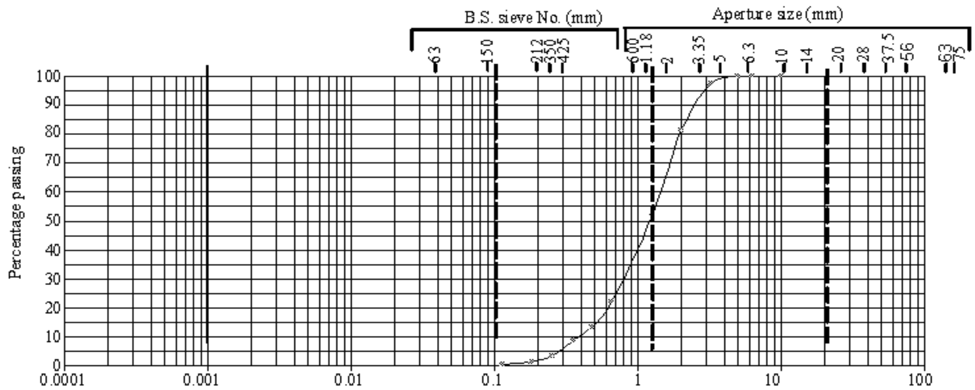

Fig. 2: Particle size distribution curve of granite fines

proportions have been used. Granite fines are used as a partial replacement for the sand in the sand-cement matrix. The percentage of the granite fines by volume of the total fine aggregate (sharp sand) is then varied in steps of 5% to a maximum of 30%.

In the manufacture of these blocks, hand mixing was employed and the materials were turned over a number of times until an even colour and consistency were attained. Water was added through a fire hose in just sufficient quantity and further turned over to secure adhesion. It was then rammed into the machine moulds, compacted and smoothed off with a steel face tool.

After removal from the machine moulds, the blocks were left on pallets under cover in separate rows, one block high and with a space between 2 blocks for at least 24 h and kept wet during this period by watering through a fine watering hose. Testing for compressive strength was then carried out at ages 7, 14, 21 and 28 days.

The hygrothermal properties: Block units exposed to flood environment take in water due to their porous nature. The volume of water absorbed is an indication of pore volume, which depends on the interstitial arrangement of the particles of the constituent materials at micro level. It is therefore, necessary to investigate the effects of the admixture on the hygrothermal properties of the block. The properties are determined as follows:
Porosity, υ is given by:

$$\upsilon = \frac{V_f}{V} \times 100\% \quad (1)$$

Permeability: The term permeability is often loosely used to cover a number of different properties. In this study, it is defined as the property of a porous medium, which characterizes the ease with which a fluid will pass through it, under the action of a pressure differential. Darcy's law for fluid flow in a permeable medium expresses permeability in terms of measurable quantities and states that the steady state rate of flow is directly proportional to the hydraulic gradient. Thus, permeability, K can be expressed as:

$$K = \frac{Q}{A[h/l]} \quad (2)$$

For uni-axial penetration employed in this investigation, it is given as:

$$K = \frac{\upsilon d^2}{2th} \quad (3)$$

Water absorption coefficient, A_w: This property is obtained using the partial immersion method. The principle is that a material that allows liquid moisture diffusion through its boundary surface would change its weight with time when it is brought in contact with liquid water. Hence, water absorption coefficient, A_w, is calculated as (Mukhopadhyaya *et al*., 2002),

$$A_w = \frac{M_t - M_i}{A\sqrt{t}} \quad (4)$$

Sorptivity: It is a measure of the capacity of the medium to absorb liquid by capillary action. The absorption of water into concrete under capillary action is dependent on the square-root of time (Hall, 1989).

$$A' = S\sqrt{t} \quad (5)$$

There are various experimental methods used to determine hygrothermal properties of a material. However, in most cases, the test method chosen for a particular property is always the one appropriate to the predominant transport mechanism acting on the block. After evaluation of various methods, it was decided that capillary rise method be employed. Basically, a sample of sandcrete block is placed with one edge in contact with water surface. The height of capillary rise is measured. The fineness of the capillary pores in the sandcrete blocks causes absorption of water by capillary attraction. Hence, a measure of the rate of absorption provides a useful indication of the pore structure. If water is absorbed rapidly, it shows that the pores are large; if the absorption rate is slow, then the pores are small. This is considered to be a useful measure of the durability of building materials.

Full immersion method was also, employed during this study to determine porosity. The porosity results obtained with the 2 methods, namely capillary rise and full immersion were compared. Necessary precautions were taken, while taking the readings and in ensuring that the specimens were as dry as possible before coming in contact with water.

RESULTS AND DISCUSSION

Results are presented in graphical form Fig. 3 and 4 show plots of compressive strength against percentage content of granite fines for the 2 mix proportions used in this investigation.

For the blocks made with a 1.6 mix proportion, the graph (Fig. 3) shows that a percentage granite fines content of 15% gave the highest compressive strength for all ages of the sandcrete block. In addition, the compressive strength increased to a maximum at about 15% granite fines content and then decreased as the percentage granite fines content increased.

At 28 days, the compressive strength was 4.19 N mm^{-2} for the 225 mm blocks at a mix proportion of 1:6 and 2.59 N mm^{-2} at a mix proportion of 1:8. The inclusion of granite fines is responsible for higher density of the blocks with a consequent increase in the compressive strength. The compressive strength increased as the percentage of granite fines content increased up to 15% after, which the compressive strength decreased with increase in the percentage granite fines content.

The enhanced strength obtained was perhaps also due to better particle packing and the consequent reduction in the volume of the voids. Furthermore, the addition of granite fines improved the grading of the fine aggregate content, thereby improving the workability of the mix and enhancing the compressive strength.

It is worthy of note that necessary precautions were taken, while conducting the experiments to determine the hygrothermal properties. Specifically, it was ensured that the specimens were as dry as possible before coming in contact with water. The hygrothermal properties presented are for the 1:6 mix for 0-15% granite fines content.

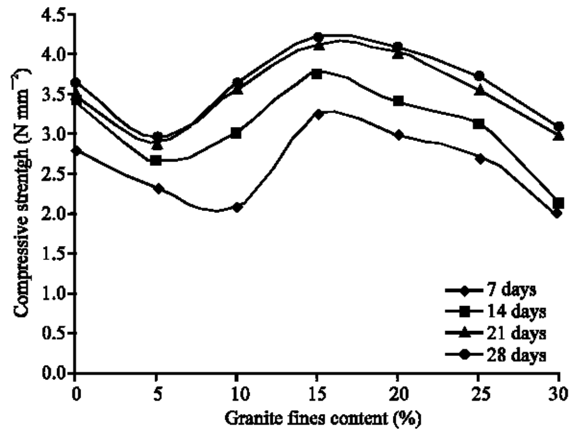

Fig. 3: Plot of compressive strength against percentage granite fines content for 1:6 mix

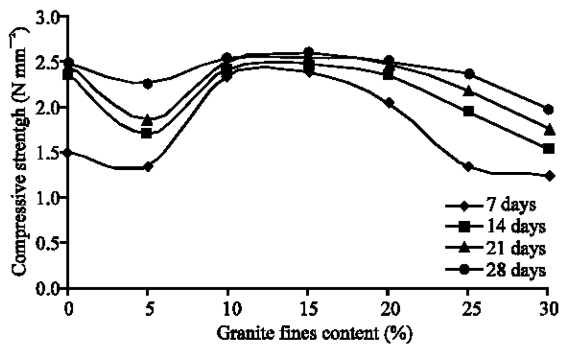

Fig. 4: Plot of compressive strength against percentage granite fines content for 1:8 mix

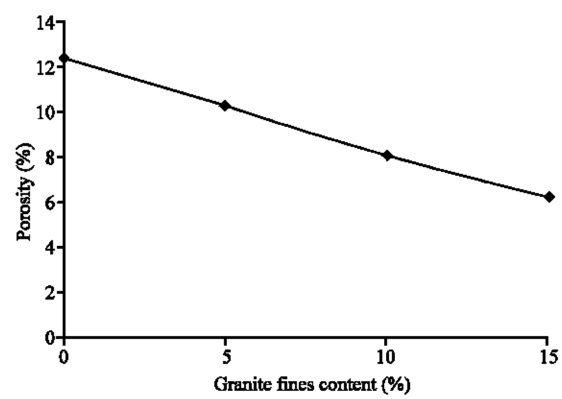

Fig. 5: Plot of porosity against percentage granite fines content for 1:6 mix

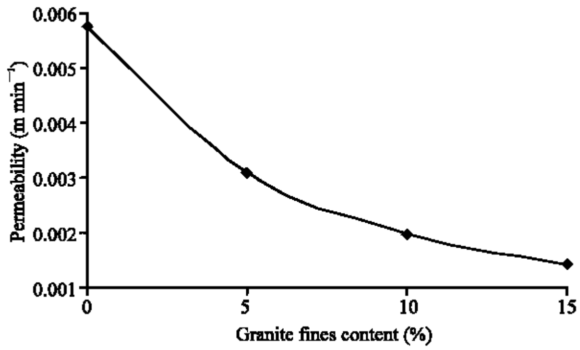

Fig. 6: Plot of permeability against percentage granite fines content for 1:6 mix

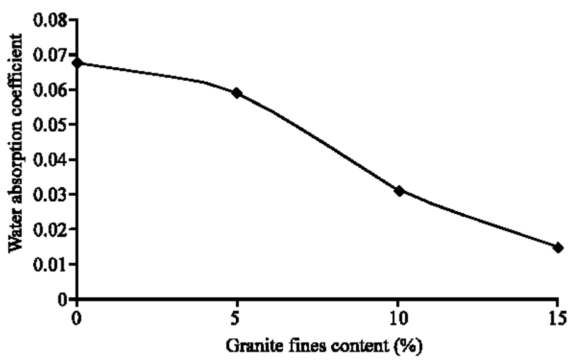

Fig. 7: Plot of water absorption coefficient against percentage granite fines content for 1:6 mix

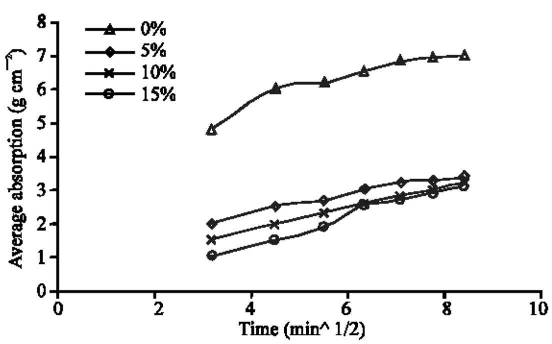

Fig. 8: Average absorption against time for 1:6 mix

The plot of porosity against percent granite fines content, Fig. 5, shows porosity of the material reduces as the percentage granite fines content increase.

From 12.5% for the control specimen (0% granite fines content), it gradually reduces to 6% for the 15% substitution. This makes sandcrete block with 15% granite fines content suitable for application in more humid areas. This implies substitution of granite fines with sand in a sandcrete block makes it more compact.

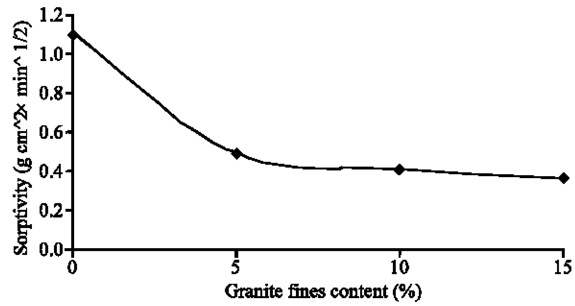

Fig. 9: Sorptivity against percentage granite fines content for 1:6 mix

The bond between the cement and granite fines becomes stronger leaving little pore volume.

In Fig. 6, permeability of the block reduces gradually as the granite fines content increases. The porosity of the block with 15% granite fines content is just 50% of that of the control (Fig. 5) but its permeability reduced to as low as 9% of the control value. The permeability plot indicates that the presence of granite fines makes it more difficult for liquid to flow through the block. It can be deduced that the block becomes less permeable as the percentage of granite fines substituted increases.

Determination of the water absorption coefficient is of relevance in knowing how the block will perform under moist conditions and subsequently where to use the block-whether in dry or moist environments. In Fig. 7, the water absorption coefficient, A_w, plot against the percentage granite fines content shows little difference between that of the control and that of the 5% granite fines content. However, at 10% substitution, A_w reduces to 50% of that of 5%. About 8% reduction is obtained between A_w for the control block and that of the block with 15% granite fines content.

The plot of the average absorption of the block against time, Fig. 8, shows an almost linear relationship with the square root of time for each percentage granite fines contents in the mix. It is observed that addition of granite fines reduced average absorption drastically.

Sorptivity is a measure of the capacity of the medium to absorb liquid by capillarity. It is observed in Fig. 9 that this capacity is drastically reduced when the granite fines are added. The sorptivity for the sandcrete blocks with varying percentage granite fines content is almost the same for all percentages.

In order to know the effects of the test method on porosity values obtained, the data for the full immersion method are compared with those obtained with the capillary rise method. Figure 10 shows that the porosity values obtained for the full immersion method are generally 4% higher than those of the capillary method.

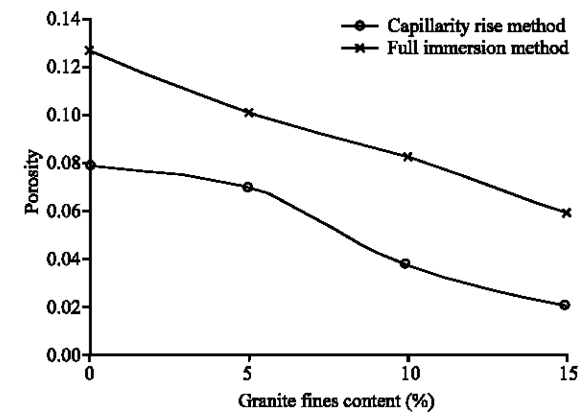

Fig. 10: Comparison of porosity test methods

This difference could be attributed to over-soaking of the specimens. The difference is found to reduce as the percentage of granite fines substituted increases.

CONCLUSION

The main conclusions derived from this investigation are as follows:

- Granite fines have a fairly significant effect on the compressive strength characteristics of sandcrete blocks. For blocks made with the 2 mix proportions used in this investigation, the compressive strength values at 28 days increased, being over 15% for the blocks made with a mix proportion of 1:6 and over 4% for the blocks made with a mix proportion of 1:8
- There is an optimum granite fines content above, which the compressive strength of the blocks began to fall as the percentage granite fines content increased
- For both mixes, this optimum granite fines content was found to be about 15%
- Although, the compressive strength of sandcrete blocks fell as the granite fines content went above the optimum value, yet it was observed that the values were still well above the control strength values even for sandcrete blocks with percentage granite fines content of 25%
- The compressive strength values of sandcrete blocks increased with age. For example, for the blocks containing 15% granite fines and manufactured using a mix proportion of 1:6; the compressive strength at 7 days was 3.24 N mm^{-2}, whereas at 28 days the compressive strength was 4.19N mm^{-2}; an increase of over 29%
- Hygrothermal results also show that the best properties of the sandcrete blocks are obtained at the optimum granite fines content of 15%. At this optimum value the sandcrete block obtained is very compact

ACKNOWLEDGEMENTS

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Notations:

A = Liquid contact area of permeable medium perpendicular to flow (m^2)
A' = Cumulative infiltration
A_w = Water absorption coefficient
h = Hydraulic head (m)
K = Coefficient of permeability or hydraulic conductivity ($m\ s^{-1}$)
l = Length of flow path (m)
M = Specimen mass gain (kg)
M_t = Specimen mass after time, t (kg)
M_i = Initial mass of the specimen (kg)
P = Percentage substitution of admixture (%)
Q = Liquid flow rate (m^3/s)
S = Sorptivity ($m/s^{½}$)
V = Volume of material sample (m^3)
t = Time taken for liquid to rise (s)
V_f = Volume of water absorbed (m^3)
υ = Porosity of the material (%)

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