Strength Property Of Sandcrete Hollow Blocks Produced With Sludge As A Partial Replacement For River Sand

[1] Nwadike Ethelbert C., [2] Chiemela Chijioke, [3] Chukwudi Prince E., [4] Onyewuchi Chibueze M.

[1, 2, 3, 4] Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria

DOI: 10.29322/IJSRP.12.05.2022.p12532
http://dx.doi.org/10.29322/IJSRP.12.05.2022.p12532

Paper Received Date: 20th April 2022
Paper Acceptance Date: 5th May 2022
Paper Publication Date: 14th May 2022

Abstract- This work investigated on the strength poperties of sandcrete hollow blocks produced with sludge as partial replacement for river sand. The properties considered were the compressive strength and water absorption. A total of 16 sandcrete blocks were produced with a single mix ratio of 1:6 (cement:sand) using a standard mould of 450mm x 225mm x 225mm having two hollow size of 131mm x 154.5mm x 225mm. The river sand used has a fineness modulus value of 2.93 and the percentage replacement of river sand with sludge was varied from 10% to 30%. The sandcrete blocks produced were cured and tested for their 28day compressive strength and water absorption. The test result shows that the compressive strength value at 10% replacement of river sand with sludge gave a highest value of 3.96N/mm^2, while it was observed that the water absorption value of the blocks increases with increase in the sludge replacement.

Index Terms- Sandcrete Block, River Sand, Sludge, Compressive Strength, Water Absorption.

I. Introduction

Sandcrete blocks are prismatic precast units made from a mixture of cement, sand and water. (Okpala, 2003). This mixture is at times described as cement stabilized sand. Thus, sandcrete block is the product of moulding the particulate plastic mixture into a desired block geometry under pressure or a combination of vibration and pressure for effective consolidation. It is sometimes referred to as a micro-concrete due to fine aggregate particles making up the material as compared to coarse aggregate and fine aggregate in concrete. This term has probably misled people to think of sandcrete blocks as having the same properties as concrete.

Traditionally, walls of houses have been constructed of mud but this practice is fast dwindling to obscurity since the advent of sandcrete blocks. The early history of its manufacture is not known but by 1960 it had established an important place in building industry in Nigeria. Sandcrete block manufacturing has over the years come to become one of the most important industries concerned with building construction in Nigeria. Early production of sandcrete blocks started with hand- moulding technique and natural curing but it is now made by semi-mechanised and fully automatic plants. Major development is seen mainly in the design and use of power operated machine for making blocks. Rosachometta vibrating machine is most popular for making Sandcrete blocks in Nigeria . Additives such as accelerators, workability aid pigments and water repellants compounds are not added to Sandcrete mixes. Sandcrete block is the principal wall unit in Nigeria as well as other African Countries. These blocks are intended for use in buildings, including walls, partitions, fences, balustrades or parts thereof.

The load bearing blocks are those which when incorporated in a wall or similar structure are capable of sustaining loadings from external sources in addition to the weight of the wall. On the other hand, non-load bearing blocks are not required to sustain any load other than their self- weight. Ideally, these strength grading should correspond to the strength of blocks produced in the block factories but this is never so because they produce blocks without adherence to the specifications

A survey conducted on block-making practice in several African countries revealed that blocks were frequently produced without reference to any specification to suit the local building requirement and that there is a wide variation in the strength of blocks as manufactured (Tyler, 1996). Fifteen years later another survey of parts of Nigeria showed that this situation is still unchanged (Florek, 2005). Also, survey in eastern Nigeria still reflect the trend (Okolie, 2004). Recent studies in Imo state revealed that there is an absence of National Building Code and Regulations, and an absence of standards for the production of many building materials, including sandcrete blocks. This lack of standards and quality control results in production of sub-standard materials and the use of these materials have dangerous consequences for the building delivery process such consequences includes:

-Rampant building failure and/or collapse, which many instances involve, lie loss of human lives.

- High maintenance cost of building.

Thus, the block manufacturing industry has a very important role to play in a country such as Nigeria where the construction industry has been increasing rapidly. Many block factories have consequently sprung up in the last decade to meet with the high demand for this constructional unit. It is therefore important that their product should be of good quality so that our buildings of which these products form a part may continue to give satisfactory performance throughout their design life.

Owing to this, there is every need for the optimization and characterization of the materials used in the construction industry (while producing hollow blocks), also disposal of sludge which is the final waste product from a water treatment plant and quarry dust which is a waste product gotten from a quarry plants are problems to the environment. The quest to find the solution to this problem gave birth to this research topic **"Strength Property of Sandcrete Hollow Blocks Produced with Sludge as a Partial Replacement for River Sand"**

II. Objectives of Study

The main objective of this work is to investigate the strength property of sandcrete hollow blocks produced with sludge as partial replacement for river sand. While, the objectives of this project are:

a) To characterize the properties of the constituent materials of sandcrete hollow blocks, made with sludge as partial replacement for river sand.
b) To determine experimentally the compressive and water absorption properties of the block.
c) To determine the optimum percentage replacement of river sand with sludge.
d) To make recommendations.

III. Materials and Method

2.1 Materials

In this work, the materials used includes; cement, river sand, water and sludge gotten from a water treatment plant in Enugu which was dried and grinded in order to get a smooth dry sludge particle.

2.2 Methods

Various tests were performed during this research and they includes;

a) Sieve analysis
b) Chemical composition and physical test on sludge
c) Bulk density
d) Compressive strength
e) Water absorption test.

2.3 Sieve Analysis

The sieving method adopted was dry sieving and a sample size of about 300g was used for the river sand and quarry dust. This test was carried out on both aggregate to determine the particle size distribution. This test was done in the laboratory using sieve size of different diameter and were stacked according to the size of sieve, that is, the largest ones on top while the smaller at the bottom. The equipment used in carrying out this test are; sieves of different diameter, a scoop which was used to collect the sample, a weighing balance which was used to determine the mass of the aggregate and a brush which was used to remove dirt from the sieve. Sieving was done mechanically using a sieve shaker.

2.4 Laboratory test on Sludge

This physical and chemical analyses conducted on the sludge is to determine the physical and chemical compositions, to know if it is a suitable material for block production.

2.5 Bulk Density Test

Bulk density gives valuable information regarding the shape and grading of the aggregate. It refers to the mass of material per unit volume, including the voids between the particles. The dry method was adopted for the determination of the bulk densities of river sand and quarry dust this test was carried out in accordance with BS 812: Part 2 and Part 1 07, (1990 and 1995). The net weight of the aggregate in the container was determined and the bulk density was calculated in kg/m^3.

2.6 Calculations/Materials proportioning by Weight

This refers to determining the quantity in weight of each constituent in the Sandcrete mix. All the materials are weighed using a weighing balance. The 225mm x 225mm x 450mm for hollow block of 40% void was used.

i. Type of Hollow Block, 225mm x 225mm x 450mm.

Volume for a full mould: 225 x 225 x 450 = $\frac{22781250mm^3}{10^9}$ = $0.02278125m^3$

Volume of the void: (131 x 154.5 x 225) x 2 = $\frac{9107775mm^3}{10^9}$ = $0.009107775m^3$

Therefore, volume of the full mould minus the void, 0.02278125 - 0.009107775 = $0.013673475m^3$

ii. Density of sandcrete block, the density of sandcrete/concrete blocks is largely a function of the aggregate density, size and grading, degree of compaction or aeration and the block form. The typical range for dry density is 500 to $2200kg/m^3$ with aerated and solid dense aggregate concrete blocks being on the lighter and heavier end of the scale respectively and light weight and dense aggregate concrete blocks of cellular and hollow form falling in the middle of the range or sole. Therefore, density = $1860kg/m^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Therefore, Mass = Density x Volume
Mass = 0.013673475 x 1860 = 25.4326635kg
Including a 10% waste, the weight of a mould would be 25.4326635 X 1.1 = 27.98kg Take weight = 28kg.
The water-cement ratio, cement-sand ratio, and mass of the constituents is shown in the Table 1 below.

Table 1 Mix Proportions for 225mm x 225mm x 450mm Sandcrete block for compressive strength test

Mix No	Mix Ratio W:C:RS:S	Water (kg)	Cement (kg)	Sand (kg)	Sludge (kg)
B0	0.55:1:6:0:0	2.2	4	24	_
B10	0.55:1:5.4:0.6	2.2	4	21.6	2.4
B20	0.55:1:4.8:1.2	2.2	4	19.2	4.8
B30	0.55:1:4.2:1.8	2.2	4	16.8	7.2

2.7 Production of Sandcrete Specimen

1. The floor surface was cleaned, wetted and dried to prevent loss of the water cement ratio and prevent excess water being added into the mix. Batching of the materials was done by weight using a weighing balance of 50kg capacity. The inside surface of the mould were coated lightly with medium viscosity oil and then placed on a clean, level and firm surface. The mould is made of metal.
2. Mixing of the constituents was done manually using shovels. The production process involved collection of sand which was left to dry, the sand which had been previously completely dried were mixed to a constant colour. The sludge which had been dried was weighed and added to the mix, Cement was then added and the whole process of mixing continued until a uniform colour was achieved. Water was finally added and the mixing continued until the colour of the paste was uniform. The mixture was then loaded into the moulds it was compacted manually and demoulded immediately.
3. 16 blocks was made, each mix had 4 specimens. Each blocks were inscribed for identification.
4. All the blocks were cured, under shade, for twenty-eight days by sprinkling them with water obtained from the laboratory daily.

2.9 Compressive strength

The blocks were crushed after twenty-eight days of curing using and electrical Universal Testing Machine (UTM). The machine has a testing range of 0KN – 1000KN. The blocks were placed in between two steel plates and the plates are wide enough as to cover the top and bottom of the blocks. The switch of the machine was turned on, then force was applied to the block until the block fails in compression. The strengths of the blocks were determined using equation 1. Four samples each were tested for a particular mix number and the average value taken as the compressive strength for the mix.

$$\text{Compressive strength} = \frac{\text{crushing load}}{\text{cross sectional area}} \quad (1)$$

2.9 Water absorption

The blocks for this test were dried in the oven, and then it were weighed. They were then immersed in water for 24 hours. On removal from water, they were reweighed within three minutes of removal to determine the quantity of water absorbed. Equation 2(3.2) was used to determine the water absorption of the blocks. Three blocks were tested for each mix number and the average taken as the water absorption of the mix.

$$\text{Absorption (\%)} = \frac{M2 - M1}{M_1} \times 100 \quad (2)$$

Where; M1 = mass of dry sample and M2 = mass of wet sample (after 24hrs in water).

IV. Results and Analysis

3.1 Sieve analysis results

The results of sieve analysis test for river sand is presented in Tables 2. The gradation chart for the river sand is shown in Figure 1

Table 2: Grain size distribution of river sand

Sieve size (mm)	**Mass of empty sieve (g)**	**Mass of sieve + soil (g)**	**Mass of soil retained (g)**	**Cumulative mass of soil retained (g)**	**Cumulative % passing**	**Cumulative % retained**
4.75	373.29	382.13	8.84	8.84	99.47	0.53
2.36	353.09	443.71	90.62	99.46	94.04	5.96
1.18	398.21	896.28	498.07	597.53	64.17	35.83
0.60	372.63	880.22	507.59	1105.12	33.73	66.27
0.30	318.27	738.92	420.65	1525.77	8.50	91.50
0.15	298.38	325.56	27.18	1552.95	6.87	93.13
0.075	311.1	312.84	1.74	1554.69	0.10	
Pan	273.02	274.65	1.63	1556.32		
						∑ = 293.24
Fineness modulus = 293.24/100 = 2.93						

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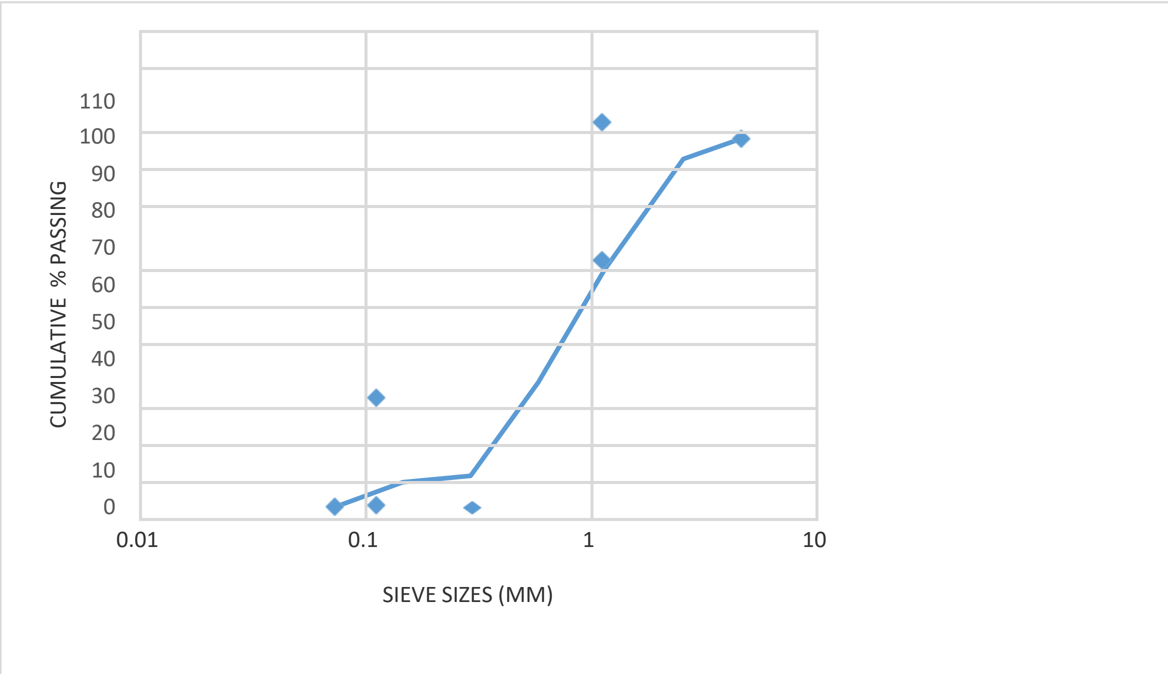

Figure 1: Gradation curve for river sand and quarry dust

From the Fig 1, the values of D10, D30, and D60 for river sand are gotten and computed to get values for Coefficient of uniformity, (Cu) and Coefficient of gradation, (Cc)
D10 = 0.32
D30 = 0.55
D60 = 1.2

Coefficient of uniformity, Cu = $\frac{D60}{D10}$ = 2. I8

Coefficient of gradation, Cc = $\frac{(D30)^2}{(D60 \times D10)}$ = 0.99

3.2 Bulk Density

The results of the bulk density test of river sand is presented in Table 3.

Table 3: Bulk density of river sand

Trial run	Trial 1	Trail 2	Trial 3
Mass (kg)	6.35	6.34	6.34
Volume of bottle (m^3)	0.0042	0.0042	0.0042
Bulk density (kg/m^3)	1511.90	1509.52	1509.52
Average bulk density (kg/m^3)	1510.31		

3.3 Chemical and Physical test result on water treatment plant sludge

The chemical and physical properties of water treatment plant sludge are given in Table 4

Table 4: Test result of water treatment sludge

Chemical property	
Element	**Result (%)**
Silicon oxide, (SiO2)	20.4
Aluminum oxide, (Al2O3)	29.6
Iron oxides, (Fe2O3)	3.2
Calcium oxide, (CaO)	37.7
Magnesium oxide, (MgO)	2.7
Sodium oxide, (Na2O)	0.4
Potasium oxide, (K2O)	1.3
Sulphates, (SO4)	0.67
Physical property	
Property	**Value**
Bulk density	1270kg/m^3
Specific gravity	1.55

3.4 Compressive strength test results

The compressive strength of the sandcrete blocks are presented In Table 5 and Figure 2

Table 5: 28 day compressive strength test result on the Sandcrete block for 10%, 20% and 30% replacement with sludge and quarry dust at a ratio of 50:50

Water-Cement Ratio	Block No.	Mass (Kg)	Density (Kg/m3)	Av. Density (Kg/m^3)	Failure Load (KN)	Comp. Strength (N/mm^2)	Av. Comp. Strength (N/mm^2)
0.55	B01	27.22	1990.72	1992.36	213	3.50	3.50
	B02	27.00	1974.63		214	3.52	
	B03	27.65	2022.16		209	3.44	
	B04	27.10	1981.94		214	3.52	
0.55	BQ101	27.80	2033.13	2018.51	242	3.98	3.96
	BQ102	27.80	2033.13		251	4.13	
	BQ103	27.20	1989.25		222	3.65	
	BQ104	27.60	2018.51		248	4.08	
0.55	B201	27.40	2003.88	1969.14	145	2.39	2.37
	B202	26.40	1930.75		155	2.55	
	B203	26.90	1967.31		144	2.37	
	B204	27.00	1974.63		132	2.17	
0.55	B301	27.20	1989.25	1912.46	102	1.69	2.01
	B302	26.20	1916.12		127	2.09	
	B303	25.40	1857.61		130	2.14	
	B304	25.80	1886.87		128	2.11	

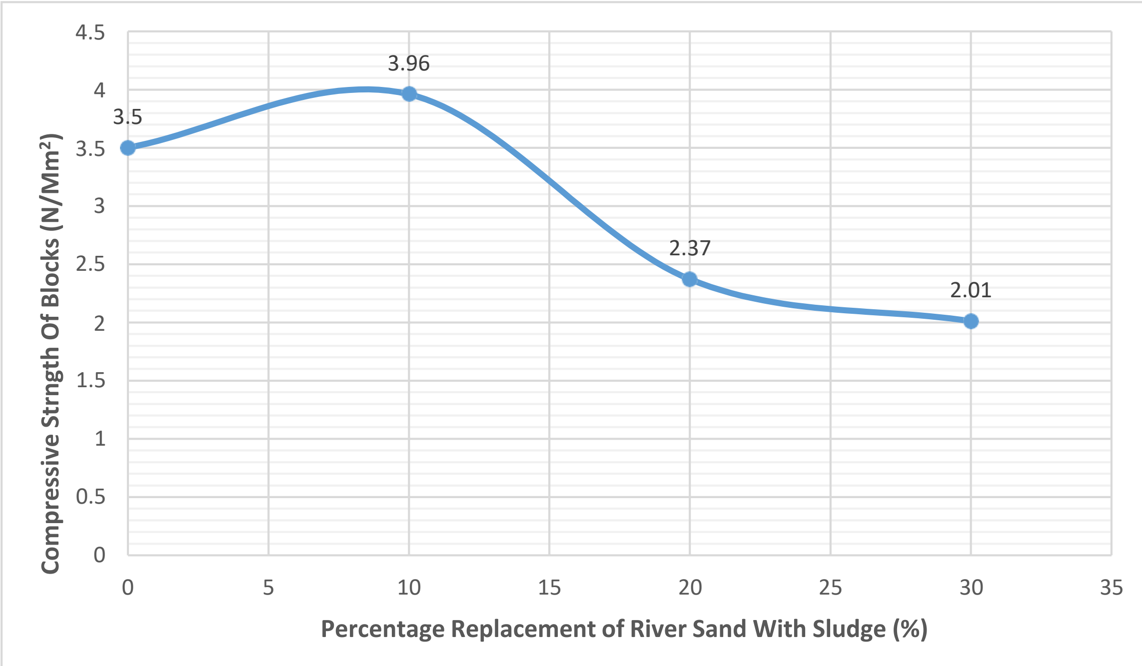

Figure 2: Line chart of the average compressive strengths

3.5 Water absorption result

The water absorption values of the sandcrete blocks are prestnted in Table 6 and Figure 3.

Table 6: 28 day water absorption test result on the Sandcrete block

Block No.	Mass of Dried Sample (Kg)	Mass of Wet Sample (Kg)	Water Absorption (%)	Average water absorption (%)
B01	0.56	0.60	7.14	7.21
B02	0.58	0.62	6.90	
B03	0.65	0.70	7.69	
B04	0.84	0.90	7.11	
B101	0.42	0.46	9.52	9.24
B102	0.60	0.64	6.67	
B103	0.65	0.72	10.77	
B104	0.60	0.66	10.00	
B201	0.50	0.58	16.00	11.95
B202	0.64	0.72	12.50	
B203	0.45	0.50	5.00	
B204	0.42	0.48	14.29	
B301	0.73	0.84	15.07	14.34
B302	0.42	0.48	14.29	
B303	0.75	0.86	14.67	
B304	0.60	0.68	13.33	

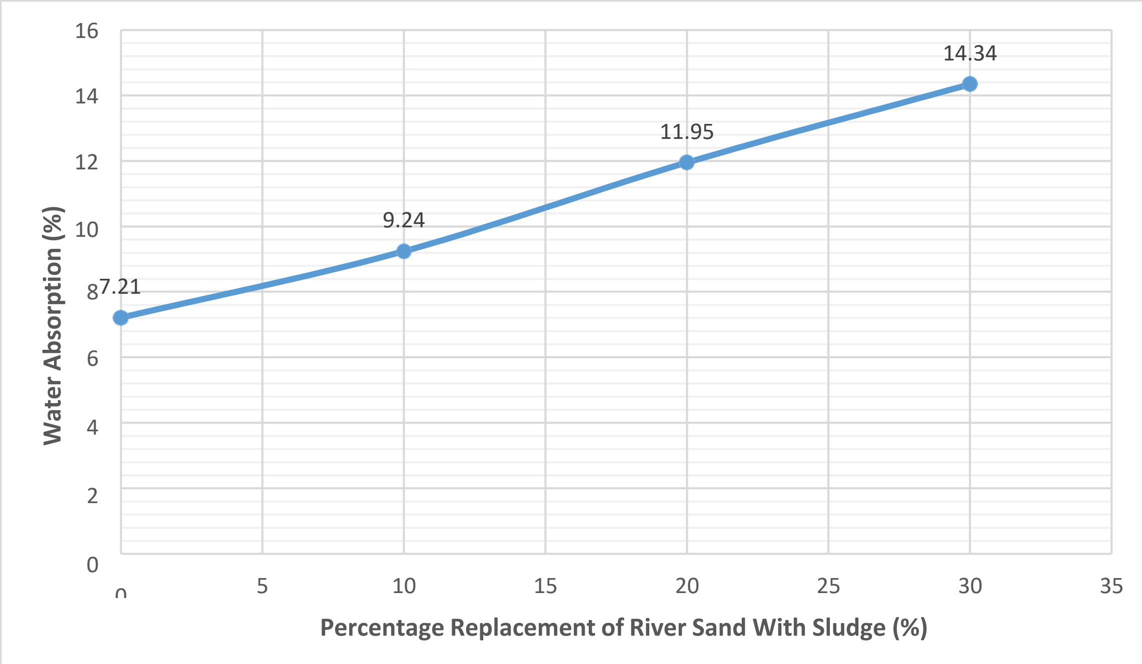

Figure 3: Chart of percentage water absorption against the percentage replacements

3.6 Analysis of Sieve analysis results

Results of sieve analysis show that both the river sand fall within Zone II of the grading of fine aggregates as given in BS-882, (1992). From Tables 4.1 the fineness modulus of river sand dust is
2.93 and this fall within the allowable range of 2.3 – 3.1, for fine aggregates in concrete work (ACI E701, 2007).
The coefficient of uniformity (Cu) and coefficient of gradation (Cc) for river sand were calculated as 2.18 and 0.99 respectively. This result shows that the river sand is almost uniformly graded as stated in BS-882, (1992).

3.7 Analysis of Bulk Density Test Results

The values for bulk density of river sand shown in table 4.3 is within the range for the respective materials. The values for the bulk densities for river sand was found to be 1510kg/m^3 and this value can be compared favourably with the values in the exiting literatures. Values of the bulk density of the materials obtained may vary, however, owing to the nature and properties of the parent materials.

3.8 Analysis of Water Treatment Sludge Test Result

From table 4.5, the result of the chemical properties of the sludge gotten from a water treatment plant shows similar properties with one of the known pozzolan (fly ash) shown in table 2.1, so sludge from a water treatment plant could be considered to be used as a constituent of sandcrete and concrete.

3.9 Analysis of Compressive Strength Results

Table 5 and Figure 2 presents the results of the compressive strength test carried out on the sandcrete blocks. Blocks produced with sludge as partial replacement to river sand for a mix ratio of 1:6 have its 28th day strength falling below the strength of pure river sand and cement except for those of the 10% replacement which had an average strength value of 3.96N/mm^2 and which falls above the minimum required strength for load bearing block for manually compacted blocks as shown in table 2.8.

3.10 Water Absorption Test Result

From Table 6 Figure 3 it was observed that the water absorption value of the sandcrete increases with respect to the increase in the sludge replacement

3.11 Conclusion

The main objectives of this work were to investigate the strength properties of sandcrete hollow blocks produced with sludge as partial replacement with river sand. From the results obtained after several laboratory test carried out, as well as the analysis. The following conclusion were arrived at.

a) Sandcrete blocks made with sludge and quarry dust as partial replacement for river sand gives its best compressive strength result at 10% replacement with a value of 3.96N/mm^2 and water-cement ratio of 0.55.
b) The percentage water absorption of the sandcrete block increase with increase in percentage replacement.
c) The optimum percentage water absorption of the sandcrete block was gotten at 10% replacement of sludge.

3.12 Recommendations

After a successful completion of this project work, the following recommendations are made:

a) A 10% replacement of sludge should be used as a partial replacement for river sand in the production of sandcrete blocks.
b) Since sludge gotten from a water treatment plant have a similar chemical properties as fly ash, further research should be carried for it to be used as a partial replacement of cement in the production of sandcrete and concrete.

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AUTHORS

First Author – Nwadike Ethelbert C., Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria
Second Author – Chiemela Chijioke, Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria
Third Author – Chukwudi Prince E, Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria
Fourth Author – Onyewuchi Chibueze M., Civil Engineering Department, Federal Polytechnic Nekede Owerri, Nigeria