Journal of Physical Science and Innovation **Volume 6, No. 2, 2014**
ISSN: 2277-0119

COMPARISON OF THE DIRECT AND INDIRECT METHODS OF MEASURING FLEXURAL STRENGTH OF CONCRETE. A CASE STUDY OF CONCRETE MADE FROM CRUSHED GRANITE ROCK

Ogah Sylvester Obam and Kassar Terungwa
Department of Civil Engineering, College of Engineering
University of Agriculture Makurdi, Nigeria
E-mail: ogahobam@gmail.com

ABSTRACT

Flexural strength of concrete could be measured by concrete cylinder specimen; the direct method of measuring the property is by concrete beam specimen. This study investigates both methods with the aim of finding the difference in the values obtained from the two methods. Laboratory experiment analysis was used for this study. Concrete made from crushed granite rock with mixed ratios of 1:2:4 and 1:1½:3 at 0.54 and 0.49 water-cement ratios respectively, were used. Sieve analysis and specific gravity tests of the aggregate samples were carried out. The 28 day mean compressive strength is 24.8 and 29.7N/mm^2 for the two ratios respectively. The mean flexural strength, for the beam and cylinder specimens are 1.9 and 2.0 N/mm^2 for the ratio 1:2:4. While the flexural strengths for the beam and cylinder specimens are 2.0 and 3.3 N/mm^2 respectively for the ratio 1:1½:3. The tensile stress values were subjected to t-test analysis. It shows that there is no significant difference between the flexural strengths obtained using beam specimen (direct method) and cylinder specimen (indirect method).

Keywords: Concrete, Tensile Strength, Beam Specimen, Cylinder Specimen

INTRODUCTION

Concrete plays an important role in the construction industry all over the world. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. In most civil engineering construction works, concrete is cast in-situ or precast. In design of concrete structures however, the first consideration is that, they should be strong enough to support the loads that they carry. This will require adequate and correct batching of the constituent materials in the right proportions. Quality test of concrete is also important to ascertain compliance with specifications. Among these tests are compressive and flexural strength of concrete. Strength of concrete is defined as the maximum load (stress) it can carry. As the strength of concrete increases, its other properties usually improve. (Anthanari,1981). Concrete is not usually designed to carry tensile load but its flexural strength is important in certain areas such as Airport Runway, Car-pack etc (Neville and Brooks, 1994). Flexural Strength is a measure of an unreinforced concrete beam or slab to resist failure in bending (Neville, 1996). The flexural strength is expressed as modulus of rupture (MR) in psi (mpa) and one the methods of its measurement is by American Standard for Testing and Materials (ASTM C) 78 (third-point loading) or ASTM C 93 (center-point loading). Flexural (MR) is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third point loading is lower than MR determined by center point loading, sometimes by as much as 15%. (Ramachandran, 1995). Typically, flexural strength of concrete is in the range 2-7 N/mm^2 (Murdock and Brooks 1991). British Standards (BS) 1881: part 118; 1983 gives the method for determining flexural strength using concrete beam size (100 x 100 x 500mm) and BS 1881: part 117; 1983 gives the method for using concrete cylinders.

Flexural Strength:

Flexural strength is measured using concrete beam specimen (Direct method), it can also be measured using cylinder concrete specimen (Indirect Method).

Flexural strength (σ) is given by (Jackson, 1984)

$$\sigma = \frac{3FL}{2bd^2} \qquad 1$$

$$\sigma = 2P/\pi Ld \qquad 2$$

Equations 1 and 2 are for beam and cylinder concrete specimens respectively.

P is maximum load
L is length (height) of the specimen
d is diameter or Width of the specimen
b is breadth of specimen

Statistical Student T-test

The t-test statistic is given by (Spigel, 1992)

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\delta\sqrt{\frac{1}{N_1}+\frac{1}{N_2}}} \qquad 3$$

$\delta = \sqrt{\frac{N_1S^2+N_2S^2}{(N_1+N_2)-2}}$, is the standard deviation

$S^2 = \frac{\sum(x-\bar{x})^2}{n}$, is the variance

$\bar{x} = \frac{\sum x}{n}$, is the mean of variable x

N is the number of samples (variable)

The degree of freedom of the t-statistic is given by N-1

MATERIALS AND METHOD

The materials used for the experiments are crushed granite rock, River gravel, Ordinary Portland cement and water. The crushed rock aggregate was obtained from Makurdi Local Government Area of Benue State, Nigeria. Ordinary Portland cement was purchased in Makurdi, Benue State. It was used as supplied. The River sand was obtained from River Benue, Makurdi. The water used for the concrete was pipe-born water supplied to the Civil Engineering Laboratory, Makurdi, Nigeria.

Sieve Analysis

The grading of the aggregates was carried out as specified by British Standard (BS) 812: section 103.1: 1985.

Specific Gravity Test

The specific gravity (G_s) test was carried out according to the procedure in BS 812: Part 2: 1975 specifications.

$$G_s = \frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_3)} \qquad 4$$

W_1 = weight of empty density bottle

W_2 = weight of bottle + sample

W_3 = weight of bottle + sample + water

W_4 = weight of bottle + water

The Concrete Production

Concrete mix ratios of 1:2:4 and 1:1½:3 were used at the water-cement ratios of 0.54 and 0.49 respectively, for production of the concrete. The fresh concrete was subjected to slump test as specified by BS 1881: part 102: 1983. Each mix was cast into ten, 150mm cube moulds and 150mm diameter x 450mm high cylinder and 150 x 150mm base and 600mm length beam moulds. The concrete specimens were removed from the moulds after 24 hours; then transferred to curing tank. They were cured for 28 days and then tested for compressive and flexural strength, as prescribed by BS 1881: part 116: 1983 and BS 1881: part 118: 1983 respectively. The flexural strength was calculated using equations 1 (beam specimen) and 2 (cylinder specimen). The values obtained for flexural strengths from the two methods will be subjected to statistical t-test as highlighted in section 1.3.

Null Hypothesis (H_o): There is no significant difference between the values of the flexural strength measured by Direct (concrete beam specimen) and Indirect (concrete cylinder specimen) methods.

Alternative Hypothesis (H_A): There is significant difference between the values of the flexural strength measured by Direct (concrete beam specimen) and Indirect (concrete cylinder specimen) methods. The test is carried out at 95 per cent confidence interval.

RESULTS AND DISCUSSION

Sieve Analysis

The results of sieve analysis of the aggregates used are shown in figures 1and 2. The sand is uniformly graded and belongs to zone C (Neville, 1996) while the crushed rock (granite) aggregate is well graded.

Specific Gravity of the Aggregates

The average specific gravities of the crushed granite and the River sand were found to be 2.65 and 2.60 respectively.

Slump Test

The average slump values for 1:2:4 and 1:1½:3 concrete are 108 and 75mm respectively. These values fall within the range of workable concrete (Jackson, 1984).

Compressive and Flexural Strength

The results of compressive and flexural strength tests are shown in Table 1. The average compressive strengths for the mix ratios 1:2:4 and 1:1½:3 are 24.8 and 29.7 N/mm^2. The compressive strengths are within the minimum required for structural concrete (Oyenuga, 2008). The concrete showed low flexural strength. This could be largely due to inaccurate determination of the property. The statistical t-test analysis on the values of the flexural strength measured by Direct and Indirect methods showed that there is no significant difference between the values obtained from the two methods.

CONCLUSION

It is a well-known fact that concrete is strong in resisting compression but weak in tension. However, flexural strength of concrete is important in engineering structures such as Air Fields/strips, Concrete Roads etc. Flexural strength of concrete is usually measured in laboratory using beam specimen. An alternative method of measuring flexure is by use of cylinder specimen. This research measures the values of flexural strength of specified concrete with the two methods. The aim is to ascertain if there is any significant difference between the values obtained from either of the methods. Laboratory experiment methods were used for the research work. The specific gravity of the River sand and crushed granite rock were found to be 2.60 and 2.65 respectively. The grading of the sand showed that it belongs to zone C (Neville, 1996). The 28 day compressive strength for mix ratios 1:2:4 and 1:1½:3 were found to be 24.8 and 29.7 N/mm^2 respectively. The 28 day average flexural strengths for the ratio 1:2:4 are 1.9 and 2.0 N/mm^2, for beam and cylinder specimens respectively. The mean flexural strength values for the ratio 1:1½:3 are 2.0 and 3.3 N/mm^2 for beam and cylinder specimens respectively. The flexural strength values were subjected to statistical t-test. It was found that there is no significant difference between the Direct and Indirect methods of measuring flexural strength.

REFERENCES

American Standards for Testing Materials (ASTM C) 78; Testing for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

Arthanari S. (1981); Building Technology and Valuation, Mcgraw-Hill Publishing Co. Ltd. 53-54

British Standard (BS) 812: part 110: 1990; Methods of determination of aggregate crushing value

BS 1881: part 102: 1983; Method for determination of slump

BS 1881: part 116: 1983; Method for determination of compressive strength of Concrete Cubes

BS 1881: part 117: 1983; Method for determination of Tensile Splitting strength

BS 1881: part 118: 1983; Method for determination of flexural strength of concrete

BS 812: part 103.1: 1985; Sieve analysis

BS 812: part 2: 1975; Methods for determination of physical properties of aggregate

Jackson, N. (1984); Civil Engineering Materials, RDC Artser Ltd, Hong Kong

Murdock L. S. and Brooks L. J. (1991); Concrete Materials and Practice, Rowland Ph. Ltd. 36-39

Neville A. M. (1996); Properties of Concrete, 5th Edition, Palgrave-New York

Neville A. M. and Brooks J. J. (1994); Concrete Technology, Longman Publishers Ltd, Singapore

Oyenuga, V. O. (2008); Reinforced Concrete Design, 2nd Edition; Asros Limited, Lagos, 3-5

Pearson E. S. and Hartley H. (1996); Biometrika Table for Statisticians; 1(3), 146

Ramachandran, (1995); Analysis of Concrete; the India Concrete Journal, 6; 45-50

Spigel M. R. (1992); Theory and Problems of Statistics, Macgraw-Hill Book, London

Table 1: Flexural Strength of the Concrete, Cylinder and Beam Specimens and Compressive Strength (28 day)

Mix ratio	Sample No.	Compressive strength (N/mm^2)	Flexural strength (N/mm^2)	
			Beam specimen	Cylinder Specimen
1:2:4	1	24.50	1.80	2.09
	2	25.08	1.68	1.90
	3	24.02	1.90	1.98
	4	25.16	2.00	2.00
	5	24.82	1.82	1.90
	6	25.10	2.00	2.20
	7	25.20	2.04	2.28
	8	24.80	1.88	2.04
	9	24.66	1.84	1.90

	10	25.00	1.98	2.10
	Average value	**24.83**	**1.89**	**2.04**
1:1½:3	1	29.02	1.86	3.40
	2	29.60	1.90	3.17
	3	30.01	2.02	3.37
	4	29.88	2.00	3.42
	5	29.46	1.88	3.38
	6	29.88	1.98	3.24
	7	29.84	1.98	3.28
	8	30.10	2.02	3.42
	9	28.94	1.86	3.20
	10	30.40	2.00	3.40
	Average value	**29.68**	**1.95**	**3.32**

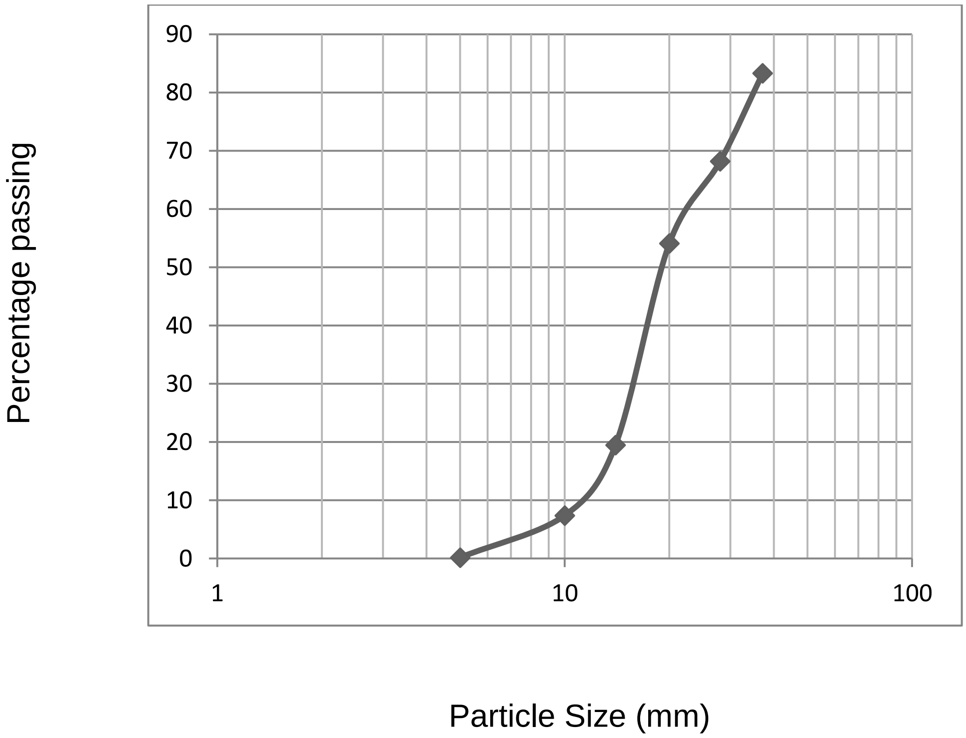

Figure1: Particle Size Distribution of Crushed Granite

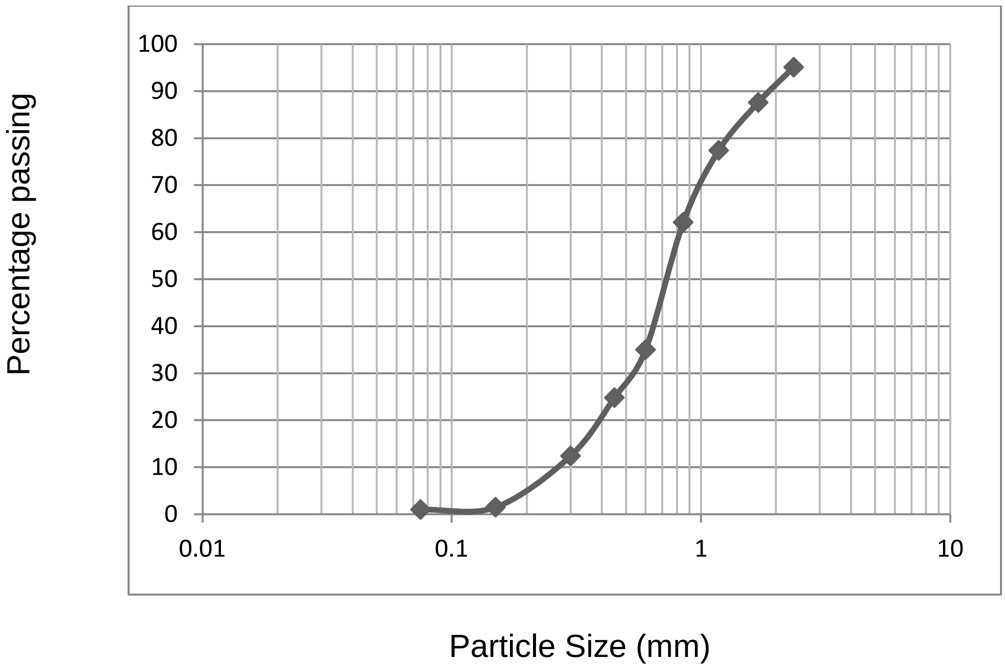

Figure 2: Particle Size Distribution of River Sand

Reference to this paper should be made as follows: Ogah Sylvester Obam and Kassar Terungwa (2014), Comparison of the Direct and Indirect Methods of Measuring Flexural Strength of Concrete. A Case Study of Concrete Made from Crushed Granite Rock. *J. of Physical Science and Innovation,* Vol. 6, No. 2, Pp. 48-54.

Biographical Note

Engr. Dr. S.O. Obam was born in July, 1966 at Oyiwo in Oju Local council area of Benue State, Nigeria. He had his Bachelor of Engineering, Master of Engineering and PhD degrees in 1988, 1998 and 2007 respectively from the University of Nigeria Nsukka. He started work as Lecturer II, at the Benue State Polytechnic Ugbokolo, in 1991. He is presently, an Associate Professor in the Department of Civil Engineering, University of Agriculture Makurdi, Nigeria. He has published over 20 papers in both local and international journals. He is also a member of several professional bodies, example, Council for the Regulation of Engineering in Nigeria (COREN) and Nigerian Society of Engineers (NSE). I have attended series of conferences and workshops. The latest ones are: COREN (Council for the Regulation of Engineering in Nigeria) Workshop on 'Engineering Regulation and Monitoring' held at Makurdi, Benue State, in April 11, 2012 and International Research and Development Institute Conference, Uyo, Akwa Ibom State; August 26, 2014. As a lecturer, he supervises both undergraduate and postgraduate students in research works, and also renders other academic and non academic services to the University and its community.

Biographical Note

Engr. Kassar Terungwa was born on July 3, 1986 in Kwande Local Government Area of Benue State, Nigeria. He started work in the Department of Civil Engineering, University of Agriculture Makurdi, in July 2012. His present rank is Lecturer II.