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EFFECTS OF VARYING WATER-CEMENT RATIOS ON DIFFERENT GRADES OF CONCRETE USING LOCALLY MATERIALS

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ABSTRACT

This research focused on laboratory tests that was conducted using locally available 10mm washed all -in gravel, quarry dust with varying water cement ratio. The research was carried-out using 108 (150 x 150 x 150) mm standard cubes that were all tested from three designed concrete mixes. In the present study, the role of water-cement ratio in compressive strength of concrete was investigated. The mixed concrete samples with water-cement ratios of 0.3, 0.35 and 0.40 were experimented for 3, 7, 21 and 28 days of curing. The results of compressive strength experiment showed that due to increase in water-cement ratio from 0.3 to 0.40, the compressive strength improved from 22 N/mm^2 to 24.33 N/mm^2 for 1:1.5:3 design mix, the compressive strength improved from 22.88 N/mm^2 to 24 N/mm^2 for 1:2:1 design mix, while compressive strength improved from 24 N/mm^2 to 25.3 N/mm^2 for 1:1:2 design mix respectively. The results for compressive strength experiments showed that the 0.4 water-cement ratio resulted in the optimum compressive strength for all three design mixes.

Keywords: Quarry dust, river washed aggregate, Portland Limestone Cement, Water-cement ratio, compressive strength, mixes.

INTRODUCTION

Concrete can be said to be the most widely used material in civil engineering construction works. It is a composite material that could be used alone or reinforced with other materials such as steel (or with local materials such as bamboo, oil palm fibers etc.) depending on the nature of its use.

The compressive strength of concrete is usually determined by performing compression test on standard sizes of concrete blocks or cylinders. The strength of concrete is affected partly by the relative proportion of cement and the fine and coarse aggregates but the water-cement ratio is another factor. There is an optimum amount of water that will produce a concrete of maximum strength from a particular mix of fine and coarse aggregate and cement. Lafe (1986).

The water-cement ratio is one of the most important aspects when it comes to maintaining the strength of concrete. It is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower water cement ratio leads to higher strength and durability, but may result in the mix having low workability making it difficult to work with and form.

A mix with low water cement ratio may not mix thoroughly, and may not flow well enough to be placed. More water than is technically necessary to react with cement is therefore used. Water cement ratios of 0.45 to 0.60 are more typically used but for higher-strength concrete, lower ratios are used, along with a plasticizer to increase flowability / workability of concrete.

For this research, Portland Limestone Cement of grades 42.5 conforming to BS12 (1971) was used as the binder. The 10mm all-in aggregate was prepared according to the Standards specified by BS 882 (1992) .The grading carried out to BS 812: 103(1995) and is used as coarse aggregate. Quarry dust (QD) replaces sand as fine aggregate.

RESEARCH SIGNIFICANCE

The main aim of this research is to develop optimal mixes meeting requirements for concrete strength, workability, durability by reducing water-cement content making use of 10mm washed all-in river gravel aggregate and quarry dust. All the materials are abundantly available within the local environment of Nigeria and incorporated into the various mixes for increased economy and environmental load reduction.

MATERIALS AND METHODS

The 10mm all-in aggregate used in this project was collected from Imo River deposits Oyibgbo between Abia, Imo State and River state boundary. The quarry dust used in this project was collected from Setracco site deposits at Okigwe, Imo state. The type of cement used for the various experiment is grade 42.5R Portland Limestone cement. All the materials used were locally sourced.

EXPERIMENTAL PROCEDURES AND PROGRAMS

Apart from characterizing the properties of the various materials, the British Standard (BS) for testing aggregates and concrete were used to describe the experimental procedures and behaviours on aggregates, fresh concrete, and hardened concrete.

Table 1: Experimental programme showing the materials, tests, number of test / samples and applicable standards

Materials	Tests	No of test/ samples	Applicable Standards
Cement	Specific Gravity	3	BS 12:part 2: 1999
	Setting Time	2	BS 12 : 1971
10mm All-in	Moisture Content	3	BS 1377: 1975
Gravel aggregates,	Specific Gravity	9	BS 812:part 2: 1975
Quarry Dust	Particle Size Distribution	2	BS 812:part 103: 1985
		6	BS 1881: Part 107: 1983.
Wet Concrete	Slump Workability	36	BS 1881:102: 1983 and ASTM
Hardened			C143/C143M: 2012
Concrete	Test after 3,7,21 and 28		
Water	days wet curing.	108	
	Water absorption Test	9	BS 1881-116: 1983
	Density	108	BS 188-122-: 1983

Table 2: Physical Properties of Materials

Properties	10mm all in gravel	Quarry dust	BS 882:1995: Clause 5.3
Coefficient of uniformity	3.05	3.5	Cu> 4
Coefficient of curvature	1.37	1.14	1.67
Fineness modulus	4.06	3.57	3.00
Specific gravity	2.85	2.65	2.70
Water absorption (%)	0.38	1.26	2.50
Density (kg/m3)	0.00166	0.00124	0.0018

Table 3: Particle Size Distribution - 10mm All-in-Gravel Aggregate

Weight of sample taken for dry/wet grading				G	500
'Weight retained on No.63 micromillimetre B.S.sieve				G	10
Weight passing No.63 micromillimetre B.S.sieve				G	0
Sieve (mm)	**Mass (g)**	**% retained**	**%passing**		
			100		100
9.520	35	7.0	93.0	100	100
4.750	38	7.6	85.4	85	95
2.360	18	3.6	81.8	72	92
2.000	57	11.4	70.4	65	85
1.180	50	10.0	60.4	55	80
0.850	52	10.4	50.0	44	75
0.600	54	10.8	39.2	35	59
0.300	100	20.0	19.2	15	30
0.150	88	17.6	1.6	5	5
0.075	8	1.6	0.0	0	0

Total Mass (g) = 500

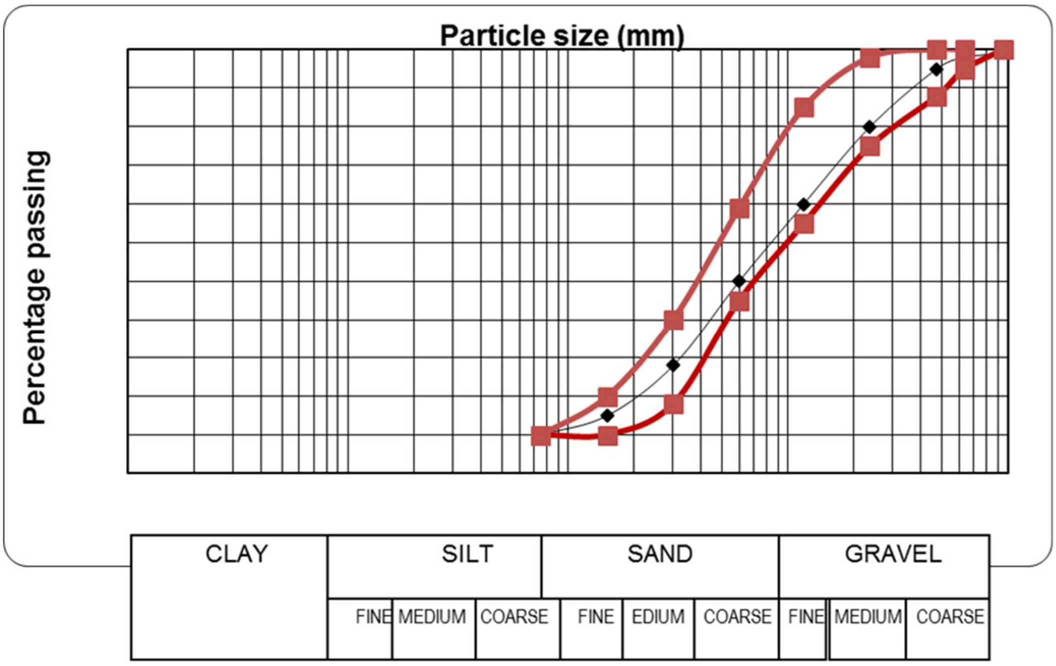

Figure 1.0 Particle Size Distribution Curve for Washed 10mm on All-in Gravel Aggregate

Table 4: Particle Size Distribution - Quarry Dust

Weight of sample taken for dry/wet grading				G	500
'Weight retained on No.63 micromillimetre B.S.sieve				g	10
Weight passing No.63 micromillimetre B.S.sieve				g	0
Sieve (mm)	Mass (g)	% retained	% passing		
			100		
9.520	12.7	2.5	99.0	100	
6.350	27.4	5.5	98.0	95	100
4.750	45.2	9.0	95.0	88	100
2.360	93.2	18.6	80.0	75	98
1.180	86	17.2	60.0	55	85
0.600	72	14.4	40.0	35	59
0.300	77.5	15.5	18.0	8	30
0.150	56	11.2	5.0	0	10
0.075	30	6.0	0.0	0	0
	Total Mass (g) = 500				

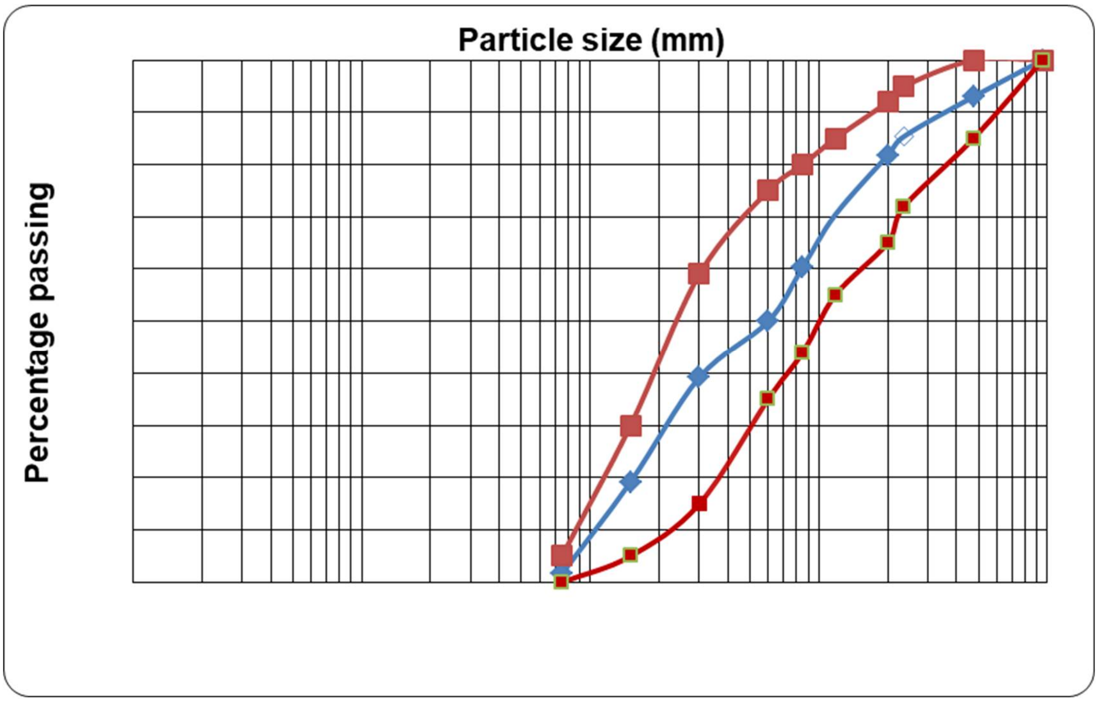

Figure 2.0 Particle size distribution curve for Quarry Dust

Particle Size Distribution

The particle size distribution of 10mm all – in gravel aggregates and quarry dust were done by sieving according to BS 812: 103:1995. The results were recorded and plotted into the grading requirements of the sieve analysis semi-log graph according to BS 882 (1992).See figures 2.0a and 2.0b respectively above.

(a)True slump

(b) Shear slump

(c) collapsed slump

Plate 1: Typical slump mesurement (True, Shear and Collapse slump)

Workability of Mixed Concrete

The concrete mix were experimented upon 25 grade of nominal mix for the various mixes stated above and tested after 3 to 28 days of curing. (150 x150x150) mm concrete cubes were experimented upon 0.30, 0.35 and 0.40 water-cement content.

The three mix proportions 1:1:2, 1:2:1 and 1:1.5:3 used in this research exhibit three basic forms of slump (True, Shear and Collapse slump).The average results were determined as shown on plates 1a, b and c.

Table 5: Average experimental values of compressive strength 1:1.5:3 mix with varying w/c ratio

Mix	Water cement	Average Comprehensive Strength (N/mm^2) at ages			
		3	7	21	28
Control mix	0.3	11.33	13.87	18.56	22
	0.35	13.11	16.88	19.77	23.88
	0.4	13.88	19.87	21.22	24.33

Table 6: Average experimental values of compressive strength 1:2:1 mix with varying w/c ratio

Mix	Water cement	Average Comprehensive Strength N/mm^2 at ages			
		3	7	21	28
Control mix	0.30	12.33	17.22	19.20	22.88
	0.350	13.56	17.88	19.87	23.00
	0.40	13.77	20.87	22.22	24.00

Table 7: Average experimental values of compressive strength 1:1:2 mix with varying w/c ratio

Mix	Water cement	Average Comprehensive Strength N/mm^2 at ages			
		3	7	21	28
Control mix					
	0.3	13.33	17.77	19.56	24
	0.35	15.11	20.88	21.77	24.88
	0.4	17.88	21.77	22.22	25.33

Failure mechanism ACI 226, (1999), and 318R (1999)

This concrete cube is made using Portland Limestone Cement. The concrete cubes are placed on the plates and the compressive machine operated. From the test conducted, it is shown that as the applied load increases on the hardened concrete, cracks begins to develop gradually and cracks fully as compressive strength is achieved. The cracks shown on the four faces are approximately similar and equa l. The faces in contact with the platens have little damages. Satisfactory (normal) failure modes are shown be plates 2a and 2b respectively

Plate 2a: Failure Mode of Concrete Cube.

Plate2b: Failure Pattern

CONCLUSION AND RECOMMENDATION

This study revealed that locally available material, 10mm washed all-in gravel and quarry dust can be used in the development of high strength concrete having high workability and compressive strength at the finished state. The analysis and discussions were concluded from the various experimental findings. Conclusions and recommendations were arrived at as stated below:

10mm all – in gravel aggregate and quarry dust are suitable for application as structural concrete. The particle size distributions plot within the BS 882 (1992) grading envelop for coarse sand confirmed by their fineness modulus values of 4.06 and 3.57 respectively. The specific gravity values of 2.85 and 2.65 for gravel and quarry dust meet the BS specifications for concrete aggregates.

The compressive strength increases marginally with increase in water cement ratio from 0.3 to 0.4. The average 28 days compressive strength of grade 42.5 achieved with 1:1:2 mix, increased from 24 N/mm^2 to 25.33 N/mm^2 which had the best strength when compared to 1:2:1 mix and 1:1.5:3 mix with compressive strength from 22.88 N/mm^2 to 24 N/mm^2, and from 22 N/mm^2 to 24.33 N/mm^2 respectively.

Water –cement mix ratio of 0.4 resulted in the having the best optimum compressive strength for all three design mixes for the concrete from the result compared to that of 0.35 and 0.3.

The design mix of 1:1:2 showed that the

compressive strength was better than 1:2:1 and 1:1.5:3 mix.

The failure mechanism of the developed high strength mixes is due to the development of smooth fracture cracks between the matrix and the aggregates. Failure was brittle in nature and accompanied by a decrease in ultimate deformation as concrete strength increased.

The application of the developed high strength concrete mixes in practical structural application will result in value addition, cost savings, enhanced service life of structures and reduction in environmental load

RECOMMENDATION

The major recommendation for this study consists of the provision of new mixes for specification in design and construction of structural works.

Further studies are recommended in the following areas:

Effect of aggregate combination to evaluate impact of fine/coarse ratio on properties of 10mm all – in gravel concrete.

Flexural, shear, tensile and elastic properties of 10mm all – in gravel concrete both in its plain and reinforced variants.

Durability, performance and sustainability evaluation of HSC.

REFERENCES

ASTM C143/C143M 2012. Standard test method for slump of hydraulic materials, Annual Book of ASTM Standards

BS Part 2 1975. Testing Aggregates 'Methods of Determination of Physical Properties

BS 12 1978. Specification for Portland cement. London British Standard Institute

BS 12: part 2 1999. Specification of specific gravity. British Standard Institution, London.

BS 812 1975. Method of Determination of Particle size and Shape. London British Standard Institute.

BS 812: Part 2 1975, Testing Aggregates 'Methods for Determination of Physical Properties', British Standard Institution, London.

BS 812: Part 103 1985, Testing Aggregates `Methods of Determination of Particle Size Distribution', British Standard Institution, London.

BS 882 1992. Specification of aggregate from natural sources for concrete British Standard Institution, London:

BS 1377 1975. Method of Determination of air content of fresh concrete. British Standard Institution, London.

BS 1881: Part 107:1983. Method of determination of density of compacted fresh concrete. British Standard Institution, London.

BS 1881: Part 108 1983, `Methods of Making Test Cubes from Fresh Concrete. British Standard Institution, London.

BS 1881: Part 106 1983, `Methods of Determination of Air Content and Fresh Concrete', British Standard Institution, London
BS 1881-102(1983). Method for determination of slump. British Standard Institution, London.

BS 1881-108 1983. Method of concrete mix design. British Standard Institution, London.

BS 1881. Part 114: 1983.Method of Determination of Density of hardened Concrete: British Standard Institution (BSI) London

BS 1881: Part 116 1983. Method of determination of compressive strength of concrete cubes. British Standard Institution, London.

BS 188-122 2011. Specification of water absorption. British Standard Institution, London.

British Standards Institution. BS 6588 1996, Specification of Portland pulverized-fuel ash cements, pp. 10. British Standards Institution.

John O'Grady 2007. Technology trends in concrete forming. Ontario cast-in-place, concrete development council: prism economics and analysis. www.ogrady.on.ca

Lafe, O. 1986. Elements of Reinforced Concrete Design. Macmillan Publishers: London, UK.

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