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Studies On Structural Response Of Sandcrete Blockwalls Under Uniaxial Compressive Load

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Abstract
This study report on the Structural behavour of Model Sandcrete Blockwalls Under Uniaxial Compressive Load. Understanding the structural response of blockwalls under uniaxial compressive load is crucial for designing safe and efficient masonry structures. The structural response of blockwalls under uniaxial compressive load, namely the stress-deformation characteristics and failure process of sandcrete blockwalls, appears to be a substantial study gap, even though masonry constructions have been extensively covered in technical literature. A direct model on a ¼ size is used to experimentally investigate the strength, deformation, and failure mechanism of sandcrete blockwall. A total of 8 model blockwalls were developed and examined for this study. All tested mixtures had an average water-to-cement ratio of 0.5. The test results shows that the Structural Response of Sandcrete Blockwalls Under Uniaxial Compressive Load varies with the strength of the sandcrete block units, the mortar strength and the length to height ratio of blockwall. The numerical values averaged from 9.30N/mm^2, 9.10N/mm^2, 6.5N/mm^2 and 6.40N/mm^2 for 1:4, 1:6, 1:8 and 1:10 mixes respectively.
Keywords: *Model, Blockwall, Compressive Load*

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I. Introduction

Analyzing how model blockwalls respond structurally to uniaxial compressive load entails examining how the blockwalls respond to forces acting along a single axis. Abrams (1982), Abrams, (1997), Yokel, Mathey, and Dikkers, (1971) reported. Understanding the load-bearing capability and failure causes of masonry structures requires an understanding of this scenario. An outline of the main findings of this study is provided below:

Sandcrete Blockwall Behaviors Under Uniaxial Load
Elastic Deformation:

The idea of "elastic deformation" explains the transient shape change that blockwalls experience in response to applied loads, temperature changes, or in some cases seismic pressures. Elastic deformation is reversible, meaning that once the applied load is released, the blockwall reverts to its original shape, in contrast to plastic deformation, which causes permanent alterations. Stress is the force applied per unit area (e.g., pressure), typically measured in Pascals (Pa) or psi as stated by Gajanan et al (1983)

Strain in blockwall study is the amount of deformation (change in shape or size) the blockwall undergoes, measured as the ratio of the deformation to the original dimensions. Syiemiong et al (2021)

When the blockwall acts elastically, the stress is directly proportional to strain, following Hooke's Law, which is represented mathematically as:

$\alpha = E. \varepsilon$

Where:
α is the stress.
E is the Young's Modulus (a material constant representing stiffness).
ε is the strain.

During elastic deformation, when the applied stress is removed, the blockwall will return to its original dimensions, indicating no permanent deformation. If stress which is the applied load continues to increase beyond a certain limit (the yield point), the blockwall undergoes plastic deformation, where the changes become permanent also report by Zahra et al (2021) and Henrique et al (2020)

Cracking and Nonlinear Behavior

When placed under substantial uniaxial loads, Sandcrete blockwalls display nonlinear behavior, which eventually causes cracking and failure. Nonlinear behavior includes irreversible deformations, crack propagation, and material degradation in contrast to the elastic response, which is governed by Hooke's Law.

With increasing load, cracks develop, typically starting in the mortar joints, leading to nonlinear behavior. As reported by **Madan** et al (1997), and vertical cracks may also form due to buckling or crushing of individual blocks.

Ultimate Strength and Failure

Eventually, the blockwall reaches its ultimate compressive strength, and failure occurs. Common failure modes observed during the test include:

i) Crushing of blocks: The blocks experience excessive stress beyond their capacity.
ii) Buckling: If the wall is slender (high height-to-thickness ratio), buckling may occur before material failure, but that was not the case of all the blockwalls in this study.
iii) Mortar joint failure: mortar joints seen localized failures before the blocks themselves fail in this test.

Stress-Strain Relationships

The manner in which masonry materials (blocks and mortar) react to applied loads is described by the stress-strain relationship of block walls. In this work, this relationship is essential to comprehending wall behavior under compression. Blockwalls behave in a nonlinear, anisotropic, and brittle manner in contrast to homogenous materials like steel, particularly when subjected to strain and shear.

II. Preparation Of Sandcrete Blockwall Test Specimens

Proper preparation of test specimens is crucial for accurate evaluation of the mechanical properties of blockwalls. The preparation process depends on the type of test being conducted, such as compressive strength, tensile strength, shear strength, or flexural strength. In this case is compressive strength. The key steps for specimen preparation follow standardized testing guidelines of ASTM C1314 (Standard Test Method for Compressive Strength of Masonry Prisms)

Material Selection

Blocks: Standard-size blocks of 225mm x 225mm x 450mm were selected as representative of the blockwall construction. Ensured that blocks were from the same batch or production to maintain uniformity.

Mortar: we used mortar that conforms to the design mix or standards for block wall construction. Mortar consistency, mix proportions, and curing time were considered in recording test results.

Construction of Specimen Walls

Model Standard Size Blockwalls: Constructed small specimen walls using the selected ¼ scaled blocks and mortar. Typically, these walls were built in layers, using blocks and mortar joints of scaled standard thickness. The walls were single-layer for this test.

Laying Blocks: Laid the ¼ scaled blocks according to the construction method being evaluated. Followed the construction standards.

Curing and Conditioning

After constructing the specimen blockwalls, allowed the mortar to cure properly before testing. The curing period varied between typically 7, 14, or 28 days. Proper curing ensured that the mortar reached its design strength and represented real construction conditions. Ensured that the curing environment was controlled, avoiding extreme humidity or dryness, as this could alter the strength properties.

Surface Preparation

Flatness: The top and bottom surfaces of the test specimens were flat to ensured uniform load distribution during testing. Surface grinding was necessary to achieve this flatness.

Cleaning: Removed any debris, dust, or foreign particles from the ¼ scaled blockwalls surfaces before testing to avoid interference with the test results.

Measurement and Dimension Verification

Measured and recorded the dimensions of the test specimens accurately using measuring tools such as calipers and measuring tape. This includes the height, width, thickness of the blocks, and mortar joints. Verified that the specimen conforms to the required standards for testing. Standard test procedures such as ASTM.

Testing Environment

Ensured the specimens were tested in a controlled environment where temperature, humidity, and other factors regulated to avoid external influences on the test results. By following these steps, test specimens for blockwalls were properly prepared, ensuring the results of structural testing machines to accurately reflected the performance of the block.

III. Test Results

"Test results" refer to the data obtained from evaluating the ¼ scaled model blockwall samples under uniaxial conditions and they are presented below.

Table 1: Stress- Strain Behaviour of Model Blockwall for Mix 1:4 (L/H= 1.6)

S/No.	Applied load KN	Compressive Stress N/mm^2	Lateral Strain (x-Direction) ($X10^{-5}$)	Longitudinal Strain (y – direction) ($X10^{-5}$)
1.	10.0	0.59	3.32	11.84
2.	25.0	1.48	7.60	30.40
3.	50.0	2.96	15.34	60.38
4.	100.0	5.90	29.30	115.40
5.	157.0	9.30	44.40	177.60
6.	150	8.9	56.02	223.2
7.	126.5	7.5	67.14	264.33

Table 2: Stress- Strain Behaviour of Model Blockwall for Mix 1:6 (L/H= 1.6)

S/No.	Applied load KN	Compressive Stress N/mm^2	Lateral Strain (y-Direction) ($X10^{-5}$)	Longitudinal Strain (x – direction) ($X10^{-5}$)
1.	10.00	0.59	20.20	5.67
2.	25.00	1.48	51.04	14.65
3.	50.00	2.96	87.50	24.50
4.	100.00	5.90	155.40	43.90
5.	153.00	9.10	230.98	65.60
6.	145.00	8.9	285.00	81.80
7.	138.40	8.2	303.00	92.00

Table 3: Stress- Strain Behaviour of Model Blockwall for Mix 1:8 (L/H= 1.6)

S/No.	Applied load KN	Compressive Stress N/mm^2	Lateral Strain (x-Direction) ($X10^{-5}$)	Longitudinal Strain (y – direction) ($X10^{-5}$)
1.	10.00	0.59	9.85	28.97
2.	25.00	1.48	23.00	70.98
3.	50.00	2.96	48.00	148.60
4.	100.00	5.90	98.50	303.00
5.	116.00	6.85	112.30	348.80
6.	114.80	6.80	123.40	403.20
7.	99.60	5.90	132.00	451.90

Table 4: Stress- Strain Behaviour of Model Blockwall for Mix 1:10 (L/H= 1.6)

S/No.	Applied load KN	Compressive Stress N/mm^2	Lateral Strain (x-Direction) ($X10^{-5}$)	Longitudinal Strain (y – direction) ($X10^{-5}$)
1.	10.00	0.59	26.99	112.00
2.	25.00	1.48	67.77	275.80
3.	50.00	2.96	135.30	551.60
4.	100.00	5.90	271.90	1122.90
5.	108.00	6.40	454.50	1298.70
6.	101.00	6.00	460.00	1320.00

Table 5: Variation of Blockwall Strength with Unit and Mortar Strength

Type	Mix Proportions	Model Length (mm)	Model Width (mm)	Model Height (mm)	Model Units Compressive Strength N/mm^2	Wall Compressive strength (N/mm^2)	Mortar Compressive Strength N/mm^2
SBW -1	1:4	450.00	37:50	281.25	7.46	9.30	15.00
SBW -2	1:6	450.00	37:50	281.25	7.46	9.10	15.00
SBW -3	1:8	450.00	37:50	281.25	7.46	9.50	15.00
SBW -4	1:10	450.00	37:50	281.25	7.46	9.40	15.00

IV. Analysis And Discussion Of Results

The practical correspondence of the values of strength of the $\frac{1}{4}$ model and prototype sandcrete blocks reported in this report gives a definite justification for the structural modeling of sandcrete blockwall as a masonry system. Thus, as a further development of this research, a series of $\frac{1}{4}$ model sandcrete blocks were produced, cured and bonded with type I, II and III mortar into structural blockwall. The blocks had aspect ratios of length to height ratio of 2 compressive load was applied gradually at incremental step of 10, 25, 50, 100kN etc., to failure from the top while the strains and cracks were observed and recorded up to point of failure. The four types of walls tested are denoted SBW-1 SBW-2, SBW-3 and SBW-4, the details of which are on Table 5.

V. Stress-Strain Relationship Of Blockwalls

The graphs in figure 1 below showed a roughly linear relationship between stress and strain that extended to almost 90% of the maximum strength of the sandcrete blockwalls that were tested for this study. A non-linear portion of the curve that extends to the point of collapse follows, which was more obviously represented for blockwalls constructed with 1:6 sandcrete block mixes.

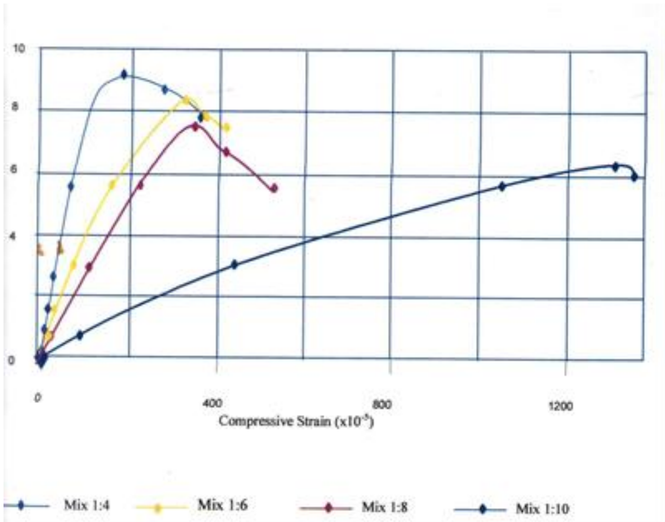

Figure 1: Stress- Strain Curves for Blockwall of Various Mixes at 28 Days and W/C = 0.5

The stress-strain curves for the various blockwall types SBW-1, SBW-2 SBW- 3 and SBW-2 tested are shown in on Figure 1, the maximum of major characteristics values is tabulated.

Table 6: Failure Loads and Stress –Strain Characteristics of Model Sandcrete Blockwalls

Mix Ratio	Lateral Strain x-Direction (x 10^{-5})	Longitudinal Strain Y- Direction (x 10^{-5})	Compressive Strength N/mm^2	Modulus of Elasticity, E (kN/mm^2) $E = \frac{\sigma y}{Ex}$	Poisson's Ration, υ $\upsilon = \frac{\varepsilon x}{\varepsilon y}$
1:4	67:14	264.33	9.30	20.950	0.25
1:6	92.00	303.00	9.10	13.870	0.28
1:8	132.00	451.90	6.85	6.100	0.32
1:10	460.00	1320.00	6.40	1.890	0.35

The measured longitudinal and transverse strains increased from the stronger mix of 1:4 to the weaker and mix of 1:10. The strains varied within a limit of 264.33 x 10^{-5} and 1320.00 x 10^{-5} for 1:4 and 1:10 mixes.

The compressive strength showed a trend with maximum values of 9.30, 9.10, 6.85 and 6.40N/mm^2 for 1:4, 1:6, 1:8 and 1:10 mixes respectively.

The passion's ratio (υ) values for the various mixes were obtained from the slopes of the linear portions of the stress-strain curves. The modulus of elasticity ranged from 20.95kN/mm^2 to 1.89 kN/mm^2 for 1.4 and 1.10 mixes. The corresponding values for poison's ratio were 0.25 and 0.35.

VI. Conclusions And Recommendations

Understanding the structural response of blockwalls under uniaxial compressive load is crucial for designing safe and efficient masonry structures. Factors such as material properties, wall geometry, bond patterns, and boundary conditions significantly influence the load-bearing capacity and failure modes. Combining experimental testing with numerical modeling provides a comprehensive understanding of this behavior.

The test results and analysis of the effects of age, bonding mortar, block unit strength, mix ratios, and water-cement ratio on the load carrying capacity and failure mechanism of the ¼ model blockwall offer verifiable proof of the reproducibility of prototype sandcrete physic-mechanical behavior under load. In specifically, the outcomes of laboratory studies and analyses of how mix and water-cement ratios affect the mechanical and physical characteristics of sandcrete blocks in prototype and ¼ scale models have revealed that:

a) 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 from the model were found to be representative and in close agreement with those of the prototype block units.

b) 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.

c) For all mixes tested at a water cement ratio of 0.5, the compressive strength of sandcrete blocks rose as predicted with the age of wet curing. The strength at 7, 14, and 21 days was 43, 75, and 92 percent of the 28-day strength, which was nearly identical for the model and prototype sandcrete blocks.

d) As a function of block unit and mortar strength, the analysis of test data for the compressive strength of ¼ model sandcrete masonry blockwalls reveals that: Up to their maximum strength, sandcrete blockwalls show a linear stress-strain relationship; beyond that, a decline in strength was noted. From the stronger mix of 1:4 to the weaker mix of 1:10, the measured longitudinal and transverse stresses reduced. For 1:4 and 1:10 blends, the maximum stresses varied within the very specific range of 264.33 x 10- 5. With maximum values of 9.30, 9.10, 6.85, and 6.40 N/mm^2 for 1:4, 1:6, 1:8, and 1:10 mixtures, respectively, the compressive strength shown a reversal of trend.

e) 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.

VII. Recommendations

The aforementioned finding attests to the validity of the Code of Practice's guideline about the usage of models for analysis and design, namely the ¼ scale model. This research's unique contribution is the extension of the code's recommendation to sandcrete masonry structures, which opens up the possibility and scope for research on sandcrete masonry structures, particularly in Nigeria and other places where heavy and sophisticated equipment isn't available for prototype scale testing. In order to resolve the national concern regarding building collapses, it is advised that model tests be used to investigate the strength, durability, and failure mechanism of the masonry structures under various stressed states, such as flexure, shear, dynamic loading, and their combination.

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