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Utilization of Scoria as Aggregate in Lightweight Concrete

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Abstract:In Nigeria, concrete production with conventional building materials are widely used. These type of materials are costly. Structural lightweight concrete is receiving more attention now since it offers the required concrete density, cost saving and reduction of negative environmental effects. This study investigates the physical and mechanical properties of lightweight concrete using scoria as partial replacement of coarse aggregate. Grade 25 concrete was produced with 0, 10, 20, 30, 50, 80, 90 and 100% scoria replacing coarse aggregate. The concretes were assessed in terms of water absorption, density, flexural and split tensile strengths. The result revealed that water absorption increases with increase in percentage of scoria with the optimum of 10.20% at 100% replacement. The split tensile strength decreases with increase in scoria from 2.32 N/mm^2 to 0.74 N/mm^2 for 0% and 100% replacement respectively at 28 days curing. Also flexural strength decreases with increase in scoria with the optimum strength of 4.55 N/mm^2 at 10% replacement. The density decreased from 2584 Kg/m^3 to 1870.9 Kg/m^3 for 0% and 100% coarse aggregate replacement respectively. The scoria aggregate satisfied the requirements of lightweight aggregate for structural concrete as per ASTM C 330.

Keywords: Density, Flexural Strength, Lightweight Aggregate, Scoria, Split Tensile Strength, Water Absorption.

I. Introduction

Aggregates arevital components of concrete, they occupy largest volume in concrete and hence the major contributors of self-weight of the concrete. Production of the crushed stone aggregate results in depletion of natural resources and environmental pollution. The concerns about the self-weight of concrete, depletion of natural resources and environmental pollution has resulted in seeking alternative sustainable lightweight aggregate that is environmentally friendly. Scoria is a rock of volcanic origin which deposits can be found around many volcanoes in many parts of the world. It is formed from vesicular fines to coarse fragments and has the basic composition of basalt. Scoria is porous, reddish or black in color, lightweight and strong enough to be used as light weight aggregate.

Concrete produced using scoria aggregates provides engineers and the construction industry withan alternative for conventional concrete because of its reduced self-weight. Depending on the importance of the structure, Light weight concrete can provide engineers with more design opportunities as the lighter concrete beams could potentially have greater spans in a structure (Lau et al., 2014).Also, concrete produced using scoria aggregates can insulate heat five to seven times better than the concrete produced using conventional aggregate. The scoria is therefore, suitable as a thermal insulating material and has the potential to be utilized in manufacturing heat-insulating concrete and building blocks having strength and durability characteristics comparable to other lightweight aggregate (Khandaker, 2006).

Natural lightweight aggregates may be defined as inherently low density natural mineral materials.Structural lightweight concrete is a structural concrete made with lightweight aggregate; the air-dried unit weight at 28 days is usually in the range of 1120 kg/m^3 to 1920 kg/m^3 and the compressive strength is more than 17 MPa(ACI, 2003). The primary user is the construction industry where weight reduction equates to cost savings. Principal products in which natural light weight aggregate is utilized because of its lower density include lightweight Portland cement concrete and light weight concrete units. In addition, due to location, some natural lightweight aggregate compete with normal weight aggregate for uses as road base and backfill material (Bryan, 1987).

Khandaker (2006) studied blended cement and lightweight concrete using scoria. Hereported that scoria concrete made with 50 to 100% scoria aggregate as replacement of coarse aggregate satisfies the criteria for semi-lightweight structural concrete. Scoria concrete made with 100% fine and coarse scoria aggregate also satisfies the criteria for lightweight structural concrete.

II. Materials and Methodology

The fine aggregate used in the study was locally available river sand passing through 5.00 mm BS sieve size with specific gravity of 2.60. Crushed granite coarse aggregate from igneous rock passing through 20.00 mm BS sieve size with specific gravity of 2.71 and aggregate crushing value of 4.2 was obtained from quarry site here in Bauchi. Ordinary Portland cement with specific gravity 3.07 having initial and final setting time of 34 minutes and 486 minutes respectively was used. Crushed scoria passing through 20.00 mm BS sieve size with specific gravity of 1.52 and aggregate crushing value of 0.38 was used. The surface of Scoria is rough, highly porous and reddish or black in color. It has void ratio of 0.6, porosity of 37.5% and bulk density of 654.9 Kg/m^3. Low specific gravity of scoria in comparison with the natural aggregate resulted in lightweight concrete when used as aggregate.

Mix proportion

A grade 25 concrete was designed and a mix proportion of 1:2:3 by the weight of ordinary Portland cement, river sand, coarse aggregate was obtained.The concrete samples were produced using 0, 10, 20, 30, 50, 80, 90 and 100% scoria replacing coarse aggregate and cured for 3, 7, 14 and 28 days respectively.

Preparation of specimens

The materials were measured by weight using beam balance. Water was measured by volume. Hand mixing was adopted throughout the experiment in accordance with BS EN 12390, Part 2 (2000)specifications. Fresh concrete workability was measured immediately after the final mixing of the concrete using slump test in accordance with BS EN 12350: Part 2 (1999)specifications. Concrete beams of sizes 100 x 100 x 450 mm and cylinders of 150 mm in diameter and 300 mm in height were cast for the determination of flexural strength and split tensile strength respectively. The tests were conducted in accordance with BS EN 12390: Part 1, 5 & 6 (2000) specifications. Concrete placement was done in layers and compacted manually using tamping rod. Air bubbles were removed by vibration using table vibrator and the surface was leveled by hand trowel. After 24 hours the specimens were removed from the mould and labeled before curing.

Specimens testing

The flexural strength test was conducted on a simply supported concrete beam using four point bending in accordance with BS EN 12390, Part 5 (2000)specifications. The value of the load at which the beams failed was used to determine the flexural strength using equation (1).

$$FlexuralStrength, F_{bt} = \frac{PL}{bd^2} \quad \ldots (1)$$

Where: P is the Maximum load, L is the span of the beam, d is depth of the beam and b is breadth of the beam.

The split tensile test was conducted on concrete cylinders using 2000 KN capacity Motorized compression machine at a loading rate of 4.42 KN/sec in accordance with BS EN 12390, Part 6(2000) specifications. The value of the load at failurewas used to calculate the split tensile strength using equation (2).

$$SplitTensileStrength, F_{ct} = \frac{2P}{\pi Ld} \quad \ldots (2)$$

Where: P is the Maximum load, L is the length of line of contact of the cylinder and d is the diameter of the cylinder.

Thedensity of the hardened concrete cylinders was determined in accordance with BS EN 12390, Part 7 (2000)specifications. The densities were calculated using equation (3).

$$Density, \rho = \frac{mass, m\ (kg)}{volume, v\ (m^3)} \quad \ldots (3)$$

The water absorption was determined on concrete cylinders. The test was carried out in accordance with BS 1881: Part 122 (1983) specifications. The water absorptions were calculated using equation (4).

$$WaterAbsorption = \frac{(massaftercuring - massbeforecuring)}{massbeforecuring} \times 100 \quad .. (4)$$

III. Results and Discussion

Table 1: Properties of concrete containing Scoria aggregate

Mix	Granite (%)	Scoria (%)	Water Absorption (%)	Density (Kg/m³)	Flexural Strength (N/mm^2)				Split Tensile Strength (N/mm^2)			
					3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
M-0	100	0	1.81	2432	3.18	4.36	4.57	5.06	2.07	2.29	2.30	2.35
M-10	90	10	2.45	2361	3.10	4.14	4.32	4.55	2.01	2.22	2.25	2.30
M-20	80	20	2.33	2331	2.76	4.05	4.18	4.33	1.80	1.98	2.15	2.28
M-30	70	30	2.53	2228	2.70	4.00	4.11	4.19	1.50	1.88	2.12	2.20
M-50	50	50	5.30	2087	2.09	3.63	3.91	4.17	1.27	1.87	2.07	2.15
M-80	20	80	5.70	1711	1.70	2.99	3.57	4.12	1.02	1.43	1.79	2.08
M-90	10	90	6.07	1615	1.01	2.13	2.74	3.81	0.81	1.00	1.22	1.48
M-100	0	100	7.01	1530	0.73	1.64	2.06	3.11	0.32	0.59	0.81	1.05

Flexural Strength

Fig. 1 shows the variation of the flexural strength with curing periods. The flexural strength increases with curing period and decreases with increase in scoria contents. Also, Fig 2 shows the relationship between flexural strength and scoria contents at 28 days curing period. The flexural strength decreased from 5.06 N/mm^2 at 0% to 3.11 N/mm^2 at 100% scoria contents at 28 days. The decrease in the strength may be attributed to low workability of the concrete due to scoria aggregate content(Lau et al., 2014). The optimum strength for mixes containing scoria was at 10% replacement with strength value of 4.55 N/mm^2 which agrees with the results of previous research(Kilic et al., 2009).

The regression equation for the relationship between the flexural strength and scoria contents is presented in equation (5). The coefficient of determination, R^2,is 0.766 and the coefficient of correlationbetween flexural strength and scoria content is – 0.8753. The R^2 value and coefficient of correlation indicate that there is a strong relationship between the flexural strength and scoria contents.

$$FlexuralStrength\,(N/mm^2) = -0.012 \times Scoriacontents\,(\%) + 4.780 \quad \ldots (5)$$

Split Tensile Strength

Fig. 3 is the plot of variation of split tensile strength with curing periods which shows that the split tensile strength increases with curing period as expected. The variation of split tensile strength with percentage replacement of granite aggregate with scoria at 28 days curing is presented in Fig. 4. The split tensile strength decreased with increase in scoria from 2.35 N/mm^2 at 0% to 1.05 N/mm^2 at 100% scoria content at 28 days. At 10% scoria content the strength of 2.30 N/mm^2 was obtained which is the maximum strength for the mixes containing scoria.

Equation (6) shows the regression equation for the relationship between split tensile strength and scoria contents. The R^2 is 0.7386 and the correlation between the split tensile strength and the percentage replacements of coarse aggregate with scoria is – 0.8585.

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$$\text{Split Tensile Strength}(N/mm^2) = -0.007 \times \text{Scoria content } (\%) + 2.3005 \quad \ldots \quad (6)$$

Density

The average density of 2584 Kg/m^3 was obtained for 0% replacement of coarse aggregate with scoria. The value is within the range of 2000 - 2600 Kg/m^3 specified by BS EN 206 part 1 (2000) for normal weight concrete. The density decreased with increase in percentage of scoria as shown in Fig. 5. At 100% replacement an average density of 1870.9 Kg/m^3 was obtained. The values are within the range of 800 - 2000 Kg/m^3 specified by BS EN 206 part 1 (2000) for lightweight concrete.

Water Absorption

The Water absorption increased with increase in coarse aggregate replacement with scoria as shown in Fig. 6. This can be attributed to the fact that water absorption of scoria is higher than that of granite aggregate. The optimum water absorption obtained was 10.20% at 100% replacement. The absence of a dense outer-shell in scoria aggregates and the higher initial absorption of light weight concrete specimens due to surface effects can partly contribute to the high water absorption (Gomes, 2015).The results obtained agreed with FIP manual of lightweight aggregate concrete (FIP,1983).

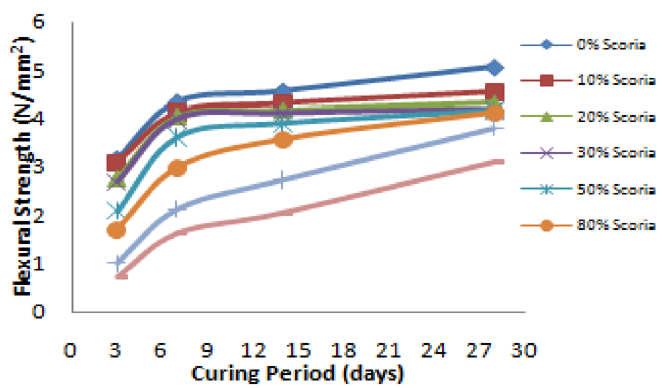

Figure 1: Variation of flexural strength with curing period

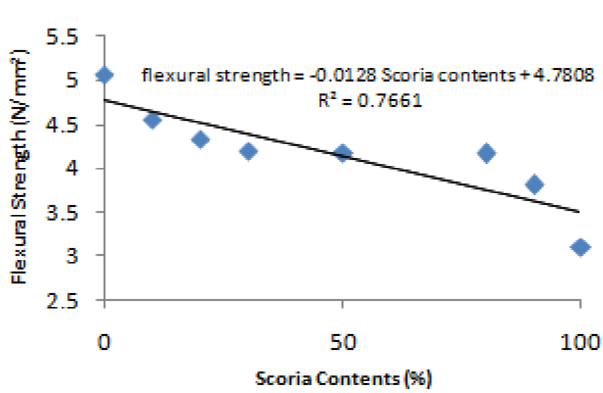

Figure 2: Variation of flexural strength with scoria content

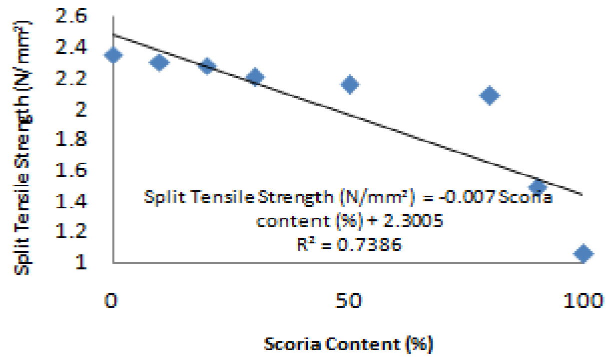

Figure 3: Variation of split tensile strength with curing period

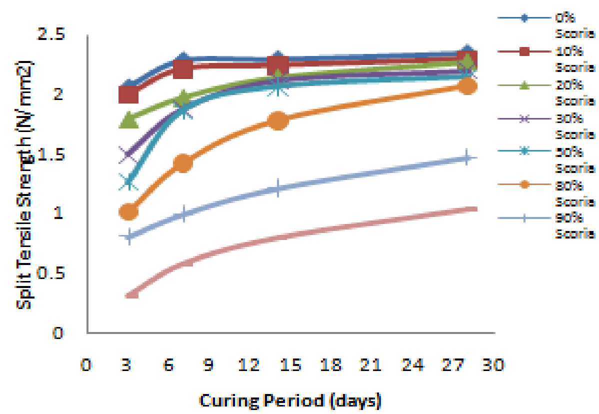

Figure 4: Variation of split tensile strength with scoria content

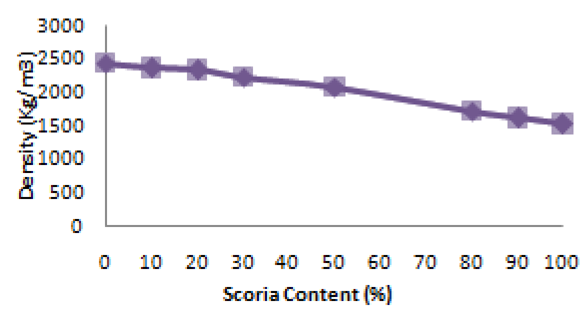

Figure 5: Variation of density with scoria content

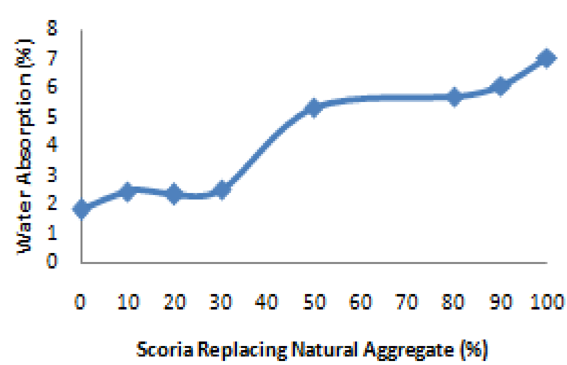

Figure 6: Variation of water absorption with scoria content

IV. Conclusions

This paper investigates the potential of scoria as a lightweight aggregate in concrete. The following conclusions are drawn from the study:

i. Scoria satisfied the requirements of lightweight aggregate for structural concrete as per ASTM C 330 (2004).
ii. To make scoria concrete with 10% to 100% scoria aggregate as replacement of coarse crushed granite aggregate by volume, a range of slump between 40 and 80 mm would provide satisfactory workability.
iii. The optimum flexural and split tensile strengths were obtained at 10% of coarse aggregate replacement with values of 4.55 N/mm^2 and 2.31 N/mm^2 respectively.
iv. Water absorption increased with increase in scoria as a replacement to coarse aggregate in concrete.

References

i. Lau, I, Setunge, S, &Gamage, N (2014). Properties of concrete using scoria lightweight aggregate concrete, in ST Smith (ed.),23rdAustralasian Conference on the Mechanics of Structures and Materials (ACMSM23), vol. I, Byron Bay, NSW, 9-12 December, SouthernCross University, Lismore, NSW. 95-100.

ii. Khandaker M. A. H. (2006). Blended cement and lightweight concrete using scoria: mix design, strength, durability and heat insulation characteristics. International Journal of Physical Sciences. 1(1), 005-010.

iii. ACI 213R-03, (2003).Guide for Structural Lightweight-Aggregate Concrete.American Concrete Institute Committee 213 Report.

iv. Bryan, D.P. (1987). Natural lightweight aggregates of the Southwest. In Proceedings of the 21st Forum on the Geologyof Industrial Minerals. Special Paper 4. Edited by H.W. Pierce.Tucson: Arizona Bureau of Geology and Mineral Technology. 55–63.

v. BS EN 12390 (2000). Testing hardened concrete - Part 2: Making and curing specimens for strength tests. British Standard Specification. London.

vi. BS EN 12350 (1999). Testing of Fresh Concrete-Part 2: Slump Test. British Standard Specification. London.

vii. BS EN 12390 (2000). Testing hardened concrete – Part 1: Shape, dimensions and other requirements for specimens and moulds. British Standard Specification. London.

viii. BS EN 12390 (2000). Testing hardened concrete - Part 5: Flexural strength of test specimens. British Standard Specification. London.

ix. BS EN 12390 (2000). Testing hardened concrete - Part 6: Tensile splitting strength of test specimens. British Standard Specification. London.

x. BS EN 12390 (2000). Testing hardened concrete - Part 7: Density of hardened concrete. British Standard Specification. London.

xi. BS 1881 (1983). Testing concrete - Part 122: Method for determination of water absorption. British Standard Specification. London.

xii. Kilic, A., Atis, C. D., Teyman, A., Karahan, O. & Ari, K. (2009). The effects of scoria and pumice aggregates on the strengths and unit weights of lightweight concrete. Scientific Research and Essay, 14, 961-965.

xiii. BS EN 206 (2000). Concrete – Part 1: Specification, performance, production and conformity. British Standard Specification. London.

xiv. Gomes, T. J. (2015). Structural Lightweight Concrete Produced with Volcanic Scoria from São Miguel Island. Instituto Superior Técnico.

xv. FIP (1983). FIP Manual of lightweight aggregate concrete, 2nd ed. London, Surrey University Press.

xvi. ASTMC330. (2004). Standard Specification for Lightweight Aggregates for Structural Concrete. American Society for Testing & Materials (ASTM),Philadelphia, USA.