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Original Article

Multiple Regression Models that Predict the Strength of Concrete Blocks

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Abstract *- The study seeks to create a multiple regression model to forecast the strength of concrete blocks mass-made in the Abakaliki metropolis of Nigeria, employing critical elements that affect the strength of blocks produced by local enterprises. The technique comprises a survey and controlled trials on concrete block samples sourced from five distinct sectors, designated as groups G2, G3, G4, G5, and G6, in addition to a Control Group (CTG) constructed in accordance with the Nigerian Industrial Specification (NIS) blueprint. The study evaluated the block size, production techniques (mechanical or manual), material selection, mix ratios, and the strength of the block samples by controlled testing. These characteristics were employed to develop a multiple regression model for forecasting the strength of block mass produced in the state. The research indicated that the identified variables strongly influence block strength, and the created model accurately predicted block strength, achieving an R-squared value of 98.03%, which signifies an exceptional fit to the data. The T-test analysis indicated no significant difference between the actual strengths and those predicted by the model, as the t-statistic (0.693) is below the t-critical value (2.03) at p>0.005. The study recommends applying the established model to forecast concrete block strength in the urban area. Rather than doing destructive testing on block samples, it is advised that construction professionals utilize the model's equation to estimate compressive strength by obtaining the requisite input data directly from block manufacturers. This research supports data-driven decision-making in maintaining quality control.*

Keywords *- Strength of Concrete Blocks, Material Selection and Proportions, Predictive model, Controlled experiment.*

1. Introduction

Concrete blocks are masonry units comprised of diverse component materials like cement, sand, stone-dust, and water (in the required proportions), formed into different dimensions depending on the shape of the mold as defined by [1]. These concrete blocks are often manufactured in a variety of diameters from 450 millimeters by 225 millimeters by 225 millimeters (9 inches), 450 millimeters by 150 millimeters by 225 millimeters (6 inches), and 450 millimeters by 125 millimeters by 225 millimeters (5 inches), with Concrete block is described as "a composite material made up of cement, sand, and water, molded into different sizes" by description of the material. Concrete block is defined as "a composite material made up of cement, sand, and water, molded into different sizes" according to.

In Nigeria, the strength and durability of concrete blocks manufactured fluctuate due to various factors, including the industries producing them, the different techniques used in manufacture, and the component materials used. However, much research in the construction industry has led to demand for specifications on the quality of concrete blocks for building houses. The demand for concrete blocks to be used in building construction has driven the request for their utilization over other products, for instance, bricks, lateritic, and mud blocks [2]. The widespread utilization of these concrete blocks has consequently triggered an increase in requests for them and necessitated an increase in production by different block manufacturing industries. The standardization of these concrete blocks produced by different industries needs to be specified for application efficiency and performance as an important material for building houses. In many cases, walls formed with concrete blocks are ordinarily not intended to sustain external loads apart from their self-weight [3]. However, cracks on the formed walls are one of many signs of failure to be witnessed before the definite collapse. The use of substandard concrete blocks that are far from being of worthy quality, in the construction of building structures [4], was detected, which contributed to a chunk of challenges in forming wall units. The increase in the rate of building failures and collapses encountered in various states in Nigeria recently has generated enough challenges in the construction industry and the general public, concerning an increase in the loss of lives (workers during construction or occupants of the building) and economic loss of valued properties.

Fig. 1 Deteriorating concrete hollow blocks of 450*225*225 mm size

1.1. Problem Statement

Research has shown significant disparities in the quality of mass-produced concrete blocks used for construction in different Nigerian states. These disparities, particularly in block strength and durability, are linked to several production factors. These include inconsistencies in mold sizes, selection and proportioning of component materials, water-cement ratios, production techniques (manual or machine), batching methods (by weight, volume, or estimation), and the duration of curing before use. Such variability makes it difficult to assess the reliability of blocks without experimental analysis. To address this, the study aims to create a multiple regression model capable of predicting the strength of blocks based on these influencing parameters.

1.2. Aim of the Research

This research aims to develop a multiple Regression prediction model that can predict the strength of concrete blocks mass-produced within a given state in Nigeria (Abakaliki metropolis), having known the modes of production, component material selections and proportions, and techniques of batching and mixing, and dimensions of the concrete blocks (total-area, net-area, and cell-cavity areas).

1.3. The Research Objectives

The following objectives are formulated in the research to:

1. Identify the indicators that lead to variations in the characteristics of concrete blocks produced within Abakaliki by different block industries operating in the state.
2. Evaluate the strength of sampled block-producing industries within the Abakaliki metropolis.
3. Develop a multiple regression model that can predict the strength of concrete blocks produced within the Abakaliki metropolis.
4. Evaluate the reliability of the developed prediction model.

Differences have been discovered in the quality of mass-produced concrete blocks across Nigerian states (through recent investigations), primarily in strength and long-term durability. These inconsistencies are attributed to a range of production-related parameters, including non-standardized mold dimensions, variability in material selection and proportioning, variations in water-cement ratios, different production methods, non-uniform batching techniques, and varying curing durations before delivery. Such uncontrolled variability presents significant challenges in evaluating block performance without the use of direct or traditional destructive testing techniques. Consequently, this study proposes the development of a predictive multiple regression model to estimate the strength of blocks based on measurable production variables. The objective is to provide a consistent approach (driven by data) to assessing the quality of blocks, thus supporting supervisory compliance and assuring quality in Nigeria’s construction industry.

2. Review of Literature

2.1. Materials For Concrete Block Production

In the past, various materials have been utilized in the production of blocks for building construction in Nigeria, including clay, lateritic clay, and mud. In the Abakaliki metropolis, for instance, many buildings were constructed with bricks, lateritic clay, and mud blocks. A handful of them are still standing, and many have deteriorated due to harsh environments that affect the durability and strength of such materials.

2.1.1. Aggregates

states that “Aggregates are mineral filler substances utilized in concrete. Commonly employed aggregates include sand, gravel, crushed stone, and quarry dust. There is also a great deal of other inorganic fillers that are additionally utilized. The sources of these aggregates can be from the natural environment or processed by industries, which occupy about three-quarters (3/4) or 75 percent of the concrete volume [5]. The [6 and 7] classified/characterized aggregate as coarse and fine grades. Nonetheless, the particle sizes, gradation, and proportioning of these aggregates in mortar matrices used in making concrete blocks influence their qualities in terms of strength and ability to resist deterioration [8].

Fig. 2 Mud blocks of size 6 inches in thickness

2.1.2. Cement

In construction, "cement" denotes the material that, under specific conditions, is utilized to bond stones, bricks, and sand together. The principal components of this particular sort of cement are predominantly lime compounds. Hydration is a chemical reaction that occurs when water is added to cement, resulting in the release of significant heat.

As the concrete solidifies, the gel formed during the hydration process gives it strength and water tightness by binding the aggregate particles together [9 and 8]. OPC, or ordinary Portland cement, is the most often used form of cement in routine concrete construction projects. According to the American Society for Testing and Materials [10], each variety of cement can be identified by its unique physical attributes. The qualities encompass fineness, soundness, consistency, heat of hydration, setting time, specific gravity, compressive strength, and loss of ignition.

According to [18] and [11], each of these characteristics has an impact on the functionality of cement itself. On the other hand, the strength and capacity to endure deterioration of a mortar matrix combination are affected by the quantity and grade of cement present in the mixture.

2.1.3. Water

Water is one of the essential materials in the production of concrete blocks. However, the quantity and quality of water in a given mortar mix proportion influence the strength and durability of concrete blocks. The primary objective of water in a mix is to activate the reaction of chemicals between cement particles ("the process termed hydration"). The water used to produce concrete or blocks must be free of impurities such as particle suspensions, acidic and alkaline solutions, mineral salts, oily substances, and other chemical structures that have the potential to react with cement and/or aggregates. Additionally, the water needs to be safe for human consumption [8]. According to the National Institute of Standards and Technology (NIS), "It is advised to utilize potable water when making concrete blocks." Water is also used in washing aggregates and the curing of hardened blocks to ensure continuous strength gain and development throughout the curing period.

2.2. Concrete Block Production

The manufacturing of concrete blocks can be done by adopting any of the following procedures: manual or mechanical mixing, batching by volume, and weight (though many block-producing industries practice batching the component materials by estimation/guesstimating).

2.2.1. Mix Proportion Ratio

has identified that the ratios of mixing various component materials during the manufacture of concrete blocks have an impact on their quality. The range of these ratios is between a '1:6 to 1:8' ratio of cement to fine aggregate (sand), while the size of coarser aggregates should not be above 10mm. However, the increase in mix proportion decreases the strength of the blocks (if the same water quantities are used). In other words, smaller ratios (1:5 and 1:6) give a rich mix that translates to higher strength, while a thin mix (that is, bigger ratios, e.g., 1:9 and 1:10) gives weaker values of strength.

2.2.2. Batching

This is the process of quantifying the component materials either by volume or by mass and introducing them into the mixture. Batching is normally done by weight or volume for the ease of combining component materials. However, most block industries operating with manual mixing techniques adopt batching by estimation/approximation, which in most cases reduces the strength and durability of concrete blocks produced as more quantities of sand are mixed than the specified ratio by the NIS blueprint.

This estimation batching technique is done by pouring a given quantity of cement on the hip of sand, and the operator will then use their individual sense of judgement and experience to quantify the amount of sand required and mix it with the help of a shovel. However, the mixing is done thoroughly until an even mortar mix matrix is achieved before pouring into the metal mold for casting. This method could lead to the addition of more sand quantities than required or specified by design codes. The produced blocks may lack strength in load-bearing masonry walls and deteriorate easily due to poor durability.

Fig. 3 Batching by Estimation/guesstimating quantities of cement, sand, and water at the site

2.2.3. Water-Cement Ratio

The ratios of water to cement deployed in mix proportions have a direct influence on the strength of concrete blocks produced. The water-cement ratios usually adopted are between 0.4 and 1. It means 0.4 times the cement volume, as mentioned by players in the block industry. Nevertheless, lower values of these water-cement ratios are necessary to achieve higher strength blocks, while higher ratios reduce the strength by a certain percentage. recommended a value of 0.8 for the 28th day compressive strength value of 3.5N/mm^2.

Curing Age

How continuous hydration of cement in concrete or block is ensured through prevention of moisture loss from the surface of hardened concrete/block at a conducive atmosphere is termed Curing, and the adequacy of this curing process is indispensable to guarantee satisfactory hydration of the cement to ensure continuous development in strength. During the curing period, water fills the pores in the cement–sand bond, allowing hydration pastes to progressively replace these voids.

In this, the development of strength in the concrete/block increases. Therefore, the development of helical cracks on the surfaces of the hardened concrete block due to dry shrinkage will be reduced with adequate and timely curing age. The curing procedure deployed during this period has a substantial effect on the characteristics of the molded blocks. The gain in strength can only be visible when curing is done early enough, and adopting the best procedure for curing up to the required age ensures continuous hydration [12].

2.2.4. Compressive Strength of Blocks

Compressive strength is expressed as the ratio of force (in the form of applied load) and net area of the element. In other words, the stress attained by the sample. This strength in compression is affected by the control of quality engaged [13], selection of suitable materials, and sufficient curing means [2], condition of testing, and perfect surface finishes [8], among other things. Two grades of blocks were identified by [14, and 15] for building, which include the following: (1) 'load-bearing' and (2) 'non–load bearing'. These grades of blocks can take any size and shape (hollow and solid forms).

[16] evaluated the level of implementation of NIS requirements in block production in the Southwest region of Nigeria. A total of 54 blocks of sizes (e.g., 225 mm and 150 mm) were sampled and examined from the following states in the Region: Lagos, Ondo, and Oyo States. The obtained samples were tested and their results compared. The values of compressive strengths of blocks within the South West could not meet the stipulated specification of. There was a shoddy quality implementation by various block manufacturing industries within the region.

According to [3], the quality of block samples taken from the city of Lagos is taken into consideration. The research considered sixty block pieces that were manufactured using a vibrating machine. They were taken among 10 different locations within the Lagos Mainland. The blocks obtained from various producers, and those manufactured, were tested for strength, dimensional tolerances, and density. The results showed low compressive strength. There was satisfaction in the densities of these blocks, but there was inaccuracy in the dimensions. Regular enforcement of quality in the production of blocks was recommended.

In summary, previous research reviewed focused on the quality of block samples in a given area and the model equation that predicts the strength of concrete; there is little or no report on a model for predicting block strengths within the Abakaliki metropolis. Rather than conducting the rigorous traditional method of testing for the strength of blocks, the proposed model will predict the strength of blocks when the vital parameters (cross-sections of the block, proportions of material constituents, and molding method)are known.

3. Methodology and Materials in the Research

3.1. Research Design

The method deployed in this research is divided into phases. The first phase involves surveying concrete blocks produced within the Abakaliki metropolis to evaluate their strengths and durability, identify the causes of variations in terms of cross-sectional dimensions, component material selection, proportions, and mode of production, as well as the curing period before use. The second phase is on the development of a multiple regression model that predicts the strength and durability of concrete blocks produced within the state, using those identified indicators as mentioned above.

3.2. Sampling of Block Manufacturing Industries within the Abakaliki Metropolis

The approach encompasses sampling of surveyed block-making industries randomly within the Abakaliki metropolis to ascertain the level of quality implementations in their manufacturing processes with respect to utilizing machines in mixing and molding, and manual hand molding tools. Many block manufacturing industries are in existence in Abakaliki metropolis; however, five (5) were sampled randomly from them for this study, with much consideration given to the means of production.

Two out of the five sampled block-making industries employ machines for mixing and molding, while the other three utilize the manual method of mixing and molding during production. Nevertheless, three specimens of 450*225*150 mm (6-inch) and 450*225*225 mm (9-inch) blocks with hollow cavities were selected from each industry and taken to the laboratory for curing and testing after 28 days. The collected 30 block specimens were given a mark (ranging from G2 to G6) for easy identification and grouped into five groups. The G2 and G3 were from the machine, while the G4, G5, and G6 were from the manual manufacturers, respectively. The sands and other Fine aggregates integrated into the design mix ratio by the 5-block industries were likewise collected, and their particle sizes were determined under the necessary codes (e.g., BS 812).

Table 1. The site survey summary of the five block industries and the control group was made in the NIS standard

	Machine Mold			Hand Mold		
	G2	**G3**	**GCT**	**G4**	**G5**	**G6**
SOURCE OF SAND	River	River	River	River	River	River
DESIGN MIX RATIO (C:S: Q)	1:6:4	1:6:4	1:4:2	1:6:5	1:10:0	1:10:0
Mode OF MIXING AND MOULDING	Mac hine	Mac hine	Mac hine	Manua l	Manual	Manual
CEMENT-SAND RATIO	0.16 67	0.16 67	0.25	0.1667	0.1	0.1
CEMENT-QUARRY DUST RATIO	0.25	0.25	0.5	0.2	0	0
RATIO OF WATER-CEMENT	1	1	0.8	Estima te	Estimate	Estimate
DAYS of CURING Prior to SUPPLY	4 days	4 days	7 days	3 days	3 days	4 days

3.3. Experimental Molding of Samples of Blocks as Specified in Nigerian Industrial Specification (NIS) Documents

Three specimens of 450*225*150mm (6-inch) and 450*225*225mm (9-inch) blocks with a hollow cavity were made using machine-mixed and molded NIS standard, termed the control groups. These specimens were marked as the control group (GCT). These hollow cavity blocks were collected from the industries, and the ones made with respect to NIS specifications were cured and tested at the laboratory to determine their qualities and the level of implementation of the NIS documents on control of quality. The materials employed by all the block industries have common qualities and grades. The type of cement deployed is Ordinary Portland cement of grade 42.5, though from different sources. Sand utilized was obtained from the river-bed, stone-dust collected from the quarry industry within Nkalagu and Abakaliki metropolis, while the water used varies from Rivers, streams, shallow wells, boreholes, and tap water. These materials were tested to be good for construction work with respect to their particle size distributions, fineness modulus value, density, and being free from impurities.

The technique adopted in curing the block samples is by water being spread on them twice a day, especially before daybreak and after sunset. This procedure is repeated on a daily basis for a curing age of 28 days before testing for strength in compression.

3.3.1. Block Dimensioning

The weight and dimensions of the block specimens were determined in their dry phase. The height, length, width, hollow-cell-cavity, inner web, and shell web of the block specimens were determined with the use of measuring tapes. At the end of the 28 days, the specimens were cured, they were allowed to dry for 24 hours and weighed, their dimensions taken before being loaded on the Universal Testing Machine (UTM) for strength testing.

3.3.2. Other Methods of Data Collection

Questionnaire

The randomly sampled five (5) block making industries within the Abakaliki metropolis were issued questionnaires to ascertain the point of collecting their component materials (fine aggregates: sand and quarry dust), type and grade of cement used, water source, values of mix design proportions, batching method, mixing technique for the various materials, means of compacting, addition of admixture (if any), curing method deployed, and the means of conforming the strength of their blocks through testing.

3.3.3. Multiple Regression Model that Predicts the Strength of Concrete Blocks

A multiple regression model was developed with the variation indicators (cross-sectional areas of the block samples, areas of the hollow-cell cavity, net areas of the block samples, ratios of cement-sand, ratios of cement-quarry-dust (stone-dust), mode of mixing and molding (machine or manual), and the curing age before supply), which served as independent variables. The strength observed after testing the samples with the UTM serves as the dependent variable. Multiple regression is a powerful statistical tool that helps to understand the complex relationships between a dependent variable (y) and multiple independent variables (predictors). By this probabilistic model built:

1. Vital indicators are identified: appraise which independent variables significantly influence the dependent variable.

2. Analyzing the Relationship: Inspect the path of these relationships between different variables and their respective strengths.
3. Deployed for prediction making: Employ the developed model to estimate results with respect to the original data.
4. Evaluating the predictions: Make use of reliability metrics (e.g., R-squared) to authenticate the dependability of the developed model.

The general additive multiple regression model can be represented as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \mathcal{E} \quad (1)$$

Where:

$Y = Dependentvariable(StrengthofBlocks)$

$X_1 = Net\ Area\ of\ block,$

$X_2 = Area\ of\ hollow - cell - cavity,$

$X_3 = cement\ sand\ ratio,$

$X_4 = cement - quarry\ dust\ ratio$

$X_5 = mode\ of\ mixing\ and\ moulding$

$(Machine = 1, manual = 0)$

$X_6 = Block\ size, \beta_0 = intercept\ called\ constant,$

$\beta_1, \beta_2, \beta_3,\ \beta_4, \beta_5, \beta_6 are\ the\ Regression\ coefficients,$

$\mathcal{E} = error\ term.$

3.3.4. Method of Data Analysis

Minitab was used to develop the multiple regression model, while a T-test was utilized for data analysis**.** The strength results obtained from the experimentation and those predicted by the developed model were tested for significance at a 95% level of significance using a T-test.

4. Result Presentation and Discussions

Observed results, through a controlled experiment on blocks collected from the sampled industries within the Abakaliki metropolis, blocks made in NIS standard, and the values predicted by the developed prediction model are presented and discussed below.

4.1. Concrete Block Samples' Characteristics

The characteristics of the 450*225*150 mm (6-inch) and 450*225*225 mm (9-inch) hollow block samples used as the control group and those collected from different block-making industries within the Abakaliki metropolis are presented in Table 2. The table indicates variations in the dimensions of the block samples, including cross-sectional areas, inner, end, and shell thicknesses, as well as areas of the hollow-cell cavities, in both block sizes, which may impact their strength. This identification of variations in dimension is in line with studies done by researchers like [3 and 16], who have shown that these variations influence the overall strength of blocks in compression.

The smaller the areas of the cell cavity, the thicker the inner, end, and center shells. This could enhance balancing the blocks during masonry wall formations. Nevertheless, the increase in the cell cavity area can be seen as a means of reducing the overall weight of the block samples, thereby avoiding overloading the building structures. The GCTa and G2agroups have the highest net areas, ranging from 41to 42 m^2, while G4a has the least value,36.45 m^2 for the 450*225*150 block sizes. The GCTb and G5b have the highest net areas, ranging from 54 to 57 m^2, while G4b has the least value, 45m^2, for the 450 * 225 * 225 mm block sizes.

Table 2. Characteristics of the 450*225*150 mm (6-inch) and 450*225*225 mm (9-inch) hollow block samples

Block Name	Block size (*Inches*)	Cavity size (*mm*)		Area of Hollow-cell-Cavity (m^2)	Gross Area (m^2)	Net Area (m^2)
GCT a	450*225*150	160	80	12.80	67.50	41.90
G2a	450*220*153	172.5	80	13.80	68.85	41.25
G3a	450*230*150	172.5	80	13.80	67.50	39.90
G4a	450*220*150	172.5	90	15.51	67.50	36.45
G5a	450*220*150	175	80	14.00	67.50	39.50
G6a	450*220*150	170	80	13.60	67.50	40.30
GCT b	450*225*225	155	145	22.48	101.25	56.30
G2b	450*225*228	165	148	24.42	102.60	53.76
G3b	450*225*225	170	145	24.65	101.25	51.95
G4b	450*225*220	180	150	27.00	99.00	45.00
G5b	450*220*225	170	145	24.65	101.25	54.20
G6b	450*220*225	165	155	25.58	101.25	50.10

4.2. Compressive Strength of the Hollow Block Samples

The following results were observed after crushing the cured concrete block samples with the UTM to evaluate the loads each can bear before failure.

Table 3. Compressive strengths of the concrete-hollow-block samples

Sample Name	Sample Number	Block size (mm)	Load at Failure (KN)	Compressive strength (N/mm^2)
GCT a	CT1	450*225*150	165	3.94
	CT2		189	4.51
	CT3		184	4.39
G2a	A1	450*220*153	128	3.10
	A2		133	3.22
	A3		130	3.15
G3a	B1	450*230*150	118	2.96
	B2		110	2.76
	B3		124	3.11
G4a	C1	450*220*150	105	2.88
	C2		100	2.74
	C3		94	2.58
G5a	D1	450*220*150	86	2.18
	D2		84	2.13
	D3		78	1.97
G6a	E1	450*220*150	82	2.03
	E2		78	1.94
	E3		74	1.84
GCT b	CT1	450*225*225	178	3.16
	CT2		192	3.41
	CT3		188	3.34
G2b	A1	450*225*228	138	2.57
	A2		142	2.64
	A3		144	2.68
G3b	B1	450*225*225	128	2.47
	B2		136	2.62
	B3		132	2.54
G4b	C1	450*225*220	110	2.44
	C2		105	2.33
	C3		102	2.27
G5b	D1	450*220*225	104	1.92
	D2		110	2.03
	D3		104	1.92
G6b	E1	450*220*225	98	1.96
	E2		102	2.04
	E3		105	2.10
Model control	0	0.0000	0.0000	0.0000

The strength of the blocks was influenced by the following factors: first, the ratios of component materials used in the manufacturing of the blocks. The GCT blocks with cement: sand: quarry dust ratios of 1:4:2 gave the maximum compressive strength, followed by G3, G2, and G4 block samples that integrated quarry dust in the design mix proportions, though with 1:6:4 and 1:6:5 mix ratios, respectively. However, G5 and G6 block samples, which used only sand as fine aggregate, gave the lowest values of strength. The result obtained is in line with the research conducted by [3], which states that the blocks produced were low in compressive strength. Nevertheless, some industries produced blocks below the blueprint document on block manufacturing. Therefore, the ratio of quarry dust added influenced the strength of the block. In other words, the best mix design ratio is 1:4:2 with maximum strength. The result revealed that the addition of quarry dust increases the strength of the blocks, but for optimal performance, the quarry dust ratio should not exceed a certain portion to avoid a negative effect on the strength of the blocks. The second factor that influences the strength of block samples is variations in the dimensions (cross-sections) of the various blocks produced by different industries involved in this study. The model control row in Table 3 was used to ensure that the prediction model returns a zero value when other independent variables are zero (0).

4.3. The Developed Multiple Regression Prediction Model Equation

The prediction model equation was developed using Minitab statistical software. The identified variation indicators from the survey investigation on the concrete blocks obtained from the 5 block industries, which were produced using NIS standard (see Tables 1 and 2), were deployed as parameters in formulating the multiple regression model equation.

Note that the mode of mixing and molding: (Machine =1, Manual =0). Recall equation (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \mathcal{E} \quad (1)$$

Table 4. Comparative analysis of Experimental and Predicted Compressive Strength Results

Sample Name	Compressive strength (N⁄mm^2)	
	Experimental values	Predicted values
GCT a	4.51	4.2613
	4.39	4.2613
	3.94	4.2613
G2a	3.22	3.1564
	3.15	3.1564
	3.10	3.1564
G3a	3.11	2.9688
	2.96	2.9688
	2.76	2.9688
G4a	2.88	2.7393
	2.74	2.7393
	2.58	2.7393
G5a	2.18	2.1041
	2.13	2.1041
	1.97	2.1041
G6a	2.03	1.9168
	1.94	1.9168
	1.84	1.9168
GCT b	3.41	3.3254
	3.41	3.3254
	3.163	3.3254
G2b	2.68	2.6590
	2.64	2.6590
	2.57	2.6590
G3b	2.62	2.5791
	2.47	2.5791
	2.54	2.5791
G4b	2.44	2.3407
	2.33	2.3407
	2.27	2.3407
G5b	2.03	1.9333
	1.92	1.9333
	1.92	1.9333
G6b	2.10	2.0574
	2.04	2.0574
	1.96	2.0574
Model control	0	0.0000

Predictor Model Regression Equation:

A= 0.00+ 0.1389 Net Area+ 0.746 Area of Hollow cell cavity (2)

B=157.7 Cement Sand Ratio-52.93 Cement Quarry Dust Ratio (3)

C=3.672 mode of mixing and molding - 3.385 Block Size (4)

Compressive strength = A+B+C (5)

The developed predictive model was applied to estimate the strength of concrete blocks using the identified variation indicators obtained from a survey of blocks produced within the Abakaliki metropolis. These predictions, along with the corresponding experimental values, are shown in Table 4 for easy comparison.

The practical implication of using this multiple regression model to predict the strength of concrete blocks is that participants in the construction industry, especially contractors and other professionals, do not need to conduct tests on the strength of block samples from individual block-producing companies. However, what they are required to gather is vital information from the block manufacturers, such as the material composition and their proportions/ratios, the production method (manual or machine), and the block dimensions. With these data, the model can be used to estimate block strength by calculating the net area and the area of the hollow cell cavity. However, a T-test analysis was conducted on the experimental and predicted values for a test on significance at 0.05 level, and the result displays that the t-stat value (0.693) is less than t-critical (2.03), therefore, the research fails to reject the null hypothesis, which suggests that there is no significant difference between the means of the two groups being compared.

4.4. Evaluation of the Developed Predictor Model Equation

4.4.1. Explanation and Explanation of the Model's Factors

The Cement-Sand ratio value of 157.7: this presents a robust, beneficial impact – a higher amount of cement contained in the mix to quantity of sand significantly enhances strength (cement content increases with respect to amount of sand, critically augments strength). A Net-Area of value 0.138: a positive factor indicates that a higher net-area gives higher strength. Therefore, the greater the net area, the higher the strength (i.e., less hollow volume). The hollow cell cavity area of value 0.746 demonstrated that an increase in the area similarly increases strength (due to an improved hollow cavity cell design that does not interfere with strength). The Cement-Quarry dust ratio of negative value -52.93: The effect of the negative sign on the equation indicates that a greater quantity of quarry dust content to the cement content drastically decreases strength. The size of the block with a negative coefficient value of -3.385: This showed that larger blocks with (possibly with smaller webs or extra cavities) decrease strength in compression. The Mode of mixing and molding, with a positive value of 3.672, revealed that improved procedures significantly strengthen the block (strengthening the block by better mixing/molding techniques). The unit change in every independent variable's coefficient characterizes a compressive strength change in the model equation developed.

4.4.2. Model Summary

The reliability of the developed predictor model equation was evaluated using the R-squared metric (R^2). The multiple regression model developed has the following values:

1. R-squared (R^2) of 98.03%, which means that 98.03% of the variation in the dependent variable/response ('compressive strength') was explained by the independent variables (predictors) in the developed model. This reflects how well the model fits the data, suggesting an excellent fit.
2. Adjusted R-squared value of 97.52%, which helps in preventing over-fitting of the developed model with unnecessary predictors, thereby indicating that most predictors in the model are useful, since the value is very close to that of R^2.

Therefore, the model's prediction can be trusted with reasonable confidence, the predictors chosen are likely relevant and informative, and there is no over-fitting. The adoption of this multiple regression model provides a practical alternative to conventional compressive strength testing.

4.4.3. The Implications in the Construction Industry

This model has significant implications:

1. Reliability Prediction ability: The model demonstrated a strong power to make predictions with an R-squared value of 98.03% for block strength estimation accuracy.
2. Considerations in designing parameters: In order to achieve strong blocks, the dimensions and cross-section of the molds need to be structured for optimal results.
3. Sustainable strength: The overutilization of quarry/stone dust reduces the strength of blocks. The structural and environmental factors must be considered and balanced by various Industries for better performance in compression strength.
4. Optimization of Material constituents: Having the knowledge of each factor's impact, block producers can have optimal mix designs and processing techniques to realize the desired strength in compression. The use of optimized cement-sand ratios and minimum quarry dust, where necessary. The performance of block strength depends wholly on water control.
5. Quality control measures: Quality control measures were achieved from the developed model by highlighting vital factors impacting block strength. Investing in better processing techniques (mixing and molding technologies) will lead to improvement in the performance of blocks.

Therefore, the model's correctness and consistency make it a valued instrument for data collection by the construction industry.

Nonetheless, the model's coefficient factors with negative values signify a probable compressive strength reduction:

1. Ratio of Water-to-cement: Block strength weakens with higher water-cement ratios. There is an increase in porosity of blocks when too much water is added to the mix, thereby reducing strength. This aligns with concrete behavior established in previous research.
2. The dimensions of the Blocks: Some kind of block dimensions may be more susceptible to strength reduction. Blocks with Larger hollow spaces tend to have lower strength in compression. This is due to additional hollow space, bigger zones of stress, or inefficient material distribution.
3. The ratios of Cement-to-quarry dust: An upsurge in the amount of quarry/stone dust proportioning a mix might negatively impact the strength. There is a significant reduction in strength when a higher amount of quarry dust (compared to cement) is added. Also, the unnecessary replacement of sand with quarry/stone dust weakens the strength of blocks.

All these identified factors should be considered by block manufacturers and contractors when designing mixes and molds for optimal strength and quality. This tactic presents an alternative (non-destructive) to old-style strength testing (destructive) by exploiting quantifiable input variables, such as material composition, production method, and dimensional parameters, collected from manufacturers.

5. Conclusion and Recommendation

5.1. Conclusion

The study revealed significant variations in block sample dimensions, including cross-sectional areas, end and shell thicknesses, and hollow-cell cavity areas, which may compromise the strength of the blocks and thereby impact structural integrity. The blocks' strength was affected by the subsequent factors: The proportions of constituent elements utilized in the production of the blocks. The findings indicated that incorporating quarry dust enhances the strength of the blocks; nevertheless, to achieve the best performance, the proportion of quarry dust must not exceed a specific limit to prevent adverse effects on block strength. The ideal mix design ratio is 1:4:2, which produces the most strength. The constructed multiple regression model was employed to forecast the compressive strength of concrete blocks based on variation indicators obtained during a field survey of block manufacturing in the Abakaliki metropolis.

The evaluation metrics, R-squared value of 94.84%, reveal how well the model is expected to perform on new value sets, unseen data, thereby minimizing over-fitting, and that predictions on new data are likely to be highly accurate, reflecting how well the model fits the data. The key advantage of employing this regression-based predictive approach lies in its ability to estimate block strength without the need for physical testing. Professionals in the construction industry can bypass experimental procedures by obtaining essential production parameters from the manufacturer. With this information, one can compute the net cross-sectional area and hollow cell cavity areas, enabling accurate strength predictions through the model.

5.2. Recommendation

Rather than conducting destructive tests on block samples, the research recommends (to construction professionals) the adoption of the model equation in estimating the compressive strength of blocks by collecting essential input parameters from block producers. The study recommends that manufacturers and builders consider the identified variation indicator factors when designing mixes and producing blocks to optimize strength and quality.

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References

[1] J.C. Ezeokonkwo, and C.U. Nwoji, "The Load Carrying Capacity Of Hollow Sandcrete Blocks," *Journals of Emerging Trends in Engineering and Applied Science*, vol. 3, no. 1, pp. 75–80, 2012. [Google Scholar] [Publisher Link]

[2] M. Abdullahi, "Compressive Strength of Sandcrete Blocks in Bosso and Shiroro Areas of Minna, Nigeria," *AU Journal of Technology*, vol. 9, no. 2, pp. 126-132, 2005. [Google Scholar] [Publisher Link]

[3] I.G. Awolusi, A.A. Soyingbe, and O.O. Oyeyipo, "An Appraisal of the Quality of Sandcrete Blocks Used for Construction in Lagos Metropolis," *Journal of Building Performance*, vol. 6, no. 1, pp. 40-49, 2015. [Google Scholar] [Publisher Link]

[4] D.E. Ewa, and J.O. Ukpata, "Investigation of the Compressive Strengths of Commercial Sandcrete Blocks in Calabar, Nigeria," *International Journal of Engineering and Technology*, vol. 3, no. 4, pp. 477-482, 2013. [Google Scholar]

[5] G.D. Taylor, *Materials in Construction - Principles, Practice and Performance*, Pearson Publishers, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[6] British Standard, "812-103.1-Testing Aggregates–Part 103: Methods for Determination of Particle Size Distribution–Section 103.1 Sieve Tests," British Standards Institution, London, 1985. [Google Scholar] [Publisher Link]

[7] British Standard: BS 882, "Specification for Aggregates from Natural Sources for Concrete," 1992. [Google Scholar]

[8] M.S. Shetty, and A.K. Jain, *Concrete Technology: Theory and Practice*, 8th Ed., pp. 1-636, 2006. [Google Scholar] [Publisher Link]

[9] David Darwin, Charles W. Dolan, and Arthur H. Nilson, *Design of Concrete Structures*, McGraw-Hill Education, pp. 1-864, 2020. [Google Scholar] [Publisher Link]

[10] American Society for Testing Materials ASTM C150/C150M-24, Standard Specification for Portland Cement, 2024. [CrossRef] [Publisher Link]

[11] S.K. Duggal, *Building Materials*, New Age International Publishers, New Delhi, India, 2003. [Google Scholar] [Publisher Link]

[12] L.O. Ettu et al., "Compressive Strength of Ternary Blended Cement Sandcrete Incorporating Saw Dust Ash and Oil Palm Bunch Ash," *International Journal of Current Trends in Engineering & Research*, vol. 2, no. 10, pp. 5-11, 2016. [Google Scholar]

[13] J.O. Afolayan, C. Arum, and C.M. Daramola, "Characterization of the Compressive Strength of Sandcrete Blocks in Ondo State, Nigeria," *Journal of CER&P*, vol. 5, no. 1, pp. 15-28, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[14] M. Abdullahi, "Compressive Strength of Sandcrete Blocks in Bosso and Shiroro Area of Minna, Nigeria," *AU Journal of Technology*, vol. 9, no. 2, pp. 126-132, 2005. [Google Scholar] [Publisher Link]

[15] Ubani Obinna, Sandcrete Blocks: Production, Specifications, Uses and Testing, Construction Materials in Engineering, 2022. [Online]. Available: htts://structville.com/sandcrete-blocks-production-specifications-uses-and-testing

[16] Adekunle M. Ajao et al., "Assessment of Sandcrete Blocks Manufacturers' Compliance to Minimum Standard Requirements by Standard Organization of Nigeria in Southwest, Nigeria," *International Journal of Applied Engineering Research*, vol. 13, no. 6, pp. 4162-4172, 2018. [Google Scholar] [Publisher Link]