Investigating the Relationship between the Production Characteristics and Quality of Concrete Produced in Aba, Abia State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author UFI designed the study, prepared the field work, and wrote the protocol, as well as the first draft of the manuscript. Author HEO managed the field survey, interpreted the data and managed the literature searches. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Quality of concrete explains considerably the state of affairs involved in the production of concrete in a particular area. The antecedents of the production process to a greater extent therefore have a way of predicting the expected quality of a product. Hence, the degree of relationship between the quality of concrete and its production characteristics is determined in the study. Field work adopted in the study comprises activity sampling and ex post facto experimental designs. These two different research designs were applied to obtain data for performance assessment of activities involved in the production procedures and laboratory tests of concrete produced at various sites in the study area respectively. The corresponding data obtained in the field work are in ordinance and ratio scales of measurement. Regression analysis was used to establish a casual relationship between the two variables - performance level of the production characteristics (x) and the compressive strength (y) of the concrete at various sites in the study area. A model relationship of simple regression analysis for the dependent and independent variables is established. Finding reveals that the better the ranking of sites in compliance with the standard practice of production

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characteristics, the higher the compressive strength property of the concrete produced on site; hence the linear relationship. The coefficient of determination shows that 93% of changes in the strength property of concrete are caused by the production characteristics. Although the highest value of compressive strength obtained as 10.80 N/mm^2 goes with the best state of affairs of the production characteristics in the study, it does not meet the minimum stipulated specification for the strength. Hence, other critical factors such as; aggregate type, and mix design should be considered for desired quality of concrete in the study area. Besides, enforcement of uniformity in production process as standard practice by all the firms should as a matter of urgency be implemented formally by the government in the state for improved quality of concrete in general.

1. INTRODUCTION

The production characteristics of concrete involve the various measures and principles applied in the design, procedure and handling of the production process. Concrete is by far the most widely used man made construction material. According to [1], most of the modern buildings in the South east, Nigeria has concrete as their major component material; hence the importance of quality in concrete work for effective delivery of construction projects. They declared that experts therefore have canvassed the assessment of quality of materials and levels of workmanship used in concrete work production in construction projects in general [1]. [4] concluded also on the need for critical assessment on the basic quality, strength and variability of materials used in forming the structural component. These factors affecting the average quality of concrete in our environment cause wide variability in the concrete used in the construction sites. The multidimensional use of concrete is made possible mainly due to the fact that the constituent ingredients are possibly modified to affect significantly the quality level and different categories of the concrete, so as to meet the demands of various conditions in a particular locality.

According to [5], different climatic conditions impose different requirements on the use of material in masonry products, especially in the tropical regions. The main variables when climatic condition is a target objective for quality control are the high daily temperature, high humidity, and higher intensity of rainfall. The advancement in concrete technology however has paved way to making the best use of locally available materials by appropriate mix proportioning and proper workmanship towards producing concrete with satisfying performance requirements. While the properties of the constituent materials are very important, the users are increasingly interested in the concrete itself having the desired properties [6]. In reality, concrete as a composite construction material is the real building material rather than the constituent ingredients which are only intermediate products. The ingredients and the production characteristics predict the quality levels of the concrete to a greater extent; hence the relationship between quality of the concrete and the measures applied in the production. It is said that quality predicts standard while standard regulates quality, therefore quality of concrete in the tropical zone reflects the antecedence of its production process and condition in the environment.

Mix proportion of the constituent materials is the most significant element of the production characteristics [7]. The mix is classified in a number of ways. They are nominal, prescribed and mix designs. The nominal mixes with varying specifications on other factors are marked with certain levels of qualities in form of standard. The conditions of the prescribed or mix design specifications as a matter of principle should also reflect their production characteristics.

According to [5], concrete products in the tropical zones are susceptible to defect, and every effort made to improve quality of the delivery yielded just a little. [2] considered that concrete will only become a quality material for improved constructions when the ingredients are properly sourced and selected; as well as produced under a controlled condition. This is not in doubt since concrete undergoes a number of operations in its production process [8]. Quality assurance and control of the product therefore are the most important issues in achieving the desired quality of concrete. There is no doubt Nigeria therefore has witnessed several failures in building structures. Even when geological tests and

various designs proved reliable; failures in most cases still continue due to issues bordering on poor quality of labour and materials like concrete. State of affairs of the constituent composition, production characteristics or other related issues on concrete works are usually the suspects. Thus, probability of failures in concrete works depend on several factors; such as variation in the quality of constituent materials, mix proportion of the constituent ingredients, efficiency of the production equipments, quality of workmanship, and supervision.

In view of the foregoing condition, there is no unique attribute to define the quality of concrete in its entirety; hence concrete can be referred to as being good, fair or poor quality. It therefore becomes necessary to define the quality in terms of desired variables like; performance characteristics, economics values, safety factors and other related factors. Consequently, assessing the prevailing production characteristics of concrete work production, and determining the average compressive strength and density of the concrete works; as well as the values of the respective characteristic properties would have led to the goal of the study.

2. RESEARCH METHODOLOGY

The study area is in the Warm Humid Climatic zone (WHC) of Nigeria. Climatic zones are categorized for the purpose of construction in Nigeria. The WHC zone is in the tropical region of Nigeria, and characterized with long torrential rainfall, high humidity and average maximum steady temperature and wind pressure [5]. This zone comprises also other cities such as; Owerri, Portharcourt, Uyo, Calabar and Yonagua cities in Imo, Rivers and Akwa-ibom, Cross River and Bayelsa states respectively, as well as many other cities within the Zone. The cities are the political and commercial hub of the respective states in the region with higher record of industrial and physical infrastructural developments. They share a lot of common features ranging from nature of soil, topography, water table and many more.

The study was carried out using method study and experimental designs. The data collected are quantitative in nature for objective deduction. The production characteristics of concrete produced in the area were obtained through activity sampling schedule, while tests on the properties of the concrete were conducted in the laboratory by ex-post facto experimental approach.

The ex post facto experimental design guided on the antecedence of the state of affairs of the production process. For every concrete test however, three cube moulds of freshly made concrete were collected. The grades of in-situ concrete sampled at the ongoing construction sites were 1:3:6 of 24mm aggregates, and 1:2:4 of 19mm aggregates mix ratios for plain concrete and structural works respectively; and average measurement taken for the compressive strength property of the concrete in the laboratory.

Data obtained through method study are from the activity sampling of concrete production procedures at selected construction sites during production processes in the study area. Work study was adopted to study the methods applied by direct observations, as well as measuring the performance compliance levels of the production characteristics on standard practice in the respective sites.

Nevertheless, the various aggregates batched for the mixes were reported to be locally sourced, and not checked for compliance with standard specifications. A standard compressive strength machine was used for testing of the compressive strength property of the concrete mixes respectively, after each curing age.

In general data were statistically analyzed using simple regression analysis with a view to forming basis for arriving at conclusion in the study. It shows the nature and amount of relationship that exists between the dependent variable (y = compressive strength of the concrete) and independent variable (x = the production characteristics) in the study. According to [3], the regression equation and its coefficient of determination are therefore expressed in the following forms:

$$Y = b_0 + b_1 X_i + E \; .... \; = \quad = \quad =$$
$$= \quad = \quad = \tag{1}$$

Where; Y is the objective function (the model),
b_0 - the intercept,
b_1 - coefficient of the independent variable (slope),
X_i - the independent (predictor) variable,
E - the error probability.

Hence, b_0 and b_1 in Equation 6 were therefore applied in these forms:

$$b1 \quad = \quad \frac{n\Sigma xiyi - \Sigma xi\Sigma yi}{n\Sigma xi2 - (\Sigma xi)2} \quad = \quad = \quad = \quad = \quad = \tag{2}$$

$$bo = Y + b1Xi \qquad (3)$$

Thus, Coefficient of determination (r^2) using sum of squares (SS) is expressed as:

$$r2 \frac{SSR}{SST} = = = = = = \qquad (4)$$

Where; SSR and SST are presented in the forms:

$$SST = \frac{\Sigma yi2}{1} - \frac{(\Sigma yi)2}{n} \text{ and, } SSR = \left\{ bi \frac{\Sigma xiyi}{1} - \frac{(\Sigma xi \Sigma yi)}{n} \right\}$$

3. PRESENTATION OF DATA, ANALYSES AND DISCUSSION

Data in the study are presented in tabular form; they are as shown in Tables 1 – 3. Table 2.0 however is represented in Fig. 1. for clarity.

The main functions of production characteristics are the concrete production procedures. The variability in their applications or compliance to standard practice influences quality of the concrete works. Site 1 is seen to have complied with the standard practice in all stages of the production than other sites in the study area; while site 2 performed poorly in its concrete production operations. Site 2 which ranks fifth has only transport operation out of other operations in the concrete production procedure to conform to standard practice. Other operations which also function significantly the average quality of concrete work are observed not to be applied well, as contained in Table 1.

In Table 2 are contained the compressive strength results of concrete produced in the respective construction sites visited in the study area. Site 1 is attributed as very good with the compressive strength of 10.80N/mm^2; while site 2 is attributed as very poor with the compressive strength of 5.50N/mm^2.

To confirm the relationship between the production characteristics' condition and the quality of the concrete works, site 1 where all the operations in the production procedures conformed to the standard practice has the highest compressive strength value (10.80N/mm^2); while site 2 with almost all the operations is noncompliant with the standard practice has compressive strength as low as 5.50N/mm^2.

According to Fig. 1. however, there is no uniformity in the quality assurance of the practices of the various sites in the study area. Negligence and ignorance especially are believed to be the major contributors to wider variability in compliance with the code of practice in concrete work production among firms in the area.

**Table 1. Work study observation for the concrete work production characteristics compliance assessment**

S/n	Batching	Mixing	Transport	Placement	Compaction	Curing	Supervision	Rank
Site 1	yes	yes	yes	yes	yes	yes	yes	1st
Site 2	no	no	yes	no	no	no	no	5th
Site 3	yes	yes	no	no	yes	yes	yes	2nd
Site 4	yes	yes	yes	no	yes	no	yes	2nd
Site 5	yes	yes	no	no	yes	yes	no	3rd

Source: Authors' Work Measurements in the Field Survey, (2020)

Table 2. Distributions on work study observation based on the performance levels of the compressive strength property

Project Site	Rating by attributes	Weighing of the Ranks on the Scale of 1 – 5 Points	Average Strength of Concrete at 28-day Curing (N/mm^2)
Site 1	Very Good	5	10.80
Site 2	Very Poor	1	5.50
Site 3	Good	4	9.20
Site 4	Good	4	8.80
Site 5	Fair	3	8.40

Source: Authors' Field Work Measurements and Experiments, (2020)
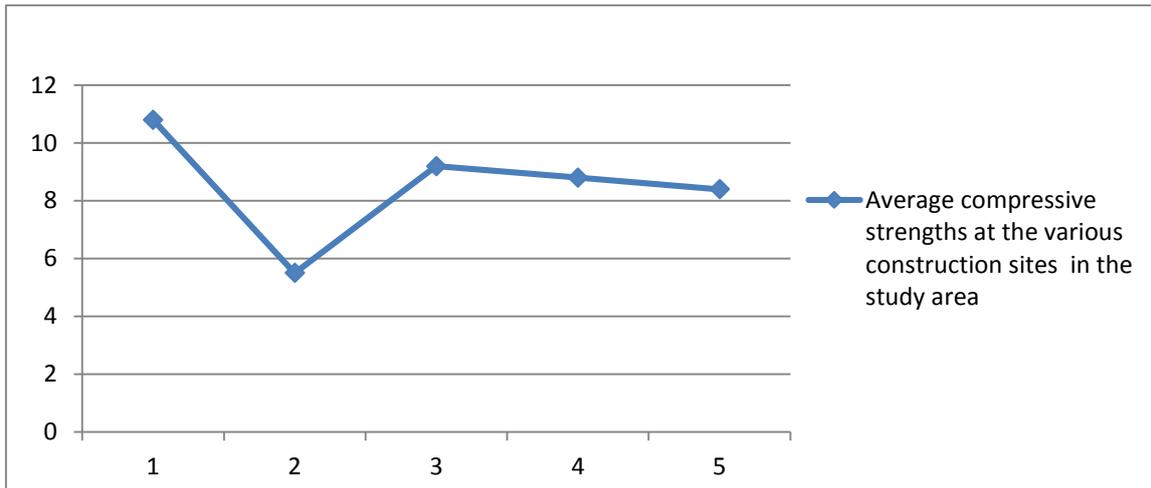
Fig. 1. The average compressive strength at various construction sites in the study area
Source: Authors' Field Work Results, (2020)

**Table 3. Schedule of the simple regression analysis**

S/n	Y	X	X²	Y²	XY
1	10.80	5.0	25	116.64	54
2	5.50	1.0	1	30.25	5.50
3	9.20	4.0	16	84.64	36.80
4	8.80	4.0	16	77.44	35.20
5	8.40	3.0	9	70.56	25.20
Total	42.70	17	67	379.53	156.70

Source: Authors' Field Work Results, (2021)

From Table 3, b_1 is calculated according to Equ. 2, while b_0 is according to Equ. 3.
Hence; $b_i = 1.20$; and $b_o = 12.62$.
Using Equ.1, the model is therefore obtained as
$Y = 12.62 + 1.20 x_i$

Consequently, the positive coefficient of x_i (the independent variable) explains that the better the ranking of sites in compliance with the standard practice of production characteristics, the higher the value of compressive strength property of the concrete produced on site. The linear relationship of the variables is seen therefore to be proportional to one another on average as shown in Fig. 2.
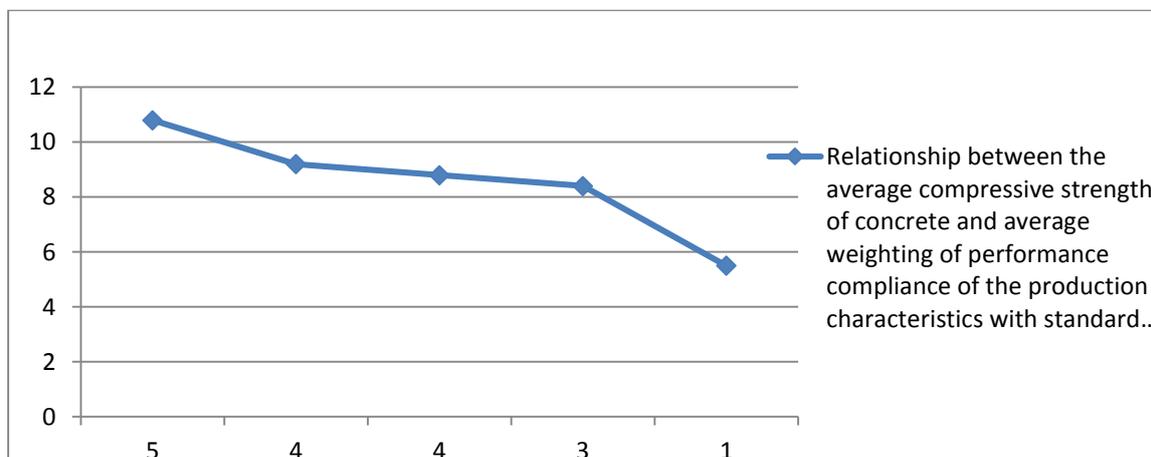
Fig. 2. Relationship between the performance's level of compliance with standard production characteristics and average values of compressive strength at various sites
Source: Authors' Method Study, (2021)

The coefficient of determination (r^2) for degree of relationship existing between the levels of performance compliance with the production characteristics and the compressive strength was determined using the sum of squares (SS) according to Equ. 4. Hence, r^2 = 0.93. This explains the level of change in the objective function (y_i) that can be influenced by the unit value of the independent variable (x_i) in the casual relationship existing between the two variables (x and y).

Thus, in the casual relationship the percentage of variation in the strength of concrete that are being influenced by the production characteristics is 93% in the study area. Hence, the independent variable (x) contributes 93% to the measured value of the dependent variable (y).

4. CONCLUSION AND RECOMMENDA-TIONS

The study establishes the relationship between production characteristics and quality of concrete produced in the study area on compressive strength. Variability in the application of production characteristics explains the reason for no uniformity in quality of concrete works production; worst of it all is the inadequate compliance with standard practice in the production procedure. Amidst these odds, quality of concrete are compromised leading to structural defects and failures.

Considering the findings, establishing basis for uniformity in standard practice by all the firms will facilitate quality control of concrete production in the area. At this point, enforcement towards compliance with the standard practice in the production will easily be achieved; hence quality of concrete in the study area would have been improved significantly to meet the minimum standard specification for desired quality in the industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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