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Research Article

The initial setting time and compressive strength of Sandcrete Blocks made with Gmelina Leaf Ash (GLA) as a partial replacement for Cement

[*1]Chiemela Chijioke, [2]Chukwudi Prince EU and [3]Jennifer George

[1, 2] Department of Civil Engineering, Federal Polytechnic Nekede, Owerri, Nigeria
[3] Department of Architecture, Taraba State Polytechnic, Suntai Jalingo, Nigeria

*Corresponding Author Email: cchijioke@fpno.edu.ng

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Abstract

This research study focuses on the assessment of the initial setting time and compressive strength of sandcrete blocks made with Gmelina leaf ash (GLA) as a partial replacement for cement. The aim of this investigation is to explore the potential use of Gmelina leaf ash as a sustainable alternative to conventional cement in sandcrete block production, with the objective of reducing environmental impacts and construction costs. A total number of 18 blocks were produced using 6 different mix ratios by replacing GLA with cement. The initial setting time test were carried out for the different mixes in order to ascertain the effect of GLA on the initial setting time of the sandcrete block. The bocks produced were cured and crush, afterwards the optimum mix ratio and compressive strength of the sandcrete block were obtained. The chemical properties of the ash obtained were similar to those of some pozzolans. Hence, the GLA can be considered a pozzolan. The compressive strength and initial setting time test results were carried out on the sandcrete blocks. Blocks were produced with GLA as a partial replacement to cement for a mix ratio of 1:6. It was observed that the compressive strength reduces slowly as the percentage replacement increases until 30% replacement, and then a high reduction was observed in the compressive strength from 40% down to 50% replacement. For the initial setting time results, the initial setting time increases as the percentage replacement increases. It can be seen that the compressive strength value of sandcrete block produced with SGA as a partial replacement for sand gave the maximum compressive strength values of 3.46N/mm^2 and an optimum compressive strength value of 3.0 N/mm^2 at 30% replacement. It can also be seen that the initial setting time follows a straight-line pattern with the percentage replacement, the initial setting time increases as the percentage replacement increases.

Keyword: Gmelina leaf ash (GLA), Sandcrete block, Setting, Compressive strength

INTRODUCTION

Sandcrete blocks are commonly used in the construction industry for various building purposes due to their ease of production, affordability, and availability of raw materials. The production of sandcrete blocks involves the use of cement as a binder, sand as the fine aggregate, and water (Mahmoud, 2012).

However, the extensive use of cement in construction contributes to environmental issues and rising costs. As a result, researchers have explored the possibility of using alternative materials, such as pozzolanic materials, to partially replace cement in sandcrete block production. One of such materials is Gmelina leaf ash, which possesses pozzolanic properties and has the potential to enhance certain properties of sandcrete blocks (Adesanya, 2019).

The history of sandcrete blocks can be traced back to ancient times when early civilizations used various types of blocks or masonry units made from natural materials like clay, mud, and straw. However, the modern development of sandcrete blocks, as we know them today, has its roots in the early 20th century (Geoffrey, 2011).

Early 1900s: The concept of using a mixture of sand and cement to produce blocks gained popularity in the early 20th century. In the United Kingdom, a system known as "Concrete Block Association" was established in 1910 to promote the use of concrete blocks in construction. In the 1920s, the first sandcrete blocks began to be produced on a commercial scale in various parts of the world. The initial focus was on using natural sands and Portland cement to create these blocks. The production of sandcrete blocks expanded during this period, as the construction industry recognized the advantages of using these blocks. Sandcrete blocks were considered more cost-effective, readily available, and easier to work with than traditional brick or stone masonry. Sandcrete blocks gained popularity in many regions, especially in Africa, where the materials for their production were abundant. During this time, the technology for manufacturing sandcrete blocks was further improved, and various types of sandcrete blocks were developed to suit different construction needs. In 1960s-1970s, the construction industry saw widespread adoption of sandcrete blocks in various building projects, including residential, commercial, and infrastructure development.

The use of sandcrete blocks became a common practice in many countries due to their versatility and cost-effectiveness. In 1980s-1990s, as the demand for sustainable and environmentally friendly construction materials increased, researchers and engineers started exploring the use of alternative materials in sandcrete block production. This led to investigations into incorporating pozzolanic materials, such as fly ash and rice husk ash, to partially replace cement in sandcrete blocks (Cook, 1984).

In 2000s-Present, Sandcrete blocks continue to be a fundamental construction material in many parts of the world, especially in regions where sand and cement are readily available. Researchers and industry professionals continue to explore ways to optimize the properties of sandcrete blocks by incorporating various additives and exploring alternative materials, such as Gmelina leaf ash, to enhance their sustainability and performance (Godwin, 2013).

Today, sandcrete blocks remain a widely used construction material, offering a cost effective and practical solution for building walls, foundations, and other structural elements. The history of sandcrete blocks reflects their evolution from simple mixtures of sand and cement to a more sophisticated building material with diverse applications in modern construction practices (Marthong, 2012).

The use of alternative materials in construction, particularly in the production of sandcrete blocks, has gained significant attention due to their potential to reduce environmental impact and enhance sustainability. Gmelina leaf ash (GLA) is one such alternative material that has shown promise as a partial replacement for cement in sandcrete block production (Hussein, 2014). However, before its widespread adoption, it is essential to assess its impact on crucial properties such as the initial setting time and compressive strength of sandcrete blocks. The initial setting time of a sandcrete block refers to the time required for the mixture to harden and develop sufficient strength to retain its shape after molding. This property is vital as it affects the production process and determines the period for handling and further processing of the blocks.
Any significant alteration in the setting time due to the incorporation of GLA could affect the efficiency and feasibility of sandcrete block production.Compressive strength is another critical property of sandcrete blocks that directly influences their structural integrity and durability (Etuk, 2012). The compressive strength indicates the maximum load the blocks can withstand before failure and is a key factor in determining their suitability for various construction applications (Boateng, 1990).

Therefore, it is crucial to evaluate the compressive strength of sandcrete blocks incorporating GLA to ensure they meet the required strength standards and can withstand the intended loads and environmental conditions. Thus, the primary problem to address in this study is to assess the effect of using Gmelina leaf ash as a partial replacement for cement on the initial setting time and compressive strength of sandcrete blocks. The investigation aims to determine if GLA can be effectively utilized in sandcrete block production without compromising these crucial properties, and if so, to identify the optimum percentage of GLA replacement that balances environmental benefits with acceptable performance characteristics.

OBJECTIVES OF STUDY

The main objective of the study is to determine the initial setting time and compressive strength of sandcrete blocks made with Gmelina leaf ash (GLA) as a partial replacement for cement, while the specific objectives are:

a. To characterize the constituent material used in producing the sandcrete block.
b. To determine the initial setting time of the different sandcrete mix.
c. To produce, cure and crush the sandcrete block made with GLA as partial replacement for cement.
d. To determine the optimum replacement of cement with GLA for initial setting time and compressive strength.
e. To compare the result gotten for the concrete produce with GLA as partial replacement for cement with those of conventional concrete.

MATERIALS AND EXPERIMENTAL METHOD

Materials

The different materials used in this research work are as follows:

Fine Aggregate: pure river sand was gotten from Otammirri river in Imo state

Cement: Ordinary Portland cement (OPC) is used as the primary binder and was gotten from a Cement Depot at Nekede in Imo State and was still at its original production state.

Gmelina Leaf Ash (GLA): Gmelina leaf was obtained from GLA trees in Federal Polytechnic Nekede and the leaves was burnt using the ashing process.

Water: Distilled water was used for the mixture and was gotten from Nekede Owerri Imo State.

Experimental Methods

Tests were performed during this research on concrete and aggregate and they include;

Sieve Analysis

The sieving method adopted was dry sieving and a sample size of about 300g was used for the fine aggregates (river sand). This test was carried out on the fine aggregates to determine the particle size distribution according to ASTM C33 / C33M-18. 2018. These tests was done in the laboratory using sieve size of different diameter and were staked according to the sieve size, 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 sizes 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.

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 void between the particles. The dry method was adopted for the determination of the bulk densities of fine and coarse aggregates. This test was carried out in accordance with BS 812: part2 and part1 07, (1990 and 1995). The net weight of the aggregate in the container was determined and the bulk density was calculated in kg/m3. The apparatus used were weighing balance of 5- 25kg capacity, cylinder of 2.83-14.15 litres nominal capacity, scoop and drying duster.

The small cylinder was used for the fine aggregate and the large one for coarse aggregate. Each cylinder was calibrated to determine its actual volume. The dried cylinder was filled with the surface and aggregate by the scoop. The aggregate discharged from a height of 5cm above the top of the cylinder. The surface was with levelled with a straight edge and the net weight of the aggregate in the cylinder was determined.

$$\text{Bulk density} = \frac{\text{Net wt. of Aggregate}}{\text{Actual volume of cylinder}}$$

Specific gravity

Specific gravity is the ratio of the density of a substance to the density of a reference substance (usually water) at a specific temperature. It is a dimensionless value and provides insights into the relative density or heaviness of a material compared to water. Specific gravity is an essential property for construction materials like cement, aggregate (sand), and ash, as it helps in understanding their characteristics and suitability for various applications.

Chemical Properties of the Ash

Gmelina (*Gmelinaarborea*) is a fast-growing tree species native to Southeast Asia and India. The ash from burning Gmelina leaf will have chemical properties similar to other wood ashes, but the specific composition may vary depending on factors such as the growth conditions of the tree and the burning process according to ASTM C618-15, 2015.

Material Proportioning by Weight

This refers to the quantity in terms of mass (kg) of each constituent material in the sandcrete mix using a mould of 450mm by 225 mm by 225mm hollow block. Using a mix of 1:2:4, the mass of the constitute material used in the production of the concrete are calculated and presented in Table 1

$$225 \text{ x } 225 \text{ x } 450 = \frac{22781250}{10^9} = 0.002278125m^3$$

$\text{Volume of hollow} = (131 \text{ x } 184.5 \text{ x } 225) \text{ x } 2 = 0.009107375m^3$
$\text{Effective volume} = 0.02278125 - 0.009107795 = 0.015673475m^3$
Mass of block, M = density of block x volume of block = ρV
= 1860 x 0.013673475 = 25.4326635kg
Adding 10% Waste = 1.1 x M = 28kg
For 3Mould = 28 x 3 = 84kg
For Mix 1 (control)
The Mix Ratio is represented as
W: C: GLA: RS = 0.5:1:0:6
Total solids = (1:6) = 7
$\text{Cement} = \frac{1}{7} \text{ x } 140 = 12\text{kg}$
$\text{Sand} = \frac{6}{7} \text{x } 140 = 72\text{kg}$
Water = C x 0.5 = 12 x 0.5 = 6kg

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

Mix No	Mix ratio W:C: GLA:RS	Water (kg)	Cement (kg)	Sand (kg)	GLA (kg)
1	1:6	6	12	72	-
2	0.9:0.1:6	6	10.8	72	1.2
3	0.8:0.2:6	6	9.6	72	2.4
4	0.7:0.3:6	6	8.4	72	3.6
5	0.6:0.4:6	6	7.2	72	4.8
6	0.5:0.5:6	6	6	72	6

Compressive Strength Test

The most common and preferred test for strength properties of concrete is compressive strength test. It is carried out using the compressive testing machine. The specimen of sandcrete block is placed in the machine and load applied. The point at which deformation or crack occurs on the specimen the testing is stopped at that point and the strength is noted in MPa's.

RESULTS AND ANALYSIS

The following results were gotten from the test conducted and are presented as follows:

Results of the Sieve Analysis Test

The sieve analysis test result for the river sand were as given in Table 2 while the graphs is presented 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 mass of soil passing (g)	% passing (%)
4.75	375.55	495.22	119.67	119.67	1985.68	94
2.36	353.00	492.58	139.58	259.25	1846.1	88
1.18	358.35	825.66	467.31	726.56	1378.79	65
0.60	342.62	892.75	550.13	1276.69	828.66	39
0.425	333.83	720.78	386.96	1663.65	441.7	21
0.30	335.37	722.33	314.11	1977.76	127.59	6
0.212	345.46	659.57	49.81	2027.57	77.78	4
0.15	325.44	375.25	20.8	2048.37	56.98	3
0.075	311.35	332.15	11.98	2060.35	45	2
Pan	293.77	305.75	45	2105.35	0	0
						∑ = 322
Fineness modulus = 322/100 = 3.22						

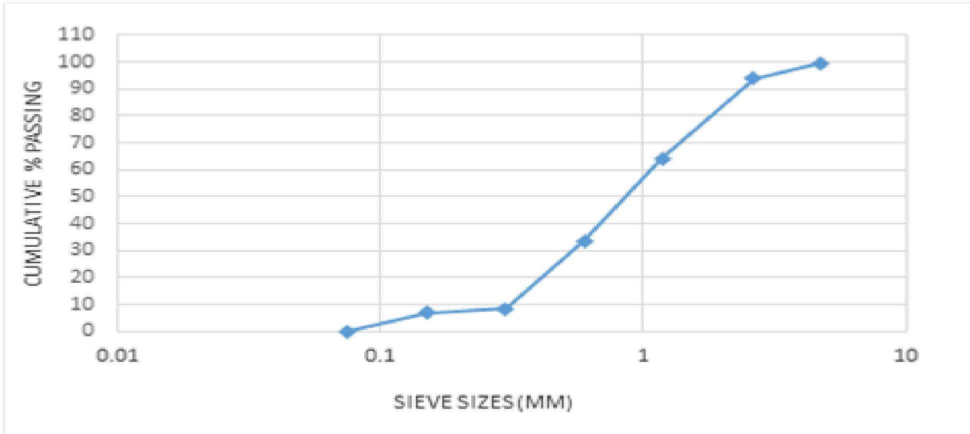

Figure 1. Gradation Curve for river sand

From the Figure 1, the values of D_{10}, D_{30}, and D_{60} for the fine aggregate is gotten and computed to get values for Coefficient of uniformity, (Cu) and Coefficient of gradation, (Cc)

$D_{10} = 0.32$, $D_{30} = 0.55$, $D_{60} = 1.2$

$$\text{Coefficient of uniformity, Cu} = \frac{D_{60}}{D_{10}} = \frac{1.2}{0.32} = 2.I8$$

$$\text{Coefficient of gradation, Cc} = \frac{(D_{30})^2}{(D_{60} \times D_{10})} = \frac{(0.55)^2}{(1.2\times 0.32)} = 0.99$$

Bulk Density Test Result

The results of the bulk density test of the river sand, cement and gmelina leaf ash are presented in Table 3a, Table 3b, Table 3c respectively.

Table 3a. Bulk density of river sand

Trial run	Trial 1	Trail 2	Trial 3
Mass (kg)	6.84	6.88	6.86
Volume of bottle (m^3)	0.0042	0.0042	0.0042
Bulk density (kg/m^3)	1628.571	1638.095	1633.333
Average bulk density (kg/m3)	1633.333		

Table 3b. Bulk density of cement

Trial run	Trial 1	Trail 2	Trial 3
Mass (kg)	6.12	6.06	6.1
Volume of bottle (m^3)	0.0042	0.0042	0.0042
Bulk density (kg/m^3)	1457.143	1442.857	1452.381
Average bulk density (kg/m^3)	1450.794		

Table 3c. Bulk density of gmelina leaf ash

Trial run	Trial 1	Trail 2	Trial 3
Mass (kg)	3.62	3.62	3.6
Volume of bottle (m^3)	0.0042	0.0042	0.0042
Bulk density (kg/m^3)	861.9048	861.9048	857.1429
Average bulk density (kg/m^3)	860.3175		

Specific Gravity Test Results

The results for the specific gravity of the river sand, cement and gmelina leaf ash are presented in Table 4a, Table 4b, Table 4c respectively.

Table 4a specific gravity of river sand

Description	Results		
	Trial 1	Trial 2	Trial 3
Weight of Pycnometer in air: W1 (g)	597	597	597
Weight of aggregates and Pycnometer: W2 (g)	794.2	795.1	794.8
Weight of aggregates, Pycnometer and water: W3 (g)	1780.7	1780.7	1779.2
Weight of water and Pycnometer in air: W4 (g)	1658	1657	1656
Apparent Specific Gravity: (W2 – W1) / [(W4 – W1) - (W3 - W2)]	2.65	2.66	2.65
Average Apparent Specific Gravity	2.65		

Table 4b. specific gravity of cement

Description	Results		
	Trial 1	Trial 2	Trial 3
Weight of Pycnometer in air: W1 (g)	597	597	597
Weight of aggregates and Pycnometer: W2 (g)	750	751	750
Weight of aggregates, Pycnometer and water: W3 (g)	1750	1751	1750
Weight of water and Pycnometer in air: W4 (g)	1646	1647	1646
Apparent Specific Gravity: (W2 – W1) / [(W4 – W1) - (W3 - W2)]	3.12	3.08	3.12
Average Apparent Specific Gravity	3.10		

Table 4c. specific gravity of gmelina ash

Description	Results		
	Trial 1	Trial 2	Trial 3
Weight of Pycnometer in air: W1 (g)	597	597	597
Weight of aggregates and Pycnometer: W2 (g)	720	720	721
Weight of aggregates, Pycnometer and water: W3 (g)	1730	1730	1728
Weight of water and Pycnometer in air: W4 (g)	1667	1667	1666
Apparent Specific Gravity: (W2 – W1) / [(W4 – W1) - (W3 - W2)]	2.05	2.05	2
Average Apparent Specific Gravity	2.03		

Chemical Properties of the GLA Ash Results

The results for the chemical properties of the GLA ash is presented in Table 5

Table 5. Chemical Properties of the GLA Ash Results

Compound	%
MnO	2.7
Al_2O_2	1.3
Fe_2O_3	5.3
K_2O	2.0
MgO	12.2
L.O.I	5.1
Na_2O	4.2
SiO_2	42.7
P_2O_3	1.0
CaO	15.4

Compressive strength test and initial setting time results

The compressive strength and initial setting time results of the sandcrete blocks are as presented in Table 6. while the graph of the percentage replacement and initial setting time are presented in Figure 2 and Figure 3 respectively.

Table 6: 28 day compressive strength test and initial setting time results on the Sandcrete block

Mix ratio W:C:GLA:RS	Block No.	Mass (Kg)	Avg. Mass (Kg)	Setting Time(min)	Avg. Setting Time(min)	Failure Load(KN)	Comp. Strength (N/mm^2)	Av. Comp. Strength (N/mm^2)
	M01	28.25		315		182	3.44	
1:6	M02	28.50	2843	312	314	185	3.50	3.46
	M03	28.55		315		182	3.44	
	M101	28.20		320		172	3.25	
0.9:5:6	M102	28.53	28.34	320	318.33	170	3.21	
	M103	28.30		315		170	3.21	3.23
	M201	27.40		325		170	3.21	
0.8:0.2:6	M202	27.47	27.44	320	323.33	165	3.12	
	M203	27.45		325		172	3.25	3.19
	M301	25.85		330		162	3.06	
0.7:0.3:6	M302	26.33	26.14	330	328.67	160	3.02	
	M303	26.24		326		155	2.93	3.00
0.6:0.4:6	M401	25.88		333		100	1.89	
	M402	25.53	25.6	330	334.33	102	1.93	
	M403	25.39		340		102	1.93	1.92
0.5:0.5:6	M501	24.05		330		95	1. 60	
	M502	24.31	24.21	342	339	90	1.50	
	M503	24.28		345		82	1.35	1.48

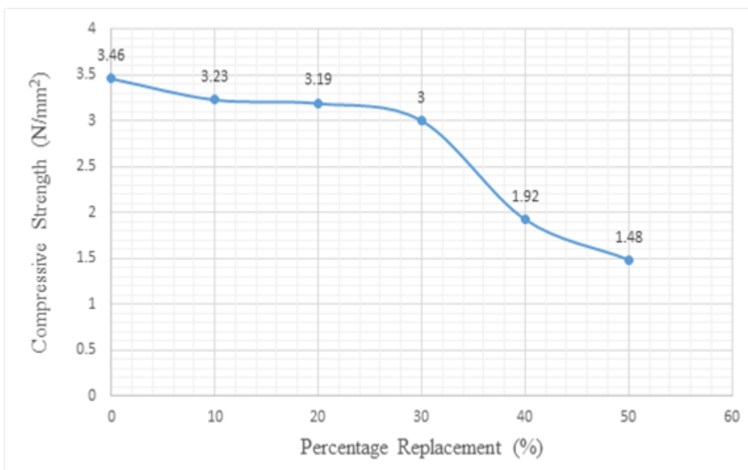

Figure 2. Line chart of the average compressive strengths

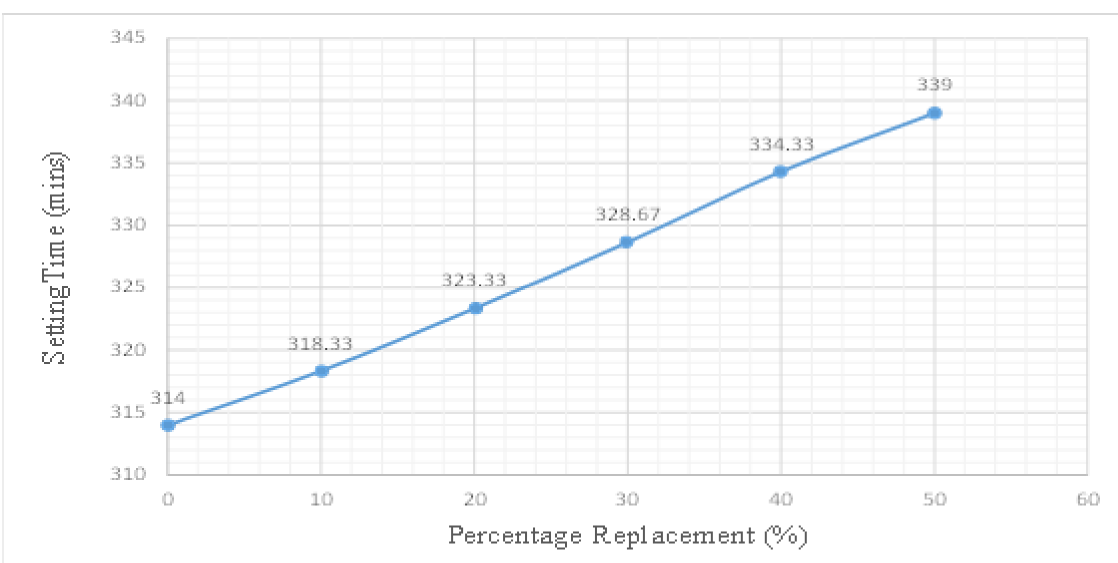

Figure 3: Line chart of the initial setting time

Analysis of Results

The chemical properties of the GLA were presented in Table 5, the chemical properties of the ash obtained are similar to those of some pozzolans. Hence, the GLA can be considered a pozzolan

Table 6 presents the results of the compressive strength and initial setting time test results carried out on the sandcrete blocks. Blocks produced with GLA as partial replacement to cement for a mix ratio of 1:6. It was observed that the compressive strength reduces slowly as the percentage replacement increases until 30% replacement, and then a high reduction was observed in the compressive strength from 40% down to 50% replacement. For the initial setting time results, the initial setting time increases as the percentage replacement increases.

From Figure 2, it can be seen that the compressive strength value of sandcrete block produced with SGA as partial replacement for sand gave the maximum compressive strength values of 3.46N/mm2 and an optimum compressive strength values of 3.0 N/mm2 at 30% replacement.

From Figure 3, it can be seen that the initial setting time follows a straight-line pattern with the percentage replacement, the initial setting time increases as the percentage replacement increases.

CONCLUSION

The main objective of the study is to determine the initial setting time and compressive strength of sandcrete blocks made with Gmelina leaf ash (GLA) as a partial replacement for cement. From the results obtained after several laboratory test carried out, as well as the analysis and discussions done in chapter four. The following conclusion been arrived at.

a. Sandcrete blocks made with GLA as partial replacement for cement gives its optimum compressive strength result at 30% replacement with a value of 3.0N/mm^2

b. The compressive strength value reduces slowly as the percentage replacement increases until 30% replacement, and then a high reduction was observed in the compressive strength from 40% down to 50% replacement.

c. The initial setting time follows a straight-line pattern with the percentage replacement, the initial setting time increases as the percentage replacement increases.

RECOMMENDATIONS

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

a. A 30% replacement of GLA with a cement in the production of sandcrete blocks.

b. GLA should be used as replacement for sandcrete blocks when initial setting time is of importance.

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