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CONTENTS

EVALUATION OF ADO-EKITI METROPOLIS SANDY SOIL COMPRESSIVE STRENGTH USING DEVELOPED HYPERBOLIC REGRESSION MODEL

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ABSTRACT

The suitability of AdoEkiti Metropolis Sand for the production of sandcrete blocks were examined to developed a model for determining their compressive strength. In this work five sand samples were collected from five different sand deposit sites within the metropolis. The sandy soil was mixed with cement in ratio 1:8 to produce the sandcrete block in compliance with Nigeria Industrial Standard. Test such as specific gravity, sieve analysis, compressive strength, absorption, impact and abrasion were performed on the sandcrete block samples. The experimental results trends were established and utilized to formulate a mathematical model with a regression and hyperbolic functions. This model enables a developer to recognize at a glance the impact of curing age and the sanddensity on the compressive strength. The compressive strength conducted on the sandcrete blocks for 3, 7 and 14days ranges between 0.5N/mm² and 2.6N/mm² experimentally and mathematically predicted 0.58N/mm² to 2.6N/mm² for all the sample types. The result also shows that the compressive strength is directly proportional to the product of the soil density and the curing age (days). Based on the test carried out and the predicted results Ado-Afao, Ado-Iworoko and Ado-Ijan sand deposits are the most suitable among the five sand deposits identified within the metropolis. It was concluded that those sand deposit site that were found suitable will bring about increase economic return to the community land owners and guide the producer of sandcrete block on the choie of quality material available within the metropolis

KEYWORDS: *Ado-Ekiti; Compressive; Hyperbolic; Model; Sandcrete; Strength.*

INTRODUCTION

Sand is a valuable resource and a main input in the construction industry in many parts of the world (Ezekiel, 2010 & Gob et al., 2005). Sand and gravel represent the highest volume of raw material used on earth after water (UNEP, 2014). Their use greatly exceeds natural renewal rates. Moreover, the amount being mined is increasing exponentially, mainly as a result of rapid economic growth in Asia (UNEP and CSIRO, 2011). Soil is an important source of raw materials such as clay, sand, gravel and minerals. Soil is a natural resource made up of gravel, sand, clay, loam which constitutes the different types. Pit sand, river sand and gravel are components of soil which takes years to be formed but extracted in a matter of days (Draggen, 2008). Sands are crucial resources to economic development activities in developed and developing nations. Recovery from river channels, flood plains and glacial deposits as well as processing of those resources is costly but valuable in construction and industry (Draggen, 2008).

Sand is an underground geological resource formed from eroded mountain rocks carried by streams and rivers. According to Isah (2011) soil has many uses, it is needed for agriculture, as a habitat and in construction, but the genesis of cash economy brought many profit driven companies to be involved in its mining both legally and illegally with little or no regard background to formation of sand deposits, legacy of the continental ice sheets that to the environment. Strebbins (2006) gave the melted thousands of years ago. As the ice melted, fast moving river were formed leaving deposits of coarse sand. The river ran into the sea; large deltas were formed with layers of sand silt. Now there is no more ice and rivers but scattered deposits of sand which are used as important natural resources. Sand deposits are porous; water can pass through this geological material, making it a source of high quality water (Strebbins, 2006). Draggen, (2008) discussed sand as commodities used in industry especially construction. In construction, the component is used either mixed with other material or as it is, while in industry, sand is used in production of other materials like aggregates. Sand mostly of quartz grains (Silicon dioxide) are derived from weathering of granite rocks. The quartz grains accumulated in rivers, streams, deltas and beeches. Therefore, quartz is very valuable as sand because of its silica content. The physical properties of sand particularly in abrasive property make their resource useful for traction on icy roads, roadways and rail road including sand blasting (Draggen, 2008). Sand is a cheap and heavy resource consisting of very small pieces of rocks and minerals, a result of weathering that forms beaches and deserts. Saviour, (2012) defined soil as a mineral which protect the environment, buffer to strong tidal waves and storms, habitat for crustacean species and marine organisms. This research seeks to study the suitability of sandy soil in the studied location for sandcrete block productions for use as a raw material for block producer within this metropolis.

Sand has been used as a building material for decades globally across various continent of the world. As the population of the world continues to grow, so does the need for infrastructures. However, most of this infrastructural has been facing a lot of challenges which includes cracking; collapse and so on in which the cause may have arises from the type of sand material used for execution of the project. Sandy soil that will be used for construction must conform to specification. Organic impurities can affect the sand containing silica which may react with the alkali in the cement causing the concrete to disintegrate. Rapid urbanization is a major cause for sand demand and is responsible for unsustainable extraction of sand from many illegal inland sand mining pits found in many part of Ado-Ekiti. Omole and Ajakaiye (1998) stated that the interaction between sand mining operations, citizen neighbors and government becomes more confrontational as a result of more sand excavation sites located in Ado-Ekiti. Conflict have centred on environmental and social issues such as noise, truck traffic, dust stream water quality, reclamation, biodegradation, pollution and visually unpleasant landscapes and the citizens concern on the adequacy of regulating effort of the government to control these negative effects (Garrod & Wilis, 1999). Mining of sand occurs both on small and large-scale in major parts of the country. With an estimated 16 million housing Deficit and infrastructural development in Nigeria, there will continue to be great demand for sand and other construction materials (Ezekiel, 2010; Gob et al., 2005 & Isah, 2011). Ado-Ekiti has experienced rapid population growth and physical expansion especially since the mild 1980s due to the influx of people from different part of Ado - Ekiti. The study came up to identify the best location for the producer of sandcrete block within the metropolis.

MATERIALS AND METHODS

Study location: Ado-Ekiti an ancient city in Nigeria is located between latitude 7034' and 7041' North of the equator and longitude 5011' and 5016' east of the Greenwich meridian. Geologically, Ado Ekiti lies entirely within the Cambrian basement complex rock group, which underlies much of Nigeria. It falls within koppen's 'a' climatic belt that is tropical wet climate. It has a population of 313,650 according to 2006 population estimation. Sand used as fine aggregate was obtained from the following five locations within Ado-Ekiti province which are Ado-Afao, Ado-Ijan, Ado-Ikere, Ado-Ilawe and Ado-Iworoko as shown in Figure 1. Sufficient quantity was collected and heaped in the laboratory. Materials like pebbles, cobbles and other unwanted objects were removed from the pile by picking and sieving in wire mesh size 4.75mm after sun drying the sand to remove the any moisture. The cement was ordinary Portland cement produced by Dangote Cement Company, Nigeria purchased from retail outlet in Ado-Ekiti, while tap water was used in mixing. Various physical tests were conducted on the materials for their characterization and assessment which conforms to BS 12.

Specimen preparation and testing

Nominal mixes of 1:6 (cement : sand) ratios by volume was used. The volume batching was so adopted as it is common practice in most construction sites in Nigeria. A water cement ratio of 0.5 was used for the mixtures. Hand mixing was used and it involved the measurement of the sand and cement which were thoroughly mixed on an impermeable hard surface, using shovel and trowel, until a uniform colour was achieved, followed by a measured quantity of water based on water cement ratio of 0.50. The mix was thoroughly done until it appeared uniform in colour and consistent. Before casting of specimens, they were then cast in a cube mould (100mm), covered with polythene bags and left for 24hours. The specimens were removed from the moulds and cured by sprinkling water on the sample until their testing ages at 3, 5, 7 and 14 days in accordance with SON, (2007). The compressive strength test was done using CONTROL CR2-030 Testing Machine of capacity 2000 KN and prior to the test; the specimens were weighed on a balance. Three specimens were used to compute the mean value in each of the testing age from the mixture.12 cubes were cast, for the investigation of the density, compressive strength, impact, abrasi on, water absorption properties of the sandcrete blocks.

Experimental procedure

Sieve analysis: of the sand samples were carried out in accordance with BS 1377, (1990) procedure. 500 grams of oven-dried sample of soil was accurately weighted. This was soaked and washed through the 0.075mm sieve. The residue was dried in the oven for 18 hours. At the end of this period, the soil was poured into a set of sieves arranged in descending order and the arrangement placed on the Endecott Sieve shaker serial number 8488. The shaker was agitated for 10 minutes. The soil retained on each sieve was weighted and the weight recorded against the sieve size. The percentage retained and passing each of the sieves was calculated. The percentage passing each sieve is then plotted against the particle size

Specific gravity: Is the ratio of the density of the solid to the density of the reference substance. Mass of bottle only as (mg) was determined as the initial weight using weighing balance. The sample was poured inside the bottle in a quarter and the weight taken as (m^2g). Distilled water was then added to the sample inside and stirred. The sample inside the bottle was filled with water; the body of the density bottle was clean to remove any water and weighed as (m^3g). The sample inside the bottle was then poured away, rinsed and then refilled with water and then weighed to determine (m^4g). The specific gravity was estimated using equation 1.

$$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad (1)$$

Compressive strength (CS): This test was performed to investigate the performance of the blocks after the normal curing age. This is the maximum load per cross sectional area of the material. This was done using CONTROL CR2-030 Hydraulic compression machine. Failure load divided by the area in (N/mm^2).

Silt Test: Fill 1% solution of common salt and water in the measuring cylinder up to 100ml mark. Now add sand to be tested to this solution till the level of the salt solution shows 150 ml mark. Shake the mixture of sand and salt solution well and keep it undisturbed for about 1hr.The silt being of finer particles than sand, will settle above the sand in a form of layer. Measure the thickness of this silt layer.

Percentage of silt by volume = (V_2/V_1) x 100

Where, Volume of sample is V_1 (ml) and Volume of silt after 1hr is V_2 (ml).

Water Absorption (WA): The water absorption property of a specimen determines the extent to which the test piece is susceptible to seepage of water through its pores when immersed in water. This test focused on the change in weight of the specimen that this provided a useful measure of the durability of bricks building materials. All the samples at the end of soaking in water and before soaking were weighed; the weights were noted (W2) and (W1) respectively. Specimens were then immersed totally in water at normal temperature for 24 hours. The final weight was calculated using Ekpunobi (2009) formula as given in equation 2.

$$W = \frac{M_{AS} - M_{BS}}{M_{AS}} \times 100 \qquad (2)$$

Where

M_{BS} = mass before soaking

M_{AS} = Mass after soaking

Abrasion Test: two separately weighed samples of the sandcrete blocks was brushed using iron file. The same effort and number of motion was used on each sample, then the final weight of each sample was taken. AB=W2-W1/W1*100.Where W1 is the Initial weight and W2= weight of sample after brushing.

Impact test: the initial weight of the sandcrete block sample was taken and then allowed to fall from a height of 2m. After the fall, the final weight of the specimen was recorded. The test was repeated two times.

MATERIALS AND METHODS

The data collected from running the experiment as highlighted by Olubayode and Akinwamide, (2014) were given in Table 1. The graph presented in Figure. 2 of Ado-Iworoko soil shows the relationship that exist between Age of curing to the compressive strength of sandcrete block. These relationships can be use to establish mathematically from the following graphs of Figures 3 and 4. The trend of the compressive strength is synonymous to the graph of half side tanh x, (hyperbolic function). The full presentation of a hyperbolic function can be seen in Figure 4 with the inclusion of a lower and upper half.

The trend Y = tanh x (Bird, 2002 & Ejiko et al., 2019).

$$\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}} \qquad (3)$$

by representing Y as a function of x that is f(x) and x as nx in order to accommodate the boundary condition the equation becomes;

$$f_{(x)} = \tanh nx$$

This function has an upper and lower boundary of +1 and -1 which follow after the compressive strength format that is deficient of the magnitude. To complement the magnitude Y is given as a function of trend and magnitude.

$$Y = AC \qquad (4)$$

Where,

C = arbitrary constant as tanh nx

A= magnitude of the center of compressive strength occurrence

The magnitude lies below the upper limit, c and a

Where the midpoint is at "A"

$$A = \frac{c-a}{2} \qquad (5)$$

$$Y = \frac{c-a}{2} \tanh nx \qquad (6)$$

To establish the constant value in the positive side, a magnitude greater than the mid point will be to balance the negative effect (Ejiko et al., 2015a).

This value therefore becomes

$$,u + y = c,$$

$$,u - y = a,$$

$$,2u = c + a$$

$$u = \frac{c+a}{2}$$

$$\sigma = \left[\left(\frac{c+a}{2}\right) + \left(\frac{c-a}{2}\right)\right] \tanh nx \qquad (7)$$

f(x) = tanh nx is for a period of 22 days (11days/section)

22days = 6x (from -3 to +3)

For $-8 \le x \le 14$,

,nx = -3

where $x = -8$, and $\tanh(-3) = -1$

$22n = 6x$,

$$n = \frac{6x}{22}$$

Since $nx = -3$, and $\tanh(-3) = -1$, $\rightarrow nx = -3$

$$\frac{6x}{22} = -3$$

Substituting x as -8 in the above equation

$$n = \frac{6 \times -8}{22} = -3$$

To attain a value that will bring nx to -3 an addition of +3 is required

$$-2.18 + 3 = 0.82$$

For to be equal to -3nx

$$\frac{6x}{22} - 0.82$$

$$\sigma = \frac{c+a}{2} + \frac{c-a}{2}\tanh\left(\frac{6x}{22} - 0.82\right) \quad (8)$$

$$\frac{2+0.6}{2} + \frac{2-0.6}{2}$$

$$\sigma = 1.3 + 0.7tanh\left(\frac{6x}{22} - 0.82\right)$$

where x is given as day D

$$\sigma = 1.3 + 0.7\tanh\left(\frac{6D}{22} - 0.82\right) \quad (9)$$

Using regressive model according to Oladebeye and Ejiko, 2007 and 2015b

y = ax + b

where,

a is the coefficient of x

b is the constant (Point of interception)

y = 0.0039848X – 5.8911y

where,

X is the density

Y is the compressive strength (N/mm²)

By regression analysis at 95% confidential level the correction coefficient is 0.906 which implies a high dgree if correlation. The final equation to determine the compressive strength is given in equation. The regression equation introduced establishes the impact of density against the compressive strength. This therefore eliminates the impact of magnitude in equation 9 that is the removal of 1.3. The new equation can now be written as

$$\sigma = 0.0039848x - 5.8911 + 0.75\tanh\left(\frac{6D}{22} - 0.82\right) \quad (10)$$

RESULTS AND DISCUSSION

The primary objective of this work is to develop a mathematical model that can represent the total experimental results of sandcrete with different density of five locations. Based on the data collected from the five locations, Iworoko was selected as reference trend in determining the trend of other locations. Figures 5 to 9 shows the representations of actual compressive strength against the model compressive strength. The model strength was found to be closely related to the actual strength. To further confirm the veracity of the developed model the correlation coefficient for the developed model and the actual strength was found to be 0.922 from the data. The trends for days 3 to 14 of the compressive strength were in continual increment of hyperbolic format. The percentage increment increases as the day progresses with an average of 46% and 54% for 7 and 14 days respectively. Acro ss the 3, 7 and 14 days curing a ratio of 1, 1.46 and 1.54 were usually observed indicating that the compressive strength increases in relation to the density and curing days. The developed model in comparison with the actual compressive strength has a low cumulative error except for that Ijan and day 3 of Ilawe location. This signifies that the developed model is highly dependable.

CONCLUSIONS AND RECOMMENDATIONS

The developed mathematical model can effectively estimate the compressive strength of selected location sandcrete at a glance. This model will help users of sandcrete block to make reliable decision as to actualize the location with the best soil compressive strength. The model developed has high correlation with the actual values; this high level of correlation displayed by the developed model shows its level of reliability, dependability and effectiveness. For utmost performance of this model, it is important for the user to ensure that the actual strength value is hyperbolic in nature when plotted on the graph before the data are used. It is therefore recommended that block moulding factories should apply the compressive strength as predicted in moulding blocks.

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Figure 1: Map of Ado-Ekiti and its Environs

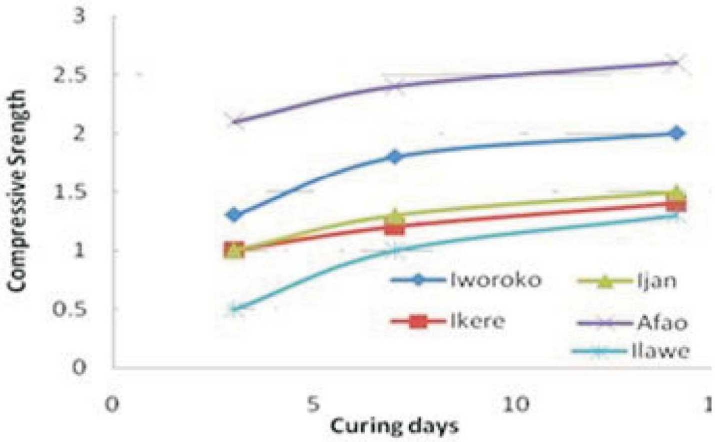

Figure 2: showing the graph of compressive strength against curing Age (days)

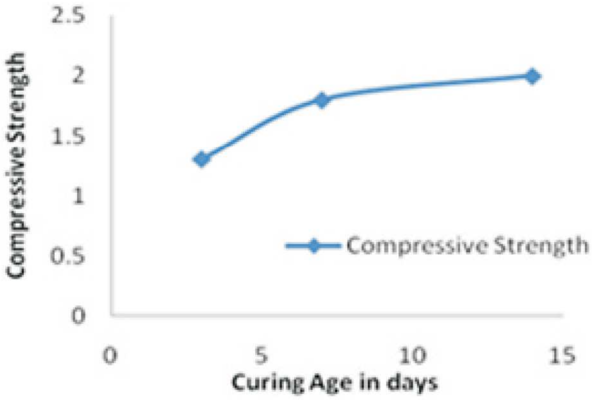

Figure 3: Ado-Iworoko Soil Relationship between Curing Days and Compressive Strength

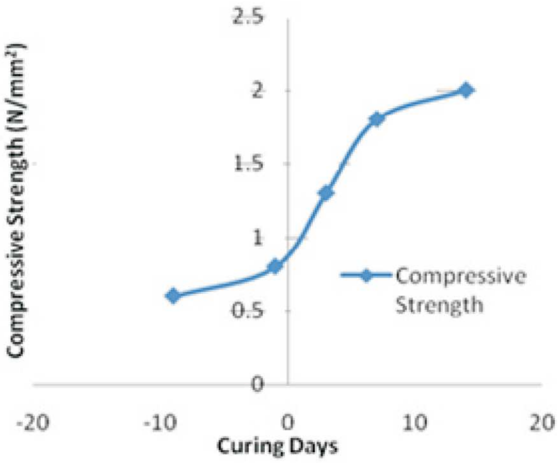

Figure 4: Graph of Hyperbolic Function with Specified Magnitude

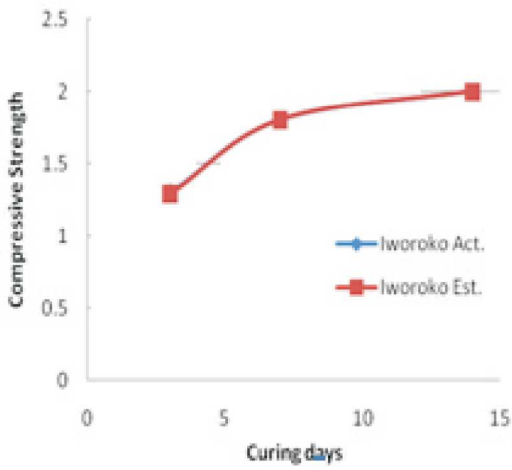

Figure 5: Iworoko Soil Compressive Strength

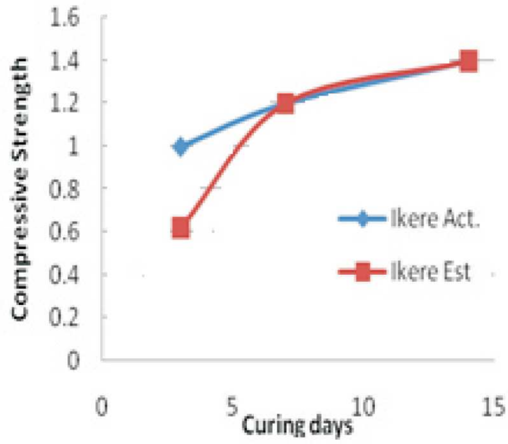

Figure 6: Ikere Soil Compressive Strength

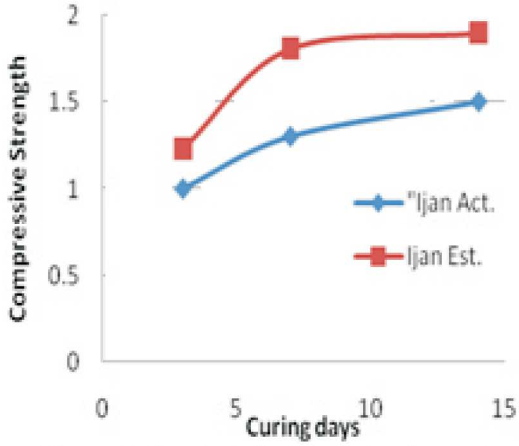

Figure 7: Ijan Soil Compressive Strength

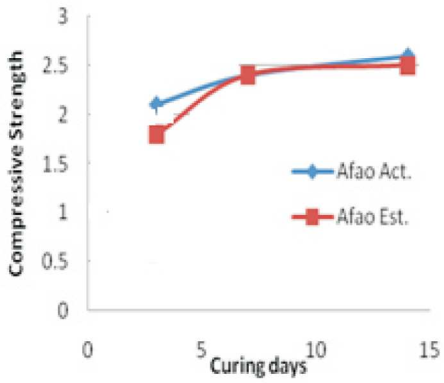

Figure 8: Afao Soil Compressive Strength

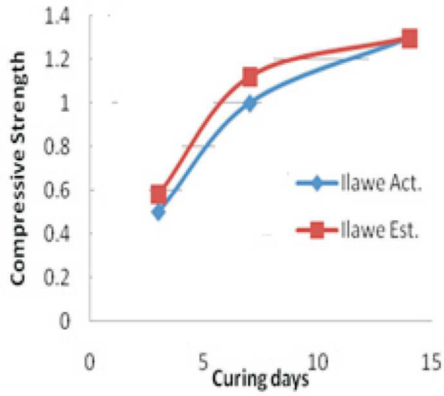

Figure 9: Ilawe Soil Compressive Strength

Table 1: Summary of Laboratory Work

Sand deposit location	Silt performed on samples %	Density (Kg/m³)	Impact %	Abrasion%	Absorption%	Compressive Strength (N/mm²)		
						3	7	14
Iworoko	6.7	1820	10.3	1.75	11.5	1.3	1.8	2.0
Ikere	6.5	1650	12.27	1.99	13.2	1.0	1.2	1.4
Ijan	5.3	1800	13.24	2.34	12.9	1.0	1.3	1.5
Afao	5	1950	9.57	1.73	10.4	2.1	2.4	2.6
Ilawe	8	1640	18.7	2.56	13.9	0.5	1.0	1.3

Table 2: Density against Compressive Strength

Density (x)	Compressive strength N/mm²
1820	1.3
1650	1
1800	1
1950	2.05
1640	0.5

Table 3: Estimated Compressive Strength using Developed Model

Sand deposit location	Density (Kg/m³)	Compressive Strength (N/mm²)		
		3	7	14
Iworoko	1820	1.29	1.8	2.0
Ikere	1650	0.6	1.22	1.37
Ijan	1800	1.23	1.81	1.9
Afao	1950	1.8	2.4	2.6
Ilawe	1640	0.58	1.12	1.3

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