International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 5 (May. 2024), PP. 129-144

Structural Modelling of Compressive Strength of Sandcrete Block Walls with Varying Age of Curing

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ABSTRACT:
Inspite of the wide coverage of masonry structures in technical literature, there appears to exist a serious gap in research on sandcrete blocks, particularly the stress-deformation characteristics and mechanism of failure of sandcrete block walls. And even more particularly, there is little or no such research based on the structural model of prototype block units, which therefore constitutes the major focus of this research paper. The methodology for using small-scale direct model for the experimental investigation of the strength, deformation and failure mechanism of sandcrete masonry structure is presented. The strength evaluation tests for the physical and mechanical properties of sandcrete block units and block walls were carried out in accordance with BS 5628(1978) and NIS 74(1976). A total of 242 prototype sandcrete specimens, 255 number of ¼ -model sandcrete blocks. The compressive strength of sandcrete block units at the optimum water-content ratio for a ¼ scale model practically coincided with those of the prototype blocks in the numerical values of about 7.96N/mm^2, 6.5N/mm^2, 4.30N/mm^2 and 3.65N/mm^2 for mix ratio of 1:4, 1:6, 1:8, and 1:10 respectively. The compressive strength of blockwall with model sandcrete blocks varied with the strength of the sandcrete block units, the mortar strength and the length to height ratio of block wall. The numerical values averaged 9.30N/mm^2, 9.10N/mm^2, 6.5N/mm^2 and 6.40N/mm^2 for 1:5, 1:6, 1:8 and 1:10 mixes respectively. Comparison of the results obtained from the model and prototype test specimens showed remarkably close agreement, quantitatively and qualitatively, with each other and with the values and trends reported by other researchers. These conclusions open a wider scope and opportunity for research into sandcrete masonry structures especially, where heavier and expensive facilities for full-scale tests are not available.

Date of Submission: 06-05-2024 Date of Acceptance: 19-05-2024

I. INTRODUCTION

The importance of housing in socio-Economic Development cannot be over emphasized. The great needs to reduce cost of buildings and therefore increase affordability and availability of housing for the ever-increasing population of the Nigerian citizenry has features as an important policy thrust of Government over the years. This has also continued to receive attention at the various works conferences of the Ministry of Works and Housing till dates, In order to respond to this dire need and drive home this important housing policy objective of government, it is extremely necessary to set up to the tempo of research and studies in economic designs, cost effective use of local materials and construction technologies amongst others. In connection with this, it must be observed that the National Road and Building Research Institute of the Ministry of Science and Technology has made reasonable progress in the use of stabilized laterite as walling materials for housing projects.

However, while other local materials such as lateritic concrete, mud used as admixtures with sea sand sandcrete and river sand sandcrete are receiving some form of research attention, there appears to be little or no conscious research efforts in the area of alternative building materials testing with scaled models, designs and appropriate construction technology development. The focus of this research therefore, is to investigate the structural adequacy and economic effectiveness of application of structural sandcrete hollow blocks for housing development using ¼ scale structural model.

Houses up to four floors using masonry block units in the form of concrete blocks and structural bricks as load bearing walls (without frame) have been in use for a very long time. Sandcrete blocks (hollow and solid) are extremely popular in Nigeria as walling material used as external walls and internal partitions. Hollow blocks have the added advantage of increased stability, material economy and relative heat insulation than the solid block.

THEORETICAL/ CONCEPTUAL FRAMEWORK OF STUDY

Structural model (reduced-scale structures) has always played a significant role in Structural Engineering research analysis and design. Experiments on reduced-scale structures have always played important role in teaching Structural Mechanical and Structural Engineering (Kunnath et. Al, 1994).

In this paper, theoretical similitude requirements to the rather extensive discipline of experimental stress analysis are used. Similitude requirements are derived from proper dimensional analysis and used as a basis for modeling and prediction of results.

It is assumed that the static compressive strength of masonry wall, **σ** depends on the loading **q** per unit length, the modulus of elasticity **E** and representative length **I**, Implicitly put

$$F(\sigma, q, E, I) = 0 \qquad 1.1$$

Selecting the modules E and length I as dimensionally independent in a static problem, as expressed by Gajanan et al (1983), equation 1.1 can be expressed in dimensional products as follows

$$G\left(\frac{\boldsymbol{\sigma}}{\boldsymbol{E}}, \frac{\boldsymbol{q}}{\boldsymbol{El}}\right) = 0 \qquad 1.2$$

$$\sigma = E\phi\left(\frac{\boldsymbol{q}}{\boldsymbol{El}}\right) \qquad 1.3$$

Assuming the same material in model and prototype based on practical homogeneity of sandcrete mix, the scale factor for material $S_E = 1$. Thus, the prototype load $q_{prot} = q_{model}\ S^2L$

Where SL is the linear scale factor.

In order words, the failure load of a model hollow sandcrete block equals the model failure load multiplied by the square of the linear scale factor. It is further postulated that if the model block predicted strength equals the prototype block strength, then a blockwall produced from prototype and model block unit independently, but bonded with the same mortar and having the same length to height ratio should have the same strength. It is obvious that the success of this position will definitely step up greater experimental interest in masonry structures to the end that the safety and efficiency of their use will be assured with greater reliability.

II. METHODOLOGY OF RESEARCH

This research work is intended as a contribution to bridge the gap of scanty information on the application of scaled structural modeling to blockwalls, especially the sandcrete blockwalls. Its focus consists mainly in the application of similarity mechanics and laboratory models to determine the structural behavior of sandcrete blockwall under various loading conditions. This research work further aimed at achieving review of Model Studies on Structural Masonry. The foundations of dimensional analysis as the basis of structural modeling can be found in the pioneering works of Buckingham, (1914) and Bridgman (1922) as well as in the later monograph of Langhaar (1951) and many others.

a) Static Models of Masonry

The modeling of masonry structures has received increased attention in the last four decades or so in the intensive works several researchers. These include Vogt (1956), Benjamin et al (1958), Murphy et al (1966), Sinha (1967) Zia et al (1970), Mohr (1971), Cranston et al (1976), Becica (1977), Harris et al (1978), in which engineering structures have been successfully modeled to reduced geometric scales. However, not much research literature was seen on structural modeling of sandcrete blockwall. A review of early works using the modeling techniques in $\frac{1}{4}$ and $\frac{1}{10}$ scale models for masonry structural studies together with similitude requirements has been presented in works of Vogt (1956). Engineering feasibility of model brick work investigations of structures was further investigated into the works of Harris (1980) and Murphy et al (1966). As well as Sinha et al (1970), who carried out a direct comparison of the strengths of prototype brickwork and its $\frac{1}{3}$ - and $\frac{1}{6}$ – scale models.

It was concluded from these early investigations that the strengths of full-size brickwork could be reproduced by means of model tests. Extension of the basic modeling techniques developed by Sinha (1967) and his co-workers at the University of Edingurgh was made to study the deflections and stresses in multi-story brick structures under lateral loads. Tests on model masonry structures have also been successfully conducted in Australia for the tower building, on axially loaded and laterally loaded brick walls at $\frac{1}{3}$ scales. The details of these tests are reported in Mohr (1971).

In the United States, the earliest reported tests using model masonry were conducted in studies dealing with the shear resistance of infill frames as expressed by Benjamin et al (1958). An extensive experimental study of multistory and multi-bay reinforced concrete masonry infill frames using $\frac{1}{4}$ scale clay bricks has provided considerable insight into the interaction of the masonry with the boundary frame in such systems. The findings from these works and from other acknowledge studies here were far reaching and from the main clauses of the Standards BS 5628 (1978) known as the Structural use of Masonry. A compressive historical review of the developments and application of structural modeling of that period is presented in the monograph of Gajanan et al (1983), which also contains invaluable information on the theory of structural modeling, experimental techniques and important case studies both for static and dynamic loading. Early attempts at the National Bureau of Standards (NBS) in the late 60s to model concrete masonry structures using carefully fabricated $\frac{1}{4}$ – scale masonry blocks made from Ottawa sand were not conclusive. The earliest reported work on the direct modeling of concrete masonry using the same $\frac{1}{4}$ scale units, manufactured for NBS by the National Concrete Masonry Association, was conducted at Draxel University by Harris et al (1978)

b) **Dynamic Models of Masonry**

Further, studies on modeling of masonry structures under dynamic and earthquake loads have been undertaken the results of which are presented in Kraawinkler et al (1978), Harris (1980) and Abrams *(1996), Paulson et al (1999). Who investigated the effects of repaid rate of loading using ¼ reduced scale masonry model, particular interest presents the Shale table studies of Chinwah et al (1990) of unread single storey masonry wall using seismic parameters for Ghana, Guinea and Cameroon.

III. MATERIALS AND METHOD

The materials used in this research were basically sand, obtained from a local source in Amassoma-Bayelsa; Portland (Dangote cement brand) and water from the Niger Delta University supply network, a 450X 150 X 225mm steel block mould. A number of the wooden ¼ Sandcrete block model moulds were constructed at the carpentry section of Agricultural and Environmental Engineering Department.

Preparation of test Specimens

The study was conducted with both prototype and model specimens. Details of these specimens are given in the following paragraphs.

Prototype Sandcrete Block Specimens

For the effect of water cement-ratio on the compressive strength of the sandcrete blockwalls and blocks, the mix proportions for mortar and block in both model and prototype used were also 1:4, 1:6, 1:8 and 1:10. Also the water content used in mortar and block in both model and prototype was varied from 0.3 to 0.7 by weight accordingly, in both cases, that is, prototype and model, wet curing was carried out for 7,14,21 and 28 days at room temperature.

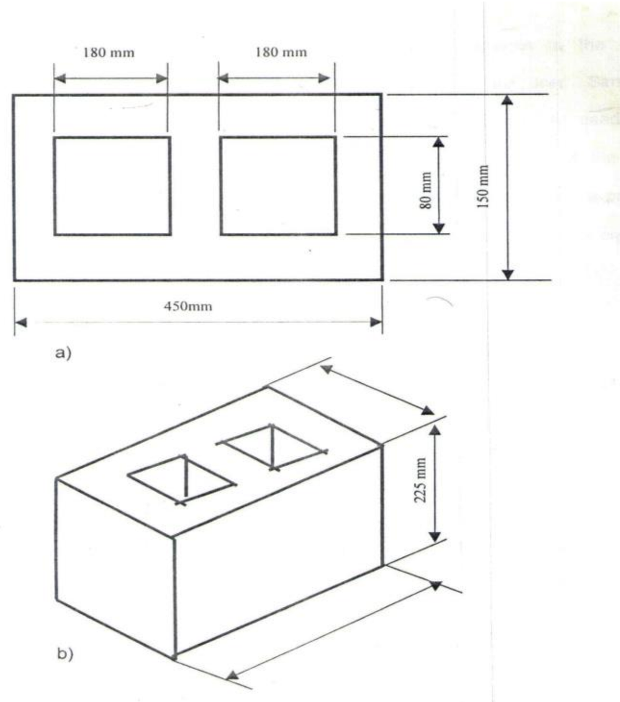

Fig. 1: Dimensions of prototype Sandcrete Block unit (a) Plan view (b) Isometric view

Model Sandcrete Block Specimen

In this research work, theoretical similitude requirements to the rather extensive discipline of experimental stress analysis are used. Similitude requirements are derived from proper dimensional analysis and used as a basis for modeling and prediction of results. It is assumed that the static compressive strength of masonry wall, σ depends on the loading q per unit length the modulus of elasticity E and representative length I, from equation 1,

F (σ, q, E, I) = 0 1

Selecting the modulus E and length I as dimensionally independent in a static problem, as expressed by Gajanan et al (1983), equation 2 can be expressed in dimensional products as follows.

$\sigma = Kq^a, E^b, I^c$ 2

Where K is a dimensionless parameter that may itself be a function of dimensionless grouping of the pertinent physical quantities, but is more often simply a constant.

In dimensionless terms, Equation 3 takes the form:

$F/L^2 = (F/L)^a (F/L^2)^b (L)^c$ 3

Forcing this expression to be dimensionally homogeneous, we then have two equations for the fundamental measures of force and length.

$(F/L^{-2}) = K\{(FL)^a (FL^{-2})^b L^c\}$ 4

Alternatively

$G(\frac{\sigma}{E}, \frac{q}{El}) = 0$ 5

$\sigma = E\phi (\frac{q}{El})$ 6

assuming the same material in model and prototype based on practical homogeneity of sandcrete mix, the scale factor for material $S_E = 1$.

Thus, the prototype load $q_{prot} = q_{model}S^2L$

Where S_L is the linear scale factor.

In order words, the failure load of a model hollow sandcrete block equals the model failure load multiplied by the square of the linear scale factor. It is further postulated that if the model block predicted strength equals the prototype block strength, then a blockwall produced from prototype and model block unit independently, but bonded with the same mortar and having the same length to height ratio should have the same strength. The structural modeling of the prototype block was carried out on the basis of similarity Mechanics reviewed in the literature. The relevant similitude requirements based on dimensional analysis for the preparation of the specimen; loading and prediction are listed in Table 3.1

TABLE 1: Similitude Requirements, Static Elastic Modelling

S/NO	Quantities	Dimensions	Scale Factor
1.	Material-related properties		
	a) Stress	FL^{-2}	S_E
	b) Modules of elasticity	FL^{-2}	S_E
	c) Poisson's ratio	-	1
	d) Strain	-	1
2.	Geometry		
	a) Linear dimension	L	S1
	b) Linear displacement	L	S1
	c) Angular Displacement	-	1
	d) Area	L^2	SI^2
3.	Loading		
	a) Concentrated load Q	F	$S_E S_I^2$
	b) Line load w	FL^{-1}	$S_E SI$

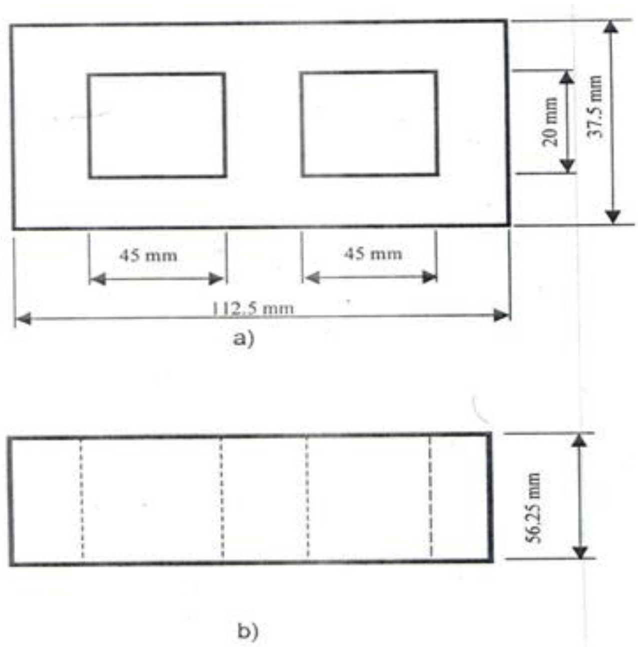

Fig 2: Dimensions of Model Sandcrete Block Unit(a) Plan view (b) Front view

MIX DESIGN ANALYSIS

The quantity of each material (Sand, cement and water) used for the moulding of sandcrete blocks for the both model and prototype was computed accordingly based on the code of practice requirement (BS 220238).

Absolute Volume of a material (AV) = $\frac{weight\ of\ material}{specific\ gravity\ of\ material}$ 1

The specific gravity and bulk density of sand and cement were determined by standard laboratory procedure and following values obtained.

Specific gravity

Sand =2.60 (ii) Cement =3.10

Bulk density

Sand = $1600kg/m^3$

The water cement ratio. W/C used for the moulding were carefully calculate as follows:

For Mix 1:4,

$W/_C$ = 0.30

Absolute volume of cement = $\frac{1 \; x \; 1440}{3.1 \; x \; 1000}$ = 0.465m^3

Absolute volume of Sand = $\frac{4 \; x \; 1600}{2.6 \; x \; 1000} = \frac{6400}{2600}$ = 2.462m^3

$W/_C =$ 0.30; Water, W = 0.30 x 1440 = 432kg

Total Volume of water (AV) = $\frac{432}{1000} = 0.432m^3$

Total Volume of materials = (0.465 + 2.462 + 0.432) = 3.359m^3

$W/_C =$ 0.40; W=00.40 x 1440 =3.359m^3

$W/_C =$ 0.50; W=0,5 x 1440 = 576kg

$W/_C =$ 0.60; W=0.6 x 1440 = 864kg

$W/_C =$ 0.7' W=0.7 x 1440=1008kg

Volume of material per meter cube of mortar

Cement:

Volume of cement/m^3 $= \frac{1}{3.359}$ = 0.2977m^3

Weight of cement/m^3 =0.2977 x 1440= 428.69kg

Sand:
Volume of sand/m^3
For 1:4 Mix

Vol. = $\frac{4}{3.359}$ = 1.191m^3

Weight = 1.191 x 1600 = 1905.6kg
For 1: 8 Mix

Volume = $\frac{6}{3.359} = 1.768m^2$

Weight = 1.786 x 1600 = 2857.6kg
For 1:8 mix

Vol. of sand/m^3 = $\frac{8}{3.359}$ = 2.382m^3

Weight of sand/m^3 =2.382 x 1600 = 3811.2kg
For 1: 10 mix

Vol. of sand/m^3 = $\frac{8}{3.359} = 2.977m^2$

Weight of sand/m^3 =2.977 x 1600 = 4763.2kg

Water
Weight of Water/m^3

$W/C =$ 0.30; W=0.4 x 428.69kg = 128.607kg

$W/C =$ 0.4; W=0.4 x 428.69 = 171.476kg

$W/C =$ 0.5; W=0.5 x 428.69 = 214.345kg

$W/C =$ 0.6; W=0.6 x 428.69 = 257.214kg

$W/C =$ 0.7; W=0.7 x 428.69 = 300.083kg

CURING

The objective of curing is to keep the sandcrete materials saturate or as almost saturated as possible until the original water- filled spaces in the cement paste have been filled to the desired extent by the products of hydration of cement. It thereby allows the sandcrete materials to develop strength in the presence of moisture. In order t obtain good compressive strength, both the cubes, model and prototype samples were cured in a water tank maintained at about a temperature of 25^0c.

TEST PROCEDURE

Sandcrete Block units

The tests were carried out both in masonry (sandcrete) block units and sandcrete blockwalls. The detail experiments for this research were carried out at the Structural Engineering laboratory of the Niger Delta University The compressive strength test of the mortar cube is show pictorially on

Plate 1: Crushing Of Sandcrete Mortar Cube For Compressive Strength

The $1/4$ scale model sandcrete hollow blocks, full-scale prototype hollows sandcrete blocks, and the various model blockwalls were tested using compressive strength testing machine to failure, and the loads at failure recorded as shown in Tables 4, 5, 6, 7, 8, 9, 10, 11, and 12.

Three specimens were all brought out from the curing at 7, 14, 21, and 28 days. The test procedure for compressive strength of prototype sandcrete Block tests were documented pictorials also as shown in

Table 4: Prototype Sandcrete hollow blocks crushing strength 7 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/220233	PB 3-4	21/10/220233	3	17.0	7	1.95	1.80
15/10/2023	PB 3-6	21/10/2023	3	16.9	7	1.94	1.50
15/10/2023	PB 3-8	21/10/2023	3	17.0	7	1.95	1.34
15/10/2023	PB 3-10	21/10/2023	3	16.9	7	1.94	0.92
15/10/2023	PB 4-4	21/10/2023	3	17.0	7	1.95	2.10
15/10/2023	PB 4-6	21/10/2023	3	17.0	7	1.95	1.95
15/10/2023	PB 4-8	21/10/2023	4	17.0	7	1.95	1.45
15/10/2023	PB 4-10	21/10/2023	3	17.0	7	1.95	1.12
15/10/2023	PB 5-4	21/10/2023	3	17.0	7	1.95	3.20
15/10/2023	PB 5-6	21/10/2023	3	16.9	7	1.94	2.95
15/10/2023	PB 5-8	21/10/2023	3	17.0	7	1.95	2.80
15/10/2023	PB 5-10	21/10/2023	3	17.0	7	1.95	0.95
15/10/2023	PB 6-4	21/10/2023	3	17.0	7	1.95	2.80
15/10/2023	PB 6-6	21/10/2023	3	17.0	7	1.95	2.10
15/10/2023	PB 6-8	21/10/2023	4	16.9	7	1.94	1.50
15/10/2023	PB 6-10	21/10/2023	3	16.9	7	1.94	0.89
15/10/2023	PB 7-4	21/10/2023	3	17.0	7	1.95	2.04
15/10/2023	PB 7-6	21/10/2023	3	17.0	7	1.95	1.60
15/10/2023	PB 7-8	21/10/2023	3	17.0	7	1.95	1.20
15/10/2023	PB 7-10	21/10/2023	3	17.0	7	1.95	0.65

Table 5: Prototype Sandcrete hollow blocks Crushing Strength at 14 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	PB 3-4	21/10/2023	3	16.60	14	1.91	4.20
15/10/2023	PB 3-6	21/10/2023	3	16.60	14	1.91	3.60
15/10/2023	PB 3-8	21/10/2023	3	16.50	14	1.89	2.00
15/10/2023	PB 3-10	21/10/2023	3	16.50	14	1.91	1.86
15/10/2023	PB 4-4	21/10/2023	3	16.50	14	1.91	4.81
15/10/2023	PB 4-6	21/10/2023	3	16.60	14	1.89	4.20
15/10/2023	PB 4-8	21/10/2023	3	16.60	14	1.89	2.50
15/10/2023	PB 4-10	21/10/2023	3	16.50	14	1.89	2.00
15/10/2023	PB 5-4	21/10/2023	3	16.50	14	1.89	5.60
15/10/2023	PB 5-6	21/10/2023	3	16. 50	14	1.89	4.91
15/10/2023	PB 5-8	21/10/2023	3	16. 50	14	1.89	3.04
15/10/2023	PB 5-10	21/10/2023	3	16. 50	14	1.89	2.66
15/10/2023	PB 6-4	21/10/2023	3	16. 50	14	1.89	5.00
15/10/2023	PB 6-6	21/10/2023	3	16. 50	14	1.89	4.2023

15/10/2023	PB 6-8	21/10/2023	3	16. 50	14	1.89	2.81
15/10/2023	PB 6-10	21/10/2023	3	16. 50	14	1.89	2.40
15/10/2023	PB 7-4	21/10/2023	3	16. 50	14	1.89	4.50
15/10/2023	PB 7-6	21/10/2023	3	16. 70	14	1.92	3.60
15/10/2023	PB 7-8	21/10/2023	3	16. 50	14	1.89	2.13
15/10/2023	PB 7-10	21/10/2023	3	16. 50	14	1.89	2.01

Table 4: Prototype Sandcrete hollow blocks Crushing Strength at 21 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	PB 3-4	14/11/2023	3	16.60	21	1.91	4.60
15/10/2023	PB 3-6	14/11/2023	3	16.60	21	1.91	3.90
15/10/2023	PB 3-8	14/11/2023	3	16.50	21	1.89	3.10
15/10/2023	PB 3-10	14/11/2023	3	16.50	21	1.89	2.30
15/10/2023	PB 4-4	14/11/2023	3	16.60	21	1.91	5.40
15/10/2023	PB 4-6	14/11/2023	3	16.60	21	1.89	4.62
15/10/2023	PB 4-8	14/11/2023	3	16.50	21	1.89	3.43
15/10/2023	PB 4-10	14/11/2023	3	16.50	21	1.89	3.00
15/10/2023	PB 5-4	14/11/2023	3	16.50	21	1.89	7.10
15/10/2023	PB 5-6	14/11/2023	3	16. 50	21	1.89	6.40
15/10/2023	PB 5-8	14/11/2023	3	16. 50	21	1.89	3.86
15/10/2023	PB 5-10	14/11/2023	3	16. 60	21	1.91	3.20
15/10/2023	PB 6-4	14/11/2023	3	16. 60	21	1.91	6.00
15/10/2023	PB 6-6	14/11/2023	3	16. 60	21	1. 91	5.50
15/10/2023	PB 6-8	14/11/2023	3	16. 60	21	1. 91	3.40
15/10/2023	PB 6-10	14/11/2023	3	16. 60	21	1. 91	2.91
15/10/2023	PB 7-4	14/11/2023	3	16. 60	21	1. 91	5.40
15/10/2023	PB 7-6	14/11/2023	3	16. 50	21	1.89	4.24
15/10/2023	PB 7-8	14/11/2023	3	16. 50	21	1.89	3.20
15/10/2023	PB 7-10	14/11/2023	3	16. 50	21	1.89	2.50

Table 6; Prototype Sandcrete hollow blocks Crushing Strength at 28 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	PB 3-4	11/11/2023	3	16.60	28	1.91	6.10
15/10/2023	PB 3-6	11/11/2023	3	16.60	28	1.91	5.40
15/10/2023	PB 3-8	11/11/2023	3	16.50	28	1.89	4.08
15/10/2023	PB 3-10	11/11/2023	3	16.50	28	1.89	2.40
15/10/2023	PB 4-4	11/11/2023	3	16.50	28	1.89	6.23
15/10/2023	PB 4-6	11/11/2023	3	16.60	28	1.91	5.58
15/10/2023	PB 4-8	11/11/2023	3	16.60	28	1.91	4.39
15/10/2023	PB 4-10	11/11/2023	3	16.60	28	1.91	3.00
15/10/2023	PB 5-4	11/11/2023	3	16.60	28	1.91	7.60
15/10/2023	PB 5-6	11/11/2023	3	16. 60	28	1.91	6.85
15/10/2023	PB 5-8	11/11/2023	3	16. 60	28	1.91	4.47
15/10/2023	PB 5-10	11/11/2023	3	16. 50	28	1.89	3.80
15/10/2023	PB 6-4	11/11/2023	3	16. 50	28	1.89	7.00

15/10/2023	PB 6-6	11/11/2023	3	16. 60	28	1. 91	6.41
15/10/2023	PB 6-8	11/11/2023	3	16. 50	28	1. 89	4.24
15/10/2023	PB 6-10	11/11/2023	3	16. 60	28	1. 91	3.60
15/10/2023	PB 7-4	11/11/2023	3	16. 70	28	1. 92	6.54
15/10/2023	PB 7-6	11/11/2023	3	16. 60	28	1.91	589
15/10/2023	PB 7-8	11/11/2023	3	16. 70	28	1.92	4.21
15/10/2023	PB 7-10	11/11/2023	3	16. 60	28	1.91	3.20

Table 8: Prototype Sandcrete hollow blocks Crushing Strength at 7 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	MB 3-4	21/10/2023	3	4.00	7	1.91	1.80
15/10/2023	MB 3-6	21/10/2023	3	3.90	7	1.86	1.65
15/10/2023	MB 3-8	21/10/2023	3	4.00	7	1.91	1.25
15/10/2023	MB 3-10	21/10/2023	3	4.00	7	1.91	0.85
15/10/2023	MB 4-4	21/10/2023	3	4.00	7	1.91	2.10
15/10/2023	MB 4-6	21/10/2023	3	3.95	7	1.89	1.95
15/10/2023	MB 4-8	21/10/2023	4	4.00	7	1.91	1.40
15/10/2023	MB 4-10	21/10/2023	3	4.00	7	1.91	1.00
15/10/2023	MB 5-4	21/10/2023	3	4.00	7	1.91	3.22
15/10/2023	MB 5-6	21/10/2023	4	3.85	7	1.84	2.85
15/10/2023	MB 5-8	21/10/2023	3	4.00	7	1.91	2.10
15/10/2023	MB 5-10	21/10/2023	3	3.90	7	1.86	0.95
15/10/2023	MB 6-4	21/10/2023	3	3.90	7	1.86	2.80
15/10/2023	MB 6-6	21/10/2023	4	4.00	7	1.91	2.00
15/10/2023	MB 6-8	21/10/2023	3	4.00	7	1.91	1.45
15/10/2023	MB 6-10	21/10/2023	3	4.00	7	1.91	0.80
15/10/2023	MB 7-4	21/10/2023	3	4.00	7	1.91	2.00
15/10/2023	MB 7-6	21/10/2023	4	4.00	7	1.91	1.55
15/10/2023	MB 7-8	21/10/2023	3	4.00	7	1.91	1.20
15/10/2023	MB 7-10	21/10/2023	3	4.00	7	1.91	0.66

Table 8: Prototype Sandcrete hollow blocks Crushing Strength at 14 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	MB 3-4	28/10/2023	3	3.90	14	1.86	4.20
15/10/2023	MB 3-6	28/10/2023	3	3.85	14	1.84	3.55
15/10/2023	MB 3-8	28/10/2023	3	3.85	14	1.84	2.10
15/10/2023	MB 3-10	28/10/2023	3	3.85	14	1.84	1.84
15/10/2023	MB 4-4	28/10/2023	3	3.90	14	1.86	4.78
15/10/2023	MB 4-6	28/10/2023	3	3.90	14	1.86	4.21
15/10/2023	MB 4-8	28/10/2023	4	3.85	14	1.84	2.50
15/10/2023	MB 4-10	28/10/2023	3	3.90	14	1.86	2.10
15/10/2023	MB 5-4	28/10/2023	3	3.90	14	1.86	5.56
15/10/2023	MB 5-6	28/10/2023	4	3.90	14	1.86	4.90
15/10/2023	MB 5-8	28/10/2023	3	3.90	14	1.86	3.00
15/10/2023	MB 5-10	28/10/2023	3	3.90	14	1.86	2.00

15/10/2023	MB 6-4	28/10/2023	3	3.85	14	1.86	5.10
15/10/2023	MB 6-6	28/10/2023	4	3.90	14	1.84	4.00
15/10/2023	MB 6-8	28/10/2023	3	3.90	14	1.86	2.75
15/10/2023	MB 6-10	28/10/2023	3	3.90	14	1.86	2.40
15/10/2023	MB 7-4	28/10/2023	3	3.90	14	1.86	4.45
15/10/2023	MB 7-6	28/10/2023	3	3.90	14	1.86	3.40
15/10/2023	MB 7-8	28/10/2023	3	3.90	14	1.86	2.00
15/10/2023	MB 7-10	28/10/2023	3	3.90	14	1.86	1.54

Table 10: Prototype Sandcrete hollow blocks Crushing Strength at 21 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	MB 3-4	4/11/2023	3	3.90	21	1.86	4.57
15/10/2023	MB 3-6	4/11/2023	3	3.90	21	1.86	3.85
15/10/2023	MB 3-8	4/11/2023	3	3.85	21	1.84	3.10
15/10/2023	MB 3-10	4/11/2023	3	3.85	21	1.84	2.20
15/10/2023	MB 4-4	4/11/2023	3	3.90	21	1.86	5.40
15/10/2023	MB 4-6	4/11/2023	3	3.85	21	1.84	4.50
15/10/2023	MB 4-8	4/11/2023	4	3.85	21	1.84	3.40
15/10/2023	MB 4-10	4/11/2023	3	3.80	21	1.82	2.80
15/10/2023	MB 5-4	4/11/2023	3	3.85	21	1.84	6.85
15/10/2023	MB 5-6	4/11/2023	4	3.85	21	1.84	6.24
15/10/2023	MB 5-8	4/11/2023	3	3.85	21	1.84	3.80
15/10/2023	MB 5-10	4/11/2023	3	3.80	21	1.82	3.15
15/10/2023	MB 6-4	4/11/2023	3	3.85	21	1.84	6.16
15/10/2023	MB 6-6	4/11/2023	3	3.85	21	1.84	5.50
15/10/2023	MB 6-8	4/11/2023	3	3.85	21	1.84	3.38
15/10/2023	MB 6-10	4/11/2023	4	3.90	21	1.86	2.85
15/10/2023	MB 7-4	4/11/2023	4	3.85	21	1.84	5.40
15/10/2023	MB 7-6	4/11/2023	3	3.90	21	1.86	4.20
15/10/2023	MB 7-8	4/11/2023	3	3.85	21	1.84	3.25
15/10/2023	MB 7-10	4/11/2023	3	3.80	21	1.82	2.42

Table 3.11; Prototype Sandcrete hollow blocks Crushing Strength at 28 days age.

Date Cast	Identification Mark	Test Date	No. of Specimens	Weight of Specimen (Kg)	Age in Days	Density of Specimen g/cm^3	Compressive Stress N/mm^2
15/10/2023	MB 3-4	11/11/2023	3	3.90	28	1.86	5.90
15/10/2023	MB 3-6	11/11/2023	3	3.90	28	1.86	5.00
15/10/2023	MB 3-8	11/11/2023	3	3.90	28	1.86	3.20
15/10/2023	MB 3-10	11/11/2023	3	3.80	28	1.82	2.50
15/10/2023	MB 4-4	11/11/2023	3	3.90	28	1.86	6.00
15/10/2023	MB 4-6	11/11/2023	3	3.90	28	1.86	5.30
15/10/2023	MB 4-8	11/11/2023	4	3.80	28	1.82	4.10
15/10/2023	MB 4-10	11/11/2023	3	3.80	28	1.86	3.10
15/10/2023	MB 5-4	11/11/2023	3	3.90	28	1.86	7.46
15/10/2023	MB 5-6	11/11/2023	4	3.90	28	1.84	6.50
15/10/2023	MB 5-8	11/11/2023	3	3.85	28	1.84	4.30

15/10/2023	MB 5-10	11/11/2023	3	3.85	28	1.86	3.65
15/10/2023	MB 6-4	11/11/2023	3	3.90	28	1.82	6.5
15/10/2023	MB 6-6	11/11/2023	4	3.80	28	1.84	6.30
15/10/2023	MB 6-8	11/11/2023	3	3.85	28	1.84	4.09
15/10/2023	MB 6-10	11/11/2023	3	3.80	28	1.82	3.60
15/10/2023	MB 7-4	11/11/2023	4	3.80	28	1.82	6.30
15/10/2023	MB 7-6	11/11/2023	3	3.80	28	1.82	5.40
15/10/2023	MB 7-8	11/11/2023	3	3.85	28	1.84	3.95
15/10/2023	MB 7-10	11/11/2023	3	3.85	28	1.84	2.10

ANALYSIS AND DISCUSSION OF RESULTS

Model studies of structural masonry have been shown to prove very effective however, there are little or no studies involving the structural modeling of sandcrete blocks masonry. This study is focused on the verification of the reproducibility of prototype engineering properties by the it's $\frac{1}{4}$ scale model. Comparisons are carried out in terms of density and compressive strength of prototype and model sandcrete blocks. A total of 271 sandcrete cubes was tested in this research, 80 cubes at the age of 7 days, 63 cubes at 14 days, 64 cubes each at 21 and 28 days. The mortar cubes were bonded and tested seven weeks before the test proper, all in accordance with the standard provisions of BS 5629. Model blockwalls were erected for blockwalls were thereafter subjected to uniaxial compressive load while stress; strains and crack patterns were observed and recorded.

All the tests were conducted in the structures laboratory of the Rivers State University of Science and Technology the individual results are attached and discussion of these results are carried out with the aid of Tables and graphs, and are presented in the rest of this chapter.

VARIATION OF COMPRESSIVE STRENGTH OF SANDCRETE BLOCK WITH AGE

The functional dependence of compressive strength of sandcrete prototype block at W/C = 0.5 on the duration of wet curing is graphically plotted in figure 4.1 The plot for model block and comparison of the prototype and model strength variation are also shown in Figures. 4.2 and 4.3.

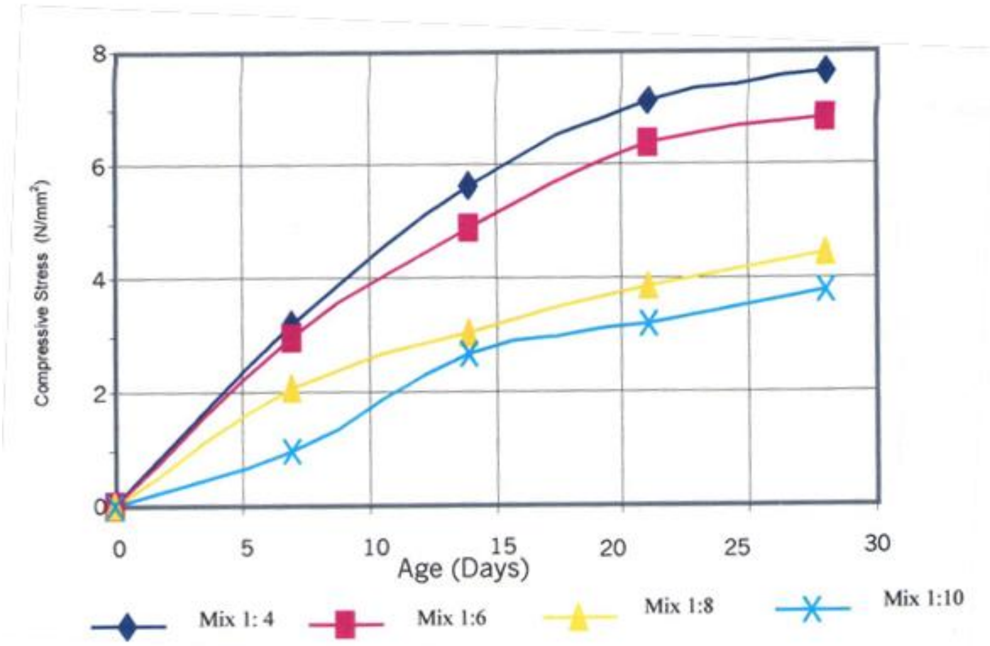

Figure 3 Relationship Between Compressive Strength and Age of Model Sandcrete Block (W/C = 0.5)

Figure 1 and 2 demonstrated the general growth tendencies of sandcrete blocks as a function of age and duration of curing. As expected, mix 1:4 yielded the highest value of compressive value of about 7.50N/mm^2 at 29 days and w/c of 0.5.
Table 4.8 shows the numerical comparison of the experimental values. From figures 4.3 and Table 4.8 the practical correspondence of the prototype and model compressive strength variation can be confirmed.
The compressive strength of Sandcrete blocks increased expectedly with the age of wet curing for all mixes tested at the water-cement ratio of 0.5. the strength at ages 7, 14,21 days constituted respectively, 43, 75 and 92 percent of the 28 day strength, which were practically the same of the prototype and model sandcrete blocks. This trend is also very close in agreement with those reported from the experimental studies of Uzomaka (1977).

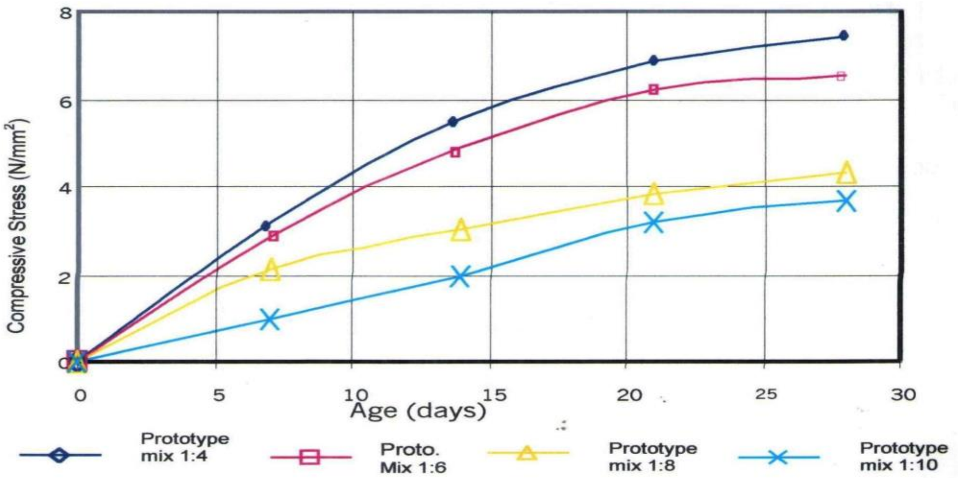

Figure 2: Relationship Between Compressive Strength and Age of Model Sandcrete Block (W/C = 0.5)

Table 7: Compressive Strength of Sandcrete Block Units at Different Ages (W/C =0.5

S/NO	Age (Days)	Model f_{cu} (N/mm^2)				Prototype f_{cu} (N/mm^2)			
1	7	1:4	1:6	1:8	1:10	1:4	1:6	1:8	1:10
2	14	3.22	2.85	2.10	0.95	3.20	2.95	2.08	0.95
3	21	5.56	4.90	3.00	2.00	5.60	4.91	3.04	2.66
4	28	7.46	6.50	4.30	3.65	7.60	6.85	4347	3.80

Table 8: Comparisons of Model and Prototype Sandcrete Block Unit Strengths at 28 Days

W/C	COMPRESSIVE STRENGTHS (N/mm^2)							
	1:10		**1.8**		**1:6**		**1:4**	
	Prototype	**Model**	**Prototype**	**Model**	**Prototype**	**Model**	**Prototype**	**Model**
0.3	2.40	2.50	4.08	3.20	5.40	5.00	6.10	5.90
0.4	3.00	3.10	4.39	4.10	5.58	5.30	6.23	6.00
0.5	3.80	3.65	4.47	4.30	6.85	6.50	7.60	7.46
0.6	3.60	3.60	4.24	4.09	6.41	6.30	7.00	6.50
0.7	3.20	3.10	4.21	3.95	5.89	5.40	6.54	6.30

All four curves exhibited some failing branch of the strength – W/C variations after W/C of 0.5 except 1:8 mix where the reduction after the peak value was insignificant. Comparison of the above results with those of Eze-Uzomaka (1977) reveals behavior of the strength parameter in a similar manner. The Maximum strength of about 3.80N/mm^2 corresponded to a water cement ratio of about 0.5
These results confirm that the physical and structural properties of sandcrete blocks can be reproduced in practical terms by it reduced scale one-quarter model

IV. CONCLUSIONS AND RECOMMENDATIONS

The test results and analysis of the influence of mix ratios, water-cement ratio, age, strength of block units and bonding mortar on the load carrying capacity and failure mechanism of the ¼ model blockwall, provides concrete evidence on the reproducibility of prototype sandcrete physic-mechanical behavior under load.

More particularly, the results of laboratory tests and analysis of the effects of mix and water-cement ratios on the physical and mechanical properties of sandcrete block in prototype and ¼ scale model have show that:

The density of sandcrete masonry block units showed no marked variation with respect to mix ratio; water content or ages of wet curing. The maximum value raged form 18.9kN/m^3 for 1:4, 1:6, 1:8 and 1:10 mixes tested. The results form the model were found to be representative and in close agreement with those of the prototype block units.

The compressive strength of sandcrete block units in model and prototype increased with increase in water-cement ratio attaining a maximum value at an optimum value of about 0.5 for all mixes tested. The maximum value at 28 days constituted 3.8N/mm^2 , 4.47 N/mm^2 , 6.85 N/mm^2 , and 7.60 N/mm^2 , for prototype 1:4, 1:6, 1:8 and 1:10 blocks respectively. The corresponding values for the model blocks consisted of 3.65 N/mm^2 , 4.3 N/mm^2 , 6.50 N/mm^2 , and 7.46 N/mm^2 . the predicted values of strength as a function of the water cement ratio are in close agreement with those of the prototype blocks.

The compressive strength of sandcrete blocks increased expectedly with age of wet curing for all mixes tested at the water cement ratio of 0.5. The strength at ages 7, 14, 21 days constituted respectively, 43, 75 and 92 percent of the 28 day strength, which were practically the same for the prototype and model sandcrete blocks.

The analysis of tests results of compressive strength of ¼ model sandcrete masonry blockwalls as a function of strength of the block units and mortar strength show that:

Sandcrete blockwalls exhibit a linear stress-strain relationship almost up to the maximum strength, after which, a decrease in strength was observed. The measured longitudinal and transverse strains decreased from the stronger mix of 1:4 to the weaker and mix of 1:10.

The modulus of Elasticity ranged from 20.95N/mm^2 for 1:4 and 1:10 mixes. The corresponding value for Poison's ratio were 0.25 and 0.35.

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