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Relation between Compressive Strength and Flexural Strength for Concrete Made With Crushed Granite Chippings

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ABSTRACT

The strength of concrete is its most important characteristic. This report studied the relation between the compressive strength and the flexural strength of concrete made with crushed granite chippings from Abakaliki in Ebonyi State. Sixty concrete cubes of dimensions 150mm were produced based on a design matrix. These were made, cured and tested according to BS 1881:1983. There were three cubes for each experimental point. Also, sixty concrete beams of dimensions 600mm x 150mm x 150mm corresponding to the mix ratios of the concrete cubes were made, cured and tested according to the same standard. The linear regression model equation was Y = 11.313X-19.327, where Y represented the compressive strengths of the concrete cubes in N/mm^2 and X, the flexural strengths of the concrete beams of corresponding mix ratio in N/mm^2.). With the confidence level of 95%, the coefficient of correlation was 0.975, an indication of the strong relation between the X and Y variables. t-Statistic being lower than t critical indicated that the two data samples were likely to have come from the same two underlying populations.

1. Introduction

Concrete is a comparatively brittle material, even though it exhibits a small amount of plastic action. It is relatively weak in tension and high in compression. The strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics, such as durability and permeability, may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste. The strength of concrete is defined as the maximum load (stress) it can carry [1]. As the strength of concrete increases its other properties usually improve. The compressive strength is used in the construction industry for the purpose of specification and quality control [2]. The flexural strength or modulus of rupture is of importance in the design of concrete roads and runways. Several factors influence the strength of concrete; among them are the constituent materials (cement, water, aggregate, and admixtures), method of preparation, curing conditions and test conditions [3]. For a given cement and acceptable aggregates, the strength that may be developed by a workable, properly placed mixture of cement, aggregate, and water (under the same mixing, curing, and testing conditions) is influenced by the ratio of cement to mixing water, ratio of cement to aggregate, the grading, surface texture, shape, strength, and stiffness of aggregate particles, and the maximum size of the aggregate [4]. Walker and Bloem [5] concluded that the strength of concrete results from: (1) the strength of the mortar;

(2) the bond between the mortar and the coarse aggregate; and (3) the strength of the coarse aggregate particle. The actual (technical) strength of cement paste is very much lower than the theoretical strength estimated on the basis of molecular cohesion, assuming the paste is perfectly homogeneous and flawless. The theoretical strength has been estimated to be as high as 10.5GPa [6]. The properties of aggregates, especially its shape and surface texture, affect the ultimate strength in compression very much less than the strength in tension. In experimental concrete, entirely smooth coarse aggregate lead to a lower compressive strength, typically by 10 per cent, than when roughened [7]. The influence of the type of coarse aggregate on the strength of concrete varies in magnitude and depends on the water/cement ratio of the mix [8]. For water/cement ratios below 0.4, the use of crushed aggregate has resulted in strengths up to 38 per cent higher than when the gravel is used. With an increase in the water/cement ratio, the influence of aggregate falls off and at a water/cement ratio of 0.65, there is no difference in the strengths of concretes made with crushed rock and gravel. The influence of aggregate on the flexural strength seems to depend also on the moisture condition of the concrete at the time of test. The shape and surface texture of coarse aggregate affect also the impact strength of concrete, the influence being qualitatively the same as on the flexural strength [9]. Kaplan [10] observed that the flexural strength of concrete is generally lower than the flexural strength of the corresponding mortar while on the other hand, the compressive strength of concrete is higher than that of mortar.

2. Materials and Method

2.1 Preparation, Curing and Testing Of Concrete Samples

The sieve analyses of the fine and coarse aggregate samples were done in accordance with BS 812: Part 1: 1975 [11] and satisfied BS 882:1992[12]. The sieving was performed using a sieve shaker. The water used in preparing the experimental samples satisfied the conditions prescribed in BS 3148:1980 [13]. The sixty required concrete cubes of dimensions 150mm were made in triplicates for each experimental point based on the mix ratios in Table 1 in accordance with the method specified in BS 1881: 108:1983 [14]. Also, sixty concrete beams of dimensions 600mm X 150mm X 150mm corresponding to the mix ratios of the cubes were made in triplicates in accordance with the method specified BS 1881: 109:1983 [15]. These specimens were cured for 28 days in accordance with BS 1881: Part 111: 1983 [16]. The cube testing was done in accordance with BS 1881: Part 116:1983 [17] using compressive testing machine. The beam testing was done in accordance with BS 1881: Part 118:1983 [18] using flexural testing machine.

2.2 Testing the Fit of the Linear Regression Equation

The linear regression equation developed would be tested to see if the predicted values of Y agreed with the actual experimental results. The null hypothesis was denoted by H_0 and the alternative by H_1. The null hypothesis was that the predicted compressive strength values and their experimentally-observed values had variances that are not significantly different. That is the two data samples were likely to have come from the same two underlying populations that have the same mean. The Student’s t-test would be used to verify this.

3. Results and Discussion

3.1 Physical and Mechanical Properties of Aggregates

Sieve analyses of both the fine and coarse aggregates were performed and the grading curves shown in Figures 1 and 2. These grading curves showed the particle size distribution of the aggregates. The maximum aggregate size for the granite chipping was 20 mm and 2mm for the fine sand. The granite chippings had water absorption of 2.7%, moisture content of 44.2%, apparent specific gravity of 2.26, Los Angeles abrasion value of 22% and bulk density of 2072.4 kg/m^3.

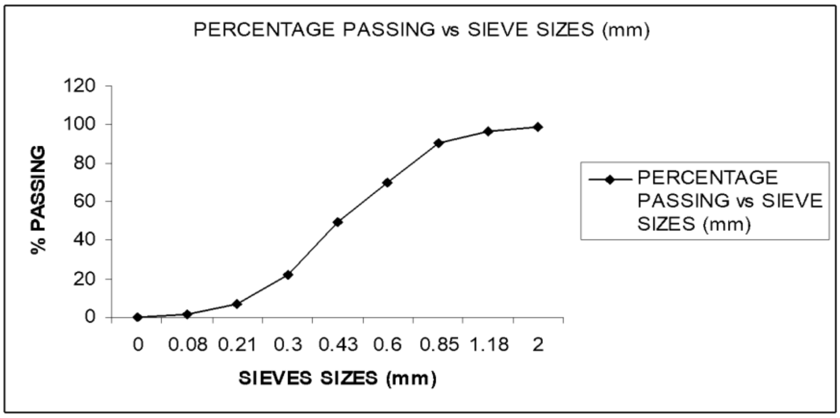

Figure 1 Grading curve for the fine aggregate

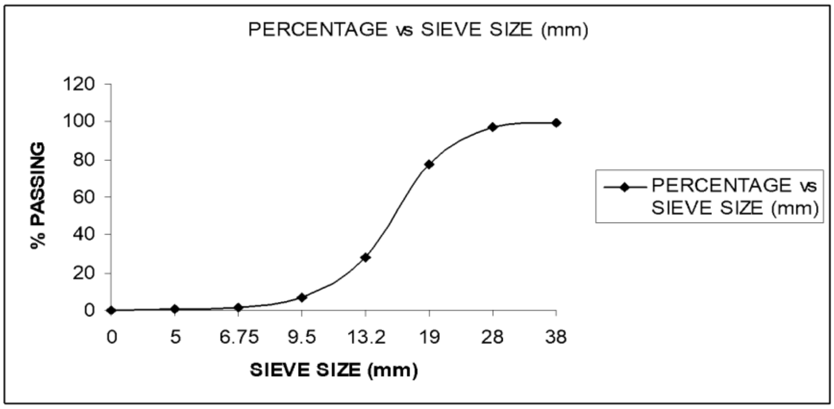

Figure 2 Grading curve for the granite chippings

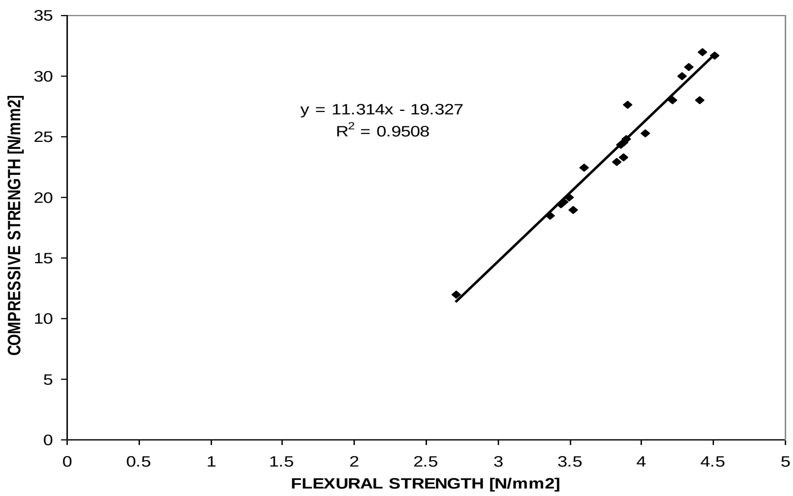

Figure3: Graph of compressive strength vs flexural strength

Table 1: Mix ratios design table

S/N	*Water/cement ratio*	*cement*	*Sand*	*Granite chippings*
1.	0.6	1	1.5	2
2.	0.5	1	1	2
3.	0.55	1	2	5
4.	0.65	1	3	6
5.	0.55	1	1.25	2
6.	0.575	1	1.75	3.5
7.	0.625	1	2.25	4
8.	0.525	1	1.5	3.5
9.	0.575	1	2	4
10.	0.6	1	2.5	5.5
11.	0.5625	1	1.5	2.75
12.	0.6	1	2.0	3.75
13.	0.55	1	1.75	3.75
14.	0.575	1	1.875	3.75
15.	0.575	1	1.375	2
16.	0.5875	1	1.625	2.75
17.	0.6125	1	1.875	3.0
18.	0.5125	1	1.25	2.75
19.	0.5375	1	1.5	3.0
20.	0.5850	1	2.25	5.25

3.2 The Regression Equation for the Compressive Strength and Flexural Strength Tests Results

The regression analysis produced the linear model, Y = 11.313X-19.327, where Y represented the compressive strength in N/mm^2 and X, the flexural strength in N/mm^2 (Figure 3). With the confidence level of 95%, the coefficient of correlation or multiple R and the coefficient of determination or R^2 were 0.975 and 0.950 respectively (see Table 2). This was an indication of the strong relation between the X and Y variables. The standard error of the regression was 1.182. F had the value of 348.1075 and the significance F was 3.18E-13. The intercept had an absolute t Stat value of 8.23 and a probability of occurring by chance, P-value of 1.63E-07. The X variable had the t Stat value of 18.66 and a P-value of 3.18 E-13. These indicated that both the X variable and the intercept were useful in predicting the values of Y.

Table 2: Output

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9751072
R Square	0.9508341
Adjusted R Square	0.9481027
Standard Error	1.1825781
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	486.8251635	486.8252	348.1075	3.18479E-13
Residual	18	25.1728365	1.398491		
Total	19	511.998			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-19.327449	2.348426897	-8.22996	1.63E-07
X Variable 1	11.314306	0.606416808	18.65764	3.18E-13

3.3 t-Test: Two-Sample Assuming Unequal Variances

The t-Test (Two-Sample Assuming Unequal Variances) is shown in Table 3. The variance of the predicted values (25.62) and the variance of the experimentally-observed values (26.94) were not significantly different. The t -Statistic was -4.38E-15 and t critical was 2.024. t-Statistic being lower than t critical indicated that the two data samples were likely to have come from the same two underlying populations that have the same mean. The probability of this occurrence, P(T<=t) two-tail was 1. The null hypothesis was satisfied and therefore the model equation was adequate.

Table 3: t-Test: Two-Sample Assuming Unequal Variances

	EXPERIMENTAL Y	*PREDICTED Y*
Mean	24.21	24.21
Variance	26.94726316	25.62237703
Observations	20	20
Hypothesized Mean Difference	0	
df	38	
t Stat	-4.38266E-15	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	1	
t Critical two-tail	2.024394147	

3.4 Comparison with Previous Works

Erntroy and Shacklock [19] studied the relation between the compressive strength and indirect-tensile strength for concretes made with various aggregates (water/cement ratio between 0.33 and 0.68, aggregate/cement ratio between 2.8 and 10.1). The aggregates used were angular granite, angular granite (4.5 per cent air), angular flint, irregular flint, round quartzite and irregular flint (4.5 per cent). The graphs of the angular granite (4.5 per cent air), irregular flint, rounded quartzite and irregular flint (4.5 per cent) were straight lines while those of the angular granite and angular flint were a bit curved. This research conforms to his findings. Jones and Kaplan [20] studied the relation between flexural strength and compressive stress at cracking for concretes made with different coarse aggregates. The graph was that of a parabola.

4. Conclusion

The regression analysis produced the linear model, Y = 11.313X-19.327, where Y represented the compressive strength in N/mm^2 and X, the flexural strength in N/mm^2. The variance of the predicted values (25.62) and the variance of the experimentally-observed values (26.94) were not significantly different. t-Statistic being lower than t critical indicated that the two data samples were likely to have come from the same two underlying populations that have the same mean. The probability of this occurrence, P(T<=t) two-tail was 1. The null hypothesis was satisfied and therefore the model equation was adequate.

Nomenclature

df	degree of freedom
F	F- observed value
MS	mean square
P-value	probability value
P(T<=t)	probability of coming from the same two underlyingpopulations.
SS	sum of squares

5. Conflict of Interest

There is no conflict of interest associated with this work.

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