www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 4 Issue 7 July 2015, Page No. 13298-13305

Investigation of The Effect Of Water-Cement Ratio On The Modulus Of Rupture Of Concrete

Onwuka. D. O[a], Awodiji. C.T.G[b] and Onwuka, S.U[c]

a,b Civil Engineering Department, Federal University of Technology, Owerri, Imo State.
c Project Management Department, Federal University of Technology, Owerri, Imo State.
E-mail: chimbaegbu@yahoo.com

ABSTRACT

This paper presents the experimental results of the investigation of the effects of water-cement ratio on the modulus of rupture of concrete. The variations of the flexural strengths of concrete mixes with varying water-cement ratio within 28 days after curing and casting, were experimentally investigated. In all a total of 15 prototype concrete beams were cast (2 specimens from each mixture) and tested so as to determine their flexural strength (modulus of rupture). The design strength level attained ranged between 4.50Mpa to 6.30Mpa for water-cement ratio ranging from 0.48 – 0.62. The results obtained showed that the values of modulus of rupture of concrete, increased as the water-cement ratio increased, until an optimum value of 6.30Mpa was attained at a water-cement ratio of 0.58. However, the water-cement ratios above 0.58, was observed to have a very significant reduction effect on the flexural strength of the concrete. Setting time test for the cement paste used for the concrete, was carried out, alongside the grain size distribution analysis of the aggregates. The initial setting time was 60 mins (1 hr.) while the final setting time was 535 mins (approximately 9 hrs). Grain size distribution of aggregates shows that the sharp river sand is a medium-fine aggregate while the granite chipping is a medium coarse aggregate.

Keyword: Water-cement ratio, modulus of rupture, concrete.

1.0 INTRODUCTION

Concrete is one of the most used materials in building and civil engineering construction works. It is a construction material composed of carefully controlled mixture of cement, aggregates (coarse and fine), water and sometimes, chemical admixtures. It takes the shape of its container or formwork when hardened and forms a solid mass when cured at a suitable temperature and humidity (Shetty, 2006). The strength of concrete is normally considered to be its most valuable property, although other characteristics such as durability and permeability, may in fact, be more important (Neville, 2006). Generally, the strength of concrete usually gives the overall picture of the quality of concrete, because strength is directly related to the structure of the hydrated cement paste. Flexural strength of concrete (modulus of rupture) is typically used in the design of pavements, because it best simulates slab flexural stresses when subjected to loading (Razon and Sohichi, 2013). However, it is commonly neglected in the design of most ordinary structural elements. Mosley and Bungey (2000), stated that compressive strength is about 8 times greater than flexural strength while Lafe (1986) says compressive strength is 10 to 13 times greater than flexural strength.

Many researchers have carried out works on the effect of water-cement ratio on concrete. These include; Ahmad and Shabbir (2005), Omotola and Idowu (2011), Ting et al (2006) etc. Among these researchers, Omotola and Idowu

(2011), investigated on the effects of water-cement ratio on the compressive strength and workability of concrete and lateritic concrete mixes. They discovered that water-cement ratio, is the main determinant of the weight, density and crushing strength of concrete cubes. They also discovered that compressive strength of lateritic concrete mix, decreases with increase in water-cement ratio, and increases with age. For any given cement content, there is an optimal water content ratio. For every kilogram of cement, about 0.25kg of water is needed to fully complete the hydration reaction (Wikipedia, 2013). This yeilds a water-cement ratio of 1:4 which is often given as a proportion of 0.25. However, a mix with a water-cement ratio of 0.25 may not mix thoroughly, and may not flow well enough to be placed, and so more water is used than is technically necessary to react with the cement. Other typical water-cement ratios that can be used ranges from 0.4 to 0.6. Using more water in the mix, assist in reducing macroscopic entrapped voids, but too much water increases microscopic capillarity (Ting et al, 2006). Conversely, using less water has the potential to allow a closer packing of cement particles, but makes it so much more difficult to expel the air voids, since lesser water means reduced mobility.

Current trend in civil engineering are towards the construction of large structures with increasing performance demands; hence there is the need to improve the optimum strength attainability of concrete structures. Thus, the purpose of this study is to optimize the water-cement ratio for the flexural strength of ordinary portland cement concrete within the range of 4.5Mpa to 6.30Mpa. Optimizing the water-cement ratio optimizes the overall strength of the concrete.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

Locally available materials were used to prepare prototype concrete beams in this work. These include Dangote cement, a brand of ordinary Portland cement, which conforms to the requirements of BS 12 (1978), sharp river sand, obtained from Otamiri river in Owerri, Imo State, granite chippings obtained from Ishiagu quarry site in Ebonyi State and water, obtained from municipal water supply. Concurrently, grain size distribution of the fine and coarse aggregates were determined by sieve analysis test. This is a process of dividing a sample of aggregate. Two samples of air dried aggregates (sand and granite chippings) were graded by shaking or vibrating a nest of stacked sizes of sieves, with the largest sieve at the top for the material retained to be coarse compared to the sieve but finer than the sieve above. The particle size distributions are shown in Figs 1 and 2. In order to evaluate the setting time of the cement paste, initial and final setting time test of the cement paste were also carried out using the vicat apparatus. To determine the initial setting time, a 1mm diameter needle attached to the plunger of the vicat apparatus and acting under the self-weight of the plunger was used to penetrate a paste of standard consistency placed in a special mould. When the paste stiffens such that the needle can't penetrate more than a depth of 33mm to 35mm, initial setting has occurred. A similar needle fitted with a metal attachment hollowed out so as to leave a circular cutting edge 5mm in diameter and set between 0.5mm between the tips of the needle was used in determining the final setting time. Final setting occurred when upon lowering, the attachment gently cover the surface of the test block, and the centre of needle made an impression, while the circular cutting edge failed to do so. The initial and final setting times are given in Table 3. The mix proportions of these constituent materials of concrete are shown in Table 4.

2.2 METHODS

The first part of the test was the laboratory testing in flexure of the 150x150x600mm prototype concrete beam specimens prepared for fifteen different concrete mixtures. These tests were conducted at the age of 28 days after curing the specimen in open water tanks. The two beams prepared from each mix, were tested and their average values recorded as the result. In conducting the flexural test, specimens were placed in a hydraulic testing machine conforming to BS 1881, Part 118 (1983), in such a manner that the load was applied to the uppermost surface as cast in the mould along two lines spaced 20cm apart. The axis of the specimen was carefully aligned with the axis of the loading device, making sure that the load applying block and the support blocks were in contact with the surface of the specimen. A load of 3% to 6% of the estimated ultimate load was then applied. It was increased until the specimen failed. The maximum load applied to the specimen during the test was recorded and the appearance of the fractured faces of the concrete was noted. The MOR of concrete was then calculated from the formula:

$$MOR = PL/ bd^2$$

where, P = maximum applied load (KN) ; L = length of the span of specimen in mm; b = average breadth in mm and d = average depth in mm

3.0 RESULTS AND ANALYSIS

Table 1 and Table 2 show the results of the seieve analysis conducted on the river sharp sand and granite chippings. The river sand is a medium-fine aggregate while the granite chipping is a medium coarse aggregate. Table 3 presents the results of initial and final setting time test of the Dangote cement paste used for the study. The result shows that the initial setting time for the cement paste is 1 hour while the final setting time was 535 mins (i.e. approximately 9 hours)

Table 1: Particle size distribution of Otamiri sharp river sand

Sieve size (mm)	Mass of sand passing (g)	Mass of sand retained (g)	% passing
5.00	500	0	100
2.36	472.50	27.50	94.50
1.18	411.45	61.05	82.29
0.850	341.35	70.10	68.27
0.600	258.00	83.35	51.60
0.425	199.55	58.45	39.91
0.300	95.00	104.15	19.08
0.212	31.95	63.05	6.39
0.150	7.95	24.00	1.59
0.075	1.15	6.80	0.23
Pan	0	1.55	0
Total		500	

Table 2: Particle size distribution of Ishiagu granite chippings

Sieve size (mm)	Mass of sand passing (g)	Mass of sand retained (g)	% passing
37.50	500	0	100
28.00	488.50	11.50	97.70
20.00	471.50	17.00	94.30
14.00	353.50	118.00	70.70
10.00	203.50	150.00	40.70
5.00	32.50	171.00	6.50
2.36	1.5	31.00	0.30
Pan	0	1.50	0
Total		**500**	

Table 3: Results of Initial & Final Setting Time Test of Dangote Cement paste.

Cement	Initial Setting Time (mins)	Final Setting Time (mins)
Dangote	**60**	**535**

Table 5 shows the experimental results i.e. modulus of rupture of concrete with their corresponding mix proportions and water-cement ratio. The maximum value of modulus of rupture attained was 6.30Mpa at a water-cement ratio of 0.58 having a mix proportion of 1:1.75:3.75. The lowest value of MOR obtained was 4.50Mpa at 0.48 water cement ratio with mix proportion of 1:2.75:5.75.

Table 4: Mix proportions of constituent materials used in producing the prototype concrete beams.

S/N0	Mixture Label	Mix proportion	Water-cement ratio	Water (Kg)	Cement (Kg)	Sand (Kg)	Granite (Kg)
1.	S1	1 : 2.75 : 5.75	0.48	1.62	3.41	9.38	19.61
2.	S2	1 : 2.5 : 4.75	0.49	1.96	3.93	9.82	18.65
3.	S3	1 : 2.5 : 6	0.50	1.71	3.41	8.53	20.46
4.	S4	1 : 2.375 : 4.875	0.51	2.01	3.93	9.33	19.14
5.	S5	1 : 2.25 : 4.375	0.52	2.23	4.25	9.56	18.59
6.	S6	1 : 2.25 : 4.5	0.52	2.19	4.18	9.41	18.81
7.	S7	1 : 2.25 : 5	0.52	2.06	3.93	8.84	19.64
8.	S8	1 : 2.25 : 4.75	0.53	2.13	4.05	9.11	19.24
9.	S9	1 : 2.125 : 4.625	0.54	2.25	4.18	8.88	19.33
10.	S10	1 : 2: 4	0.55	2.56	4.63	9.26	18.51
11.	S11	1 : 2 : 4.75	0.55	2.30	4.18	8.36	19.86
12.	S12	1 : 1.75 : 4.125	0.58	2.71	4.71	8.25	19.44
13.	S13	1:1.75:3.75	0.58	2.87	4.98	8.72	18.69
14.	S14	1 : 1.5 : 3.5	0.60	3.24	5.40	8.10	18.90
15.	S15	1:1.5:4.375	0.62	2.92	4.71	7.07	20.62

Table 5: Experimental results of MOR Tests

S/N0	Mixture Label	Mix proportion	Water-cement ratio	MOR (Mpa)
1.	S1	1 : 2.75 : 5.75	0.48	4.50
2.	S2	1 : 2.5 : 4.75	0.49	4.60
3.	S3	1 : 2.5 : 6	0.50	5.40
4.	S4	1 : 2.375 : 4.875	0.51	4.70
5.	S5	1 : 2.25 : 4.375	0.52	5.00
6.	S6	1 : 2.25 : 4.5	0.52	5.50
7.	S7	1 : 2.25 : 5	0.52	5.20
8.	S8	1 : 2.25 : 4.75	0.53	5.20
9.	S9	1 : 2.125 : 4.625	0.54	5.70
10.	S10	1 : 2: 4	0.55	6.00
11.	S11	1 : 2 : 4.75	0.55	6.20
12.	S12	1 : 1.75 : 3.75	0.58	6.30
13.	S13	1 : 1.75 : 4.125	0.58	6.15
14.	S14	1:1.5:3.5	0.60	5.90
15.	S15	1:1.5: 4.375	0.62	5.60

It is observed that the value of MOR increased as water-cement ratio increased until an optimum value of 0.58 water-cement ratio was attained. After this point, values of MOR began to reduce. The experimental values of modulus of rupture are plotted against their corresponding water-cement ratio as shown in Fig 1, and in the form of a bar chart as shown in Fig 2.

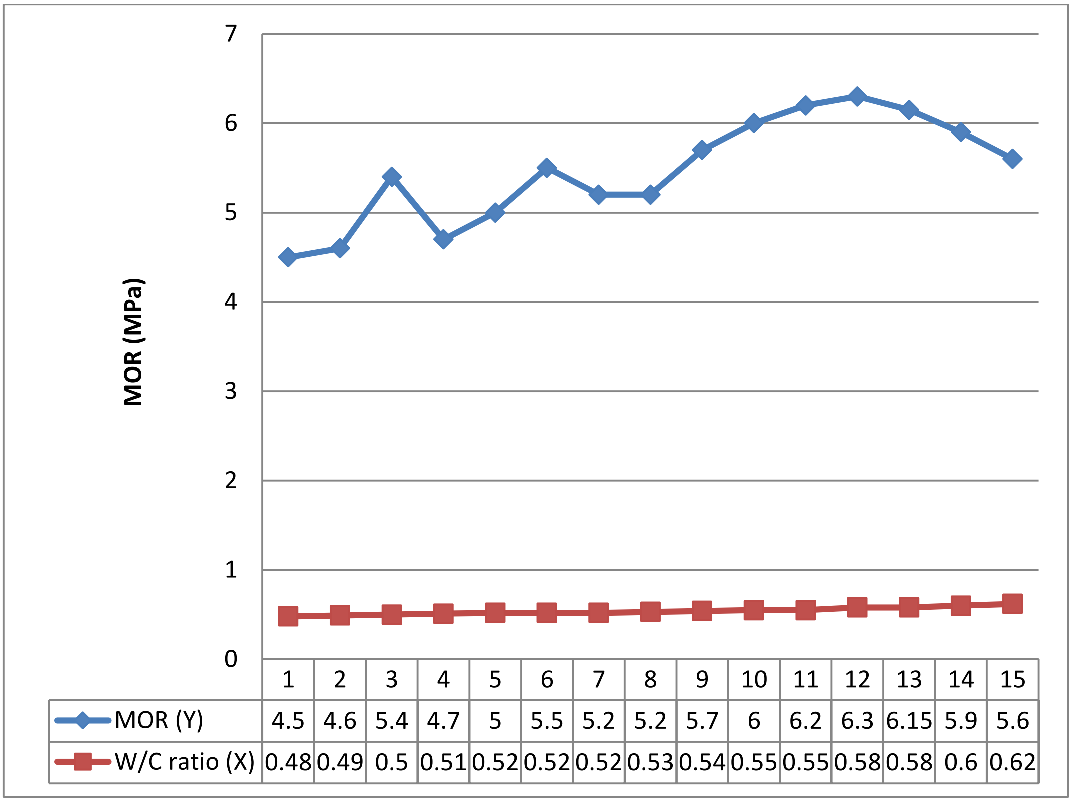

Fig 1: Plot of the MOR of the concrete mixes against water-cement ratio.

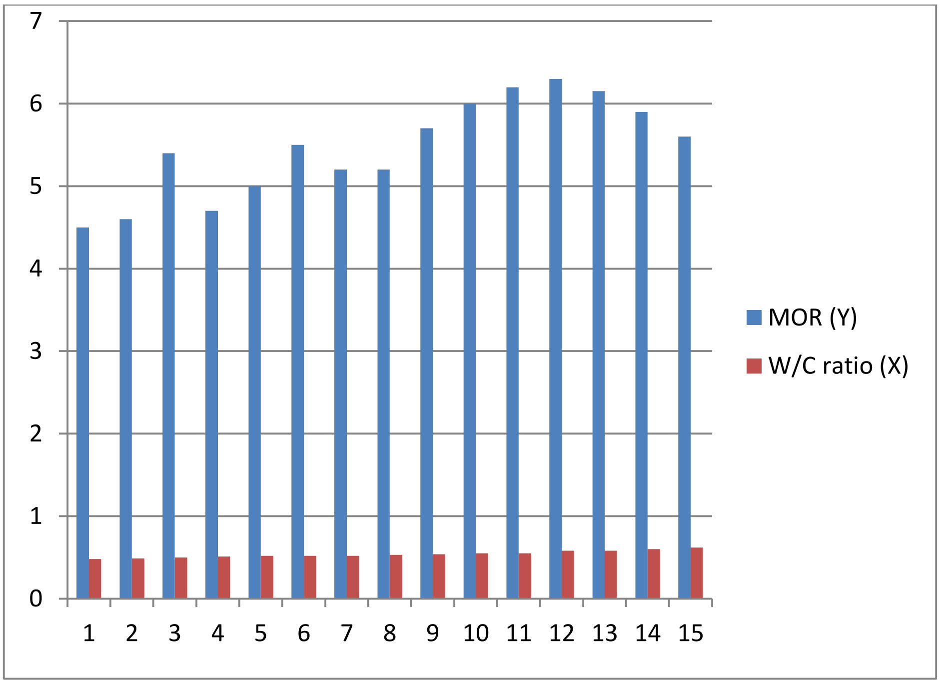

Fig 2: Bar chart of the concrete mixes against water-cement ratio

4.0 CONCLUSIONS

A close look at the MOR results shown in Table 5 and Fig 1, indicates that for the same quantity of cement, the values of Modulus of rupture, MOR of the prototype concrete beams, increased, until it reached an optimum value of 6.30MPa at a water-cement ratio of 0.58. Thereafter, the MOR reduced with increased water-cement ratio. Thus a mix proportion of 1:1.75:3.75 yeilded an optimum MOR of 6.30MPa at an optimum water-cement ratio of 0.58.

REFERENCES

Ahmad, S. & Shabbir, F. (2005). ***"Effect of Different mix ratios and water cement ratios on sulphate attack on concrete"***, 30th Conference on Our World in Concrete & Structures. August 2005, Singapore. Available from (http://cipremier.com/100030012)

BS 1881, Part 118 (1983): "***Method of Determination of Flexural Strength***", BSI-London.

Lafe, O. (1986), ***"Elelements of reinforced concrete design",*** Macmillan publishers: London, UK.

Mosley, W.H. & Bungey, J.H. (2000), ***"Reinforced concrete design"*** 5th edition. Macmillan publishers limited: London, UK.

Neville, A.M. (2006). ***"Properties of Concrete"*** 4th Edition, Dorling Kindersley (India) Pvt. Ltd.

Omotola, A. & Idowu, O.I. (2011), ***"Effects of water-cement ratios on the compressive strength and workability of concrete and lateritic concrete mixes"*** The pacific journal of science and technology, vol. 12, number 2, Nov. 2011.

Razon, D. & Sohichi, H. (2013), ***"Correlation between strength and combined non-destrcutive tests for concrete using high-early strength cement",*** available from http://www.ncts.upd.edu.ph/ Accessed March 2013.

Shetty, M. S. (2006). ***"Properties of Concrete"***, Multicolour revised edition, S. Chad & Company Ltd. New Delhi, India.

Tung-Chai, L., Hasanan, M.N., & Rachmat, M. (2006), ***"The Effects of water-cement ratios on concrete paving block"*** Regional past-graduate conference on engineering and science (RPCES 2006) , Johore, 26th -27th July.

Wikedepia, ***"Water-Cement ratio"***, available from http://www.goggle.com/search. Accessed March, 2013.