EFFECTS OF MIX RATIOS ON THE CHARACTERISTICS OF RECYCLED IRON AND STEEL SLAG CONCRETE

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ABSTRACT

Suitability of Recycled Iron and Steel Slag (RISS) aggregate as alternative aggregate to granite was assessed from the effects of mix ratio on the characteristic of RISS concrete produced with different mix ratios for the study. The materials used for the study includes Recycled Iron and Steel Slag (RISS), Granite, Sharp sand, Ordinary Portland Cement (OPC) and Water. Mineral compositions of the aggregate (RISS and granite) were assessed using X-ray Diffraction (XRD); aggregate properties assessed include Aaggregate Crushing Value (ACV) and Aggregate Impact Value (AIV). Sieve analysis was implored for gradation of the aggregate. Control and treatment concrete cubes and beams were produced with mix ratios (MR) of 1:1½:3, 1:2:4 and 1:3:6 at water cement ratios of 0.65, 0.60 and 0.55; RISS replacement (RR) observed are 10, 20, 40 and 60%. Concrete for the study was batched, mixed, cast and finished with a steel trowel and cured at temperature of 27^0C $\pm$ 2^0C. The effects of MR on the Compressive Strength (CS) at 7 to 365 days and Flexural Strength (FS) at 28 days were evaluated. Data generated were analysed using Analysis of Variance (ANOVA) at 5% level of significance. XRD showed that both aggregate contains quartz (silicon oxide). The ACV and AIV for granite and RISS aggregates were (8.58 and 20.00) and (9.64 and 24.33) respectively. The sieve analysis showed a well graded RISS and granite aggregate with coefficient of concavity (Cc) and coefficient of curvature (Cu) of (1.33, 1.01 and 1.00) and (4.00, 4.61 and 4.35) for MAS of 37.5, 20 and 12 mm respectively. The CS at 365 days for MR: 1:1½:3, 1:2:4 and 1:3:6 for MAS: 37.5, 20.0 and 12.0 mm were (33.56 - 34.95 MPa), (20.82 - 25.73 MPa) and (18.77 - 23.95 MPa); (32.05 – 33.95 MPa), (20.65 – 25.48 MPa) and (18.53 – 23.55 MPa) and (31.86 – 33.68 MPa), (20.45 – 25.55 MPa) and (18.26 – 23.46 MPa) respectively. The FS at 28 days for MR: 1:1½:3, 1:2:4 and 1:3:6, are (0.225 – 0.245 MPa), (0.202 – 0.217 MPa), and (0.134 – 0.210 MPa); (0.232 – 0.250 MPa), (0.204 – 0.219 MPa) and (0.137 – 0.212 MPa); and (0.234 – 0.255 MPa), (0.205 – 0.219 MPa) and (0.174 – 0.215 MPa) for WCR: 0.65, 0.60, and 0.55 respectively. MR 1:1½:3, 1:2:4 and 1:3:6 differentiated concrete produced with RISS aggregate into their recommended usage in heavy reinforced concrete/precast concrete works, reinforced concrete and mass concrete works.

Keywords: Compressive strength, Flexural strength, Recycle iron and steel slag, Mix ratio and Concrete.

1.0 INTRODUCTION

Demand for granite aggregate have been on the increase in this twentieth century, reasons adduce for this was partly due to its increasing use in Building and Civil Engineering works and partly due to industrial and technological revolution.

Increase in demand for granite aggregate has led to depletion of available stock of granite rock which resulted into environmental degradation. Alternative aggregate to granite includes gravel, pumice, periwinkle shell, and palm kernel shell to mention but a few. These alternative aggregate has limitation to their usage ranges from voids in concrete, organic matter in the matrix of concrete and aggregate laden with silt and clay materials.

Many developed nations of the world have embraced the use of slag aggregate (known here as recycle iron and steel slag, RISS); postulating standard and specifications for usage such as BS EN 12620: 2002 for Air-cooled Blast Furnace Slag and JIS A5011-1:2013 for Slag Aggregate Concrete. The slag aggregate used by these developed nations are mainly waste from production of iron and steel products from iron-ore; unlike locally source RISS aggregate which are from recycle of waste metallic municipal waste (MMW) that litters ours cities and towns.

For RISS aggregate to be accepted locally as alternative aggregate to granite in concrete production, the need to know it performance characteristics and especially the behaviour of concrete produce with RISS aggregate under the same environmental conditions and variables such as water cement ratios (WCR), maximum aggregate sizes (MAS), % RISS replacement (%RR) must be ascertained. This will enable the researcher to know the degree of suitability of RISS aggregate in concrete production. This study is concern with effects of mix ratios (MR) on concrete produce with RISS aggregate.

2.0 EXPERIMENTAL PROCEDURE

2.1 MATERIALS

Materials used for the purpose of the study include recycle iron and steel slag (RISS) and granite (coarse aggregate), sharp sand (fine aggregate), Ordinary Portland Cement (cement) and water.

RISS aggregate was sourced from two inland rolling mills which are Major Engineering Company, Ikorodu referred to as RISS A and Selsa metal, Otta referred to as RISS B; and one mini mill which is Continental Iron and Steel Company, Ikeja referred to as RISS C. The RISS aggregate was crushed and sieved into three maximum aggregate sizes 37.5, 20 and 12 mm; One third of each RISS aggregate maximum aggregate sizes (MAS) was thoroughly mixed together and used for the study. Sharp sand for the study was obtained from Ogun River at Owode. Granite aggregate was obtained from Ratcon Limited quarry site along Lagos - Ibadan expressway, sieved into the three maximum aggregate sizes (MAS) for RISS aggregate. OPC for the study was of grade 43 complying with NIS 444-1: 2003 was used as the binding agent. The cement was sourced from Lafarge Cement Company, Ewekoro, Ogun State, Nigeria. Water for the study was obtained from the tap at the Construction Workshop, Nigeria Building and Road Research Institute (NBRRI), Otta, Ogun State. The water was free of dirt and impurities.

2.2 SPECIMEN PREPARATION

The specimens for XRD (granite and RISS) were finely ground and homogenized, average bulk compositions were determined. The powdered samples were prepared using the sample preparation block and compressed in the holder to create flat, smooth surfaces which were later mounted on the sample stage in the XRD cabinet. Specimens (RISS and granite) for ACV and AIV tests were dried, crushed and passed through 12.5 mm sieve and retained on 10 mm sieve. RISS A, B and C obtained for sieve analysis were stalked to dry and crushed; one third of each set were thoroughly mixed together. The materials for concrete were batched, mixed and cast into moulds containing reinforcing cage of four (4) numbers 12mm main bars and 8 mm links at 200 mm spacing.; the concrete specimens were de-moulded after 24 hours, cured at temperature of 27^0C $\pm$ 2^0C in curing tank until testing date for compressive strength and flexural strength tests. Three separate mix ratios 1:1½:3, 1:2:4 and 1:3:6 were batched with maximum aggregate sizes 37.5, 20 and 12 mm and percentage RISS replacement of 0, 10, 20, 40 and 60 were adopted. Total of 2430 and 405 concrete cubes and beams were cast.

2.3 X-RAY DIFFRACTION (XRD) ANALYSIS

Theta-theta setting of reflection-transmission spinner stage was implored to analyse the prepared powdered samples of RISS A, B, C and granite aggregate. Two-theta starting position was 4 degrees and ends at 75 degrees with a two-theta step of 0.026261at 8.67 seconds per step. Tension of 45VA was developed when a current of 40mA was passed into the tube. Gonio scan with a programmable divergent slit of 5 mm width mask was used to record continuously the intensity of the diffracted X-rays as the samples and the detector rotate through their respective angles. A peak in intensity occurs when the mineral contains lattice planes with d-spacing appropriate to diffract X-rays at that value of θ; each peak consists of two separate reflections ($K\alpha_1$ and $K\alpha_2$), at small values of 2θ the peak locations overlap with $K\alpha_2$ appearing as a hump on the side of $K\alpha_1$. Greater separation occurs at higher values of θ. Typically these combined peaks are treated as one. The 2λ position of the diffraction peak was typically measured as the centre of the peak at 80% peak height.

The d-spacing of each peak was then obtained by solution of the Bragg equation for the appropriate value of λ. Once all d-spacing have been determined, automated search/match routines compare the *d*s of the unknown to those of known materials. Because each mineral has a unique set of d-spacing, matching these d-spacing provides an identification of the unknown sample.

2.4 AGGREGATE CRUSHING VALUE (ACV) TEST

The ACV test was carried out as prescribed by BS EN 1097-2: 1998; the prepared samples of RISS and granite aggregate were filled in cylindrical moulds measure 11.5 cm in diameter and 18 cm high in three layers, each layer was tampered with a standard rod 25 times. The test samples were weighed (W_1) and place in the test cylinders (15.2 cm diameter). The specimens were subjected to compressive load of 40 tonnes (400 kN) gradually applied in 10 minutes. The materials passing through 2.36 mm sieve were separated and weighed (W_2). The weight of these materials (fines), expressed as a percentage of the weight of the total sample (W_1), gives the aggregate crushing value (ACV).

2.5 AGGREGATE IMPACT VALUE (AIV) TEST

The AIV test was carried out as prescribed by BS 812-112: 1990 and BS EN 1097 – 2: 1998; the prepared samples (RISS and granite aggregate) were filled into cylindrical moulds, 10.2 cm internal diameter and 5 cm height in three layers, each layer being given 25 strokes with a rod. The impact was provided by dropping a hammer of weight 14.0 kg through a height of 380 mm. The samples were transferred to the cups of aggregate impact testing machine and were tapped 25 times with the rod. The crushed aggregate were sieved on 2.36 mm sieve, the weight (W_1) of materials passing through 2.36 mm sieve expressed as a percentage of the total weight (W_2) of the sample gives the aggregate impact value. Aggregate Impact value is expressed as the ratio of weight of materials passing through 2.36 mm (W_1) to the total weight (W_2) of the samples.

2.6 SIEVE ANALYSIS (GRADATION)

In coarse aggregate analysis a predetermine quantity (weight) of prepared samples (RISS and granite) aggregate was put on top of set of 50, 37.5, 28, 20, 14, 12, 10, 6.3 and 2.36 mm British Standard (BS) sieves placed one over the other in the order of their aperture, the largest aperture sieve was placed at the top and the smallest aperture sieve at the bottom. A receiver was placed at the bottom, and a cover at the top of the whole assembly, the whole assembly was fitted on a sieve shaking machine. Shaking was done for 10 minutes; the portion of the sample that was retained on each sieve was weighed. The percentage of sample retained on each sieve was calculated on the basis of total weight of sample, and from these results, percentage passing through each sieve was calculated.

2.7 COMPRESSIVE STRENGTH TEST

The test was carried out as prescribe by BS 1881: Part 116, 1983. The prepared concrete cube (150 mm × 150 mm × 150 mm) samples was wiped clean of grit, allowed to dry for 1 hour and placed centrally in the compressive testing machine that tests cube specimens in accordance with BS 1881:

Part 115, 1983 and load to destruction, the highest load reached was recorded. The compressive strength was measured to the nearest 0.5 N/mm^2. The report state: identification mark, nominal size, date of test, age of specimen, compressive strength, curing conditions and any unusual appearance of fracture. Compressive strength test was conducted at 7, 14, 28, 90, 180 and 365 days, a total of 2430 concrete cubes were tested for compressive strength.

2.8 FLEXURAL STRENGTH TEST

Flexural strength test was carried out as prescribe by BS 1881: Part 118, 1983b, the machine used conforms to (BS 1881: Part 188, 1983. The third point loading of the machine was set-up, the specimen (100 mm × 150 mm × 450 mm) concrete beam was put in place; the actuator gradually released the load steadily and without shock at 0.06 ± 0.04 N/ (mm^2 s). The rate of loading was maintained without change until failures occur. The result was read off from the analogue screen and tabulated. The flexural strength was calculated as shown in equation 1, 405 concrete beams were tested for flexural strength.

$$F_{cf} = \frac{F \times L}{d_1 \times d_2^2} \qquad 1$$

3.0 RESULTS AND DISCUSSION

3.1 X-RAY DIFFRACTION (XRD)

The result of XRD for RISS aggregate was presented in Figure 1; it was observed from the graph that RISS aggregate contains Magnetite, Ilmenite and Quartz as the predominant minerals with chemical formula $Fe{+}{+}Fe{+}{+}{+}2O_4$, $Fe{+}{+}TiO_3$ and SiO_2 respectively. This revealed that RISS aggregate contained ferrous materials with silicon oxide, having passed through blast furnace the RISS aggregate became lighter in nature. Quartz was detected at 28˚ theta with 3800 counts while magnetite Ilmenite was detected at 35˚ theta with 4000 counts. Smeared peak with many short orders and dumps was also observed suggesting that the RISS aggregate was mainly in amorphous phase with traces of crystalline structures which resulted from the rapid cooling method adopted when the slag emerges from the blast furnace.

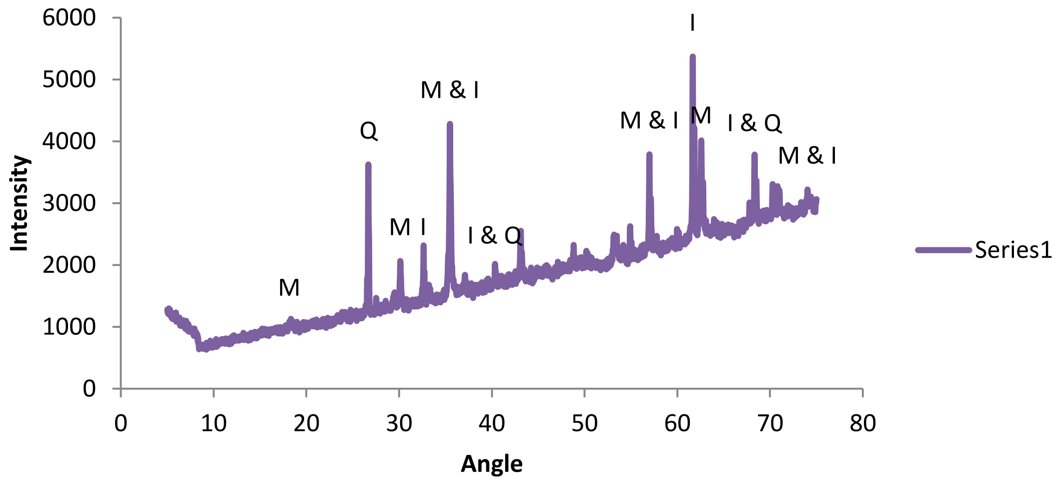

Figure 1: XRD plot of RISS aggregate

Figure 2 showed the XRD for granite aggregate, it was observed from the graph that granite aggregate contains quartz, annite, microcline and albite as the predominant minerals. Annite are phyllosilicate mineral found in Mica family which are rich in silicon oxide and iron II oxide, with chemical formula $KFe_3^{2+}AlSiO_3O_{10}\ (OH)_2$, Microcline chemical formula is

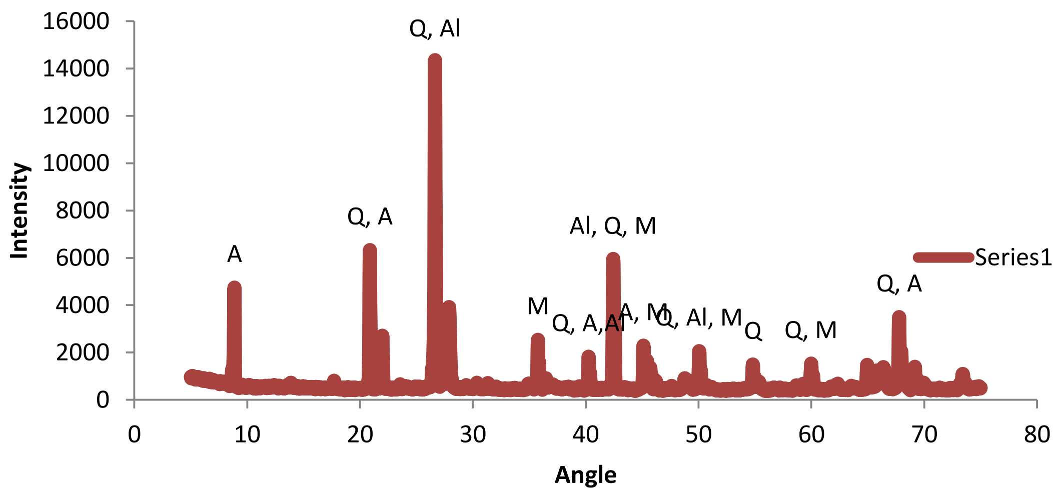

Figure 2: XRD plot of granite aggregate

$KAlSi_3O_8$, it is rock forming tectosilicate mineral and potassium-rich alkali feldspar with minor amount of sodium. Albite is a plagioclase feldspar mineral rich in silicon oxide, sodium and aluminium oxides. The graph further revealed that quartz albite was detected at 27˚ theta with the highest counts of 15000 followed by Quartz Annite detected at 21˚ theta with counts of 7500, Microcline Albite detected at 28˚ theta with counts of 5000 and Quartz Microcline Albite detected at 42.5˚ theta with counts of 5000. Also observed from the graph was peaks with short order and bumps; there were irregular base line with pulse shape that confirms amorphous phase with traces of crystalline structure. The presence of silicon oxide known as quart was observed from both figures 1 and 2, this attested to the similarity observed in the chemical property of the two aggregate.

3.2 AGGREGATE CRUSHING VALUE (ACV)

Table 1 showed that the values of ACV for RISS and granite aggregate are 9.64 and 8.58, respectively. These values are less than 10 as specified by BS 812 Part 110: 1990; BS EN 1097-6: 2000. Hence, both aggregate are classified as exceptionally strong and can withstand crushing force under load. These two aggregates are durable and can be used as aggregate in concrete production. Omopariola and Jimoh (2018) had 6.2 and 9.45 for the value of ACV which confirms the results of the study.

3.3 AGGREGATE IMPACT VALUE (AIV)

The result of AIV conducted on the RISS and granite aggregate is as presented in Table 2. The AIV for both aggregate are 23.33 and 20 respectively; the result indicated that both aggregate can be used for heavy duty concrete flooring, concrete pavement floor and any other concrete works as specified in BS 812 Part 109: 1990. The AIV obtained by Pajgade and Thakur (2013) and Subathra and Gnanavel (2014) are 23.21 and 4.3, and 25.26 and 9.03; which confirms the result of the study.

3.4 SIEVE ANALYSIS

Figures 3 and 4 shows the graphs of sieve analysis conducted on RISS and granite aggregate; from the figures the coefficient of uniformity, C_U are (4.00, 4.61 and 4.35) and (4.64, 3.85 and 4.00) and coefficient of curvature, C_C are (1.33, 1.01 and 1.00) and (1.76, 1.16 and 1.01) for maximum aggregate sizes of 37.5, 20 and 12 mm respectively; these values were greater or equal to 4.00 for C_U and less than 3 for C_C as specified by BS EN 12620 which depict well graded, strong and dense aggregate. Deduction from Figure 5 showed that the C_U for sharp sand was 13.3 which is within limit specified by BS EN 12620, this implies that the sharp sand used for the study was well graded aggregate.

3.5 EFFECTS OF MIX RATIOS ON THE COMPRESSIVE STRENGTH OF CONCRETE

The effects of mix ratios 1:1½:3, 1:2:4 and 1:3:6 on the compressive strength of concrete for MAS of 37.5, 20 and 12 mm is presented in Figure 6. Figure 6a, b and c showed the results of the compressive strength values for MAS 37.5, 20 and 12 mm which ranges between (33.56 – 34.95 MPa), (20.82 – 25.73 MPa) and (18.77 – 23.95 MPa); (32.05 – 33.95 MPa), (20.65 – 25.48 MPa) and (18.53 – 23.55 MPa); (31.86 – 33.68 MPa), (20.45 – 25.55 MPa) and (18.26 – 23.46 MPa) respectively. Deductions from analysis of variance (ANOVA) of the effects of mix ratios on the compressive strength of concrete shown in Table 3 shows that values of compressive strength obtained for mix ratio 1:1½:3 are significantly higher than the compressive strength values obtained for mix ratio 1:2:4 and the values of compressive strength obtained for mix ratio 1:2:4 are significantly higher than that obtained for mix ratio 1:3:6; this differentiate the concrete produced with RISS and granite aggregate into their respective recommended usage as specified by BS 812 – 2: 1995 into heavy reinforced concrete/precast concrete works, reinforced concrete and mass concrete. Similar studies by Aginam, *et al.* (2013) and Hamid and Ramin (2018) concluded that the compressive strength of concrete produced with four different mix design methods is different. Umar *et al.* (2019) observed that the compressive strength for mix ratios 1:2:4 and 1:1.5:3 at 28 day are 18.55 and 25.03 N/mm^2 and 25.77 and 26.51 N/mm^2 for coarse aggregate size of 20 and 25 mm respectively which confirm the finding of this study that the higher the mix ratio the higher the compressive strength of concrete.

3.6 EFFECTS OF MIX RATIOS ON THE FLEXURAL STRENGTH OF CONCRETE

The effects of mix ratios 1:1½:3, 1:24 and 1:3:6 on the flexural strength of concrete beams at 28 day's curing is presented in Figure 7. The values of flexural strengths for the treatments concrete beams with mix ratios 1:1½:3, 1:24 and 1:3:6 and water cement ratio 0.65 ranges between (0.229 - 0.245 MPa), (0.210 – 0.217 MPa) and (0.152 – 0.210 MPa) respectively these values are greater than the values obtained for the flexural strengths for control concrete beams of 0.225 MPa, 0.202 MPa, and 0.134 MPa respectively. Similar trends were observed in the values of flexural strengths in the mix ratios 1:1½:3, 1:24 and 1:3:6 for other water cement ratios of 0.60 and 0.55. It was also observed that the values of flexural strength in mix ratio 1:1½:3 are greater than the values of flexural strength in mix ratio 1:2:4 which were also greater than the values obtained for mix ratio 1:3:6. Deductions from these observations was that treatment concrete beams has greater flexural strength than the control concrete beams which increases as the percentage replacement of RISS aggregate increases; and increases from mix ratio 1:3:6 to 1:2:4 and 1:1½:3. The higher flexural strength observed in treatment concrete beams were attributed to the presence of RISS aggregate which increases as the percentage RISS increases. The implication of this finding was that concrete works that require higher flexural strengths can be produce with inclusion of RISS aggregate.

Mtallib and Marke (2010) concluded that for 1:2:4 and 1:3:6 nominal mix ratios, at 0.56 WCR the flexural strength is 2.24, 2.40 and 2.50 N/mm^2 and 2.41, 2.69 and 3.03 N/mm^2 respectively, these values confirm the findings of this study that the higher the mix ratio the higher the flexural strength of concrete.

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Table 1: Aggregate crushing value for RISS and granite aggregate

PARAMETER	**RISS AGGREGATE**									**GRANITE AGGREGATE**		
	RISS A			RISS B			RISS C					
	1ST Trial	2ND Trial	3RD Trial	1ST Trial	2ND Trial	3RD Trial	1ST Trial	2ND Trial	3RD Trial	1ST Trial	2ND Trial	3RD Trial
W_1(Kg)	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
W_2(Kg)	0.30	0.31	0.32	0.33	0.32	0.30	0.31	0.32	0.31	0.28	0.27	0.29
ACV	9.23	9.54	9.85	10.15	9.85	9.23	9.54	9.85	9.54	8.50	8.31	8.92
Av. ACV		9.54			9.74			9.64			8.58	
Av. ACV (A, B & C)						9.64						

Where:

W_1 = Total weight of aggregate

W_2 = Weight of aggregate passing 2.36 sieve size; ACV = Aggregate crushing value; Av. $ACV = \frac{W_2}{W_1} \times 100$; Av. ACV (A, B & C) = Average Aggregate value (A, B & C)

Table 2: Aggregate impact value (A.I.V) for RISS and granite aggregates

PARAMETER	RISS AGGREGATE									GRANITE		
	RISS A			RISS B			RISS C					
	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3st Trial	1st Trial	2nd Trial	3rd Trial	1st Trial	2nd Trial	3rd Trial
M_1	235	232	235	234	235	236	235	234	232	234	235	233
M_2	54	56	62	52	61	59	54	52	60	47	47	49
AIV	23	24	26	22	26.0	25	23	22	26	20	20	21
Av. AIV		25			24			24			20	
Av. AIV (A, B & C)					24.33							

Where:

M_1 = Oven dried Sample (g)

M_2 = Oven dried Sample Passing 2.36mm Sieve

Aggregate Impact Value (AIV) = $\frac{M_2}{M_1} \times 100$

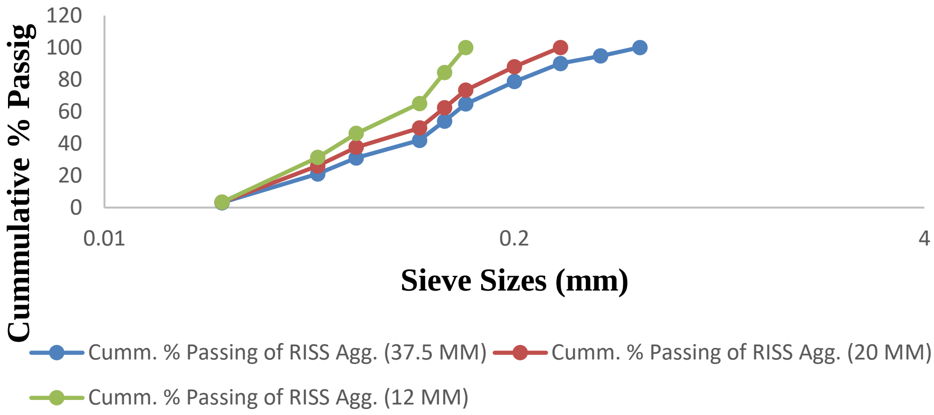


Figure 3: Particle size distribution graph of RISS aggregate for 37.5, 20.0, and 12.0 mm MAS.

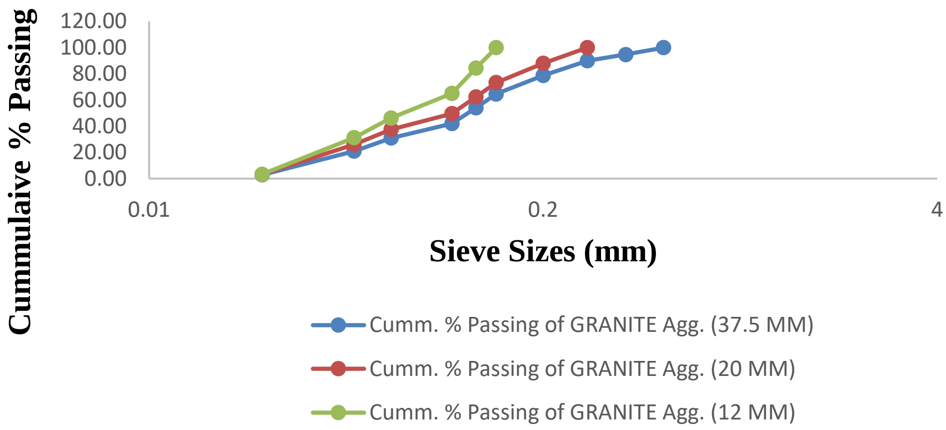


Figure 4: Particle size distribution graph of granite aggregate for 37.5, 20.0, and 12.0 mm MAS.

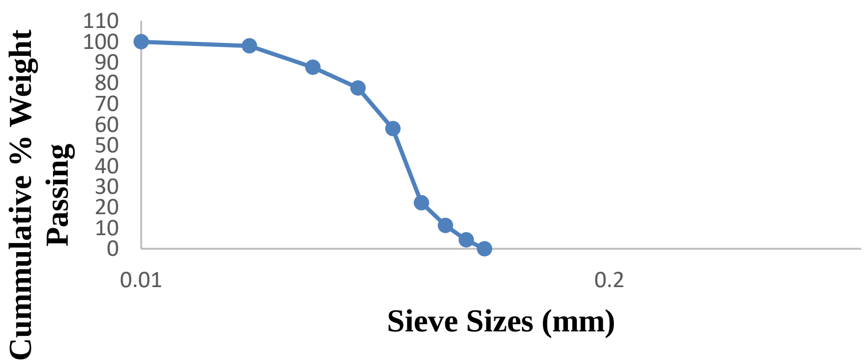
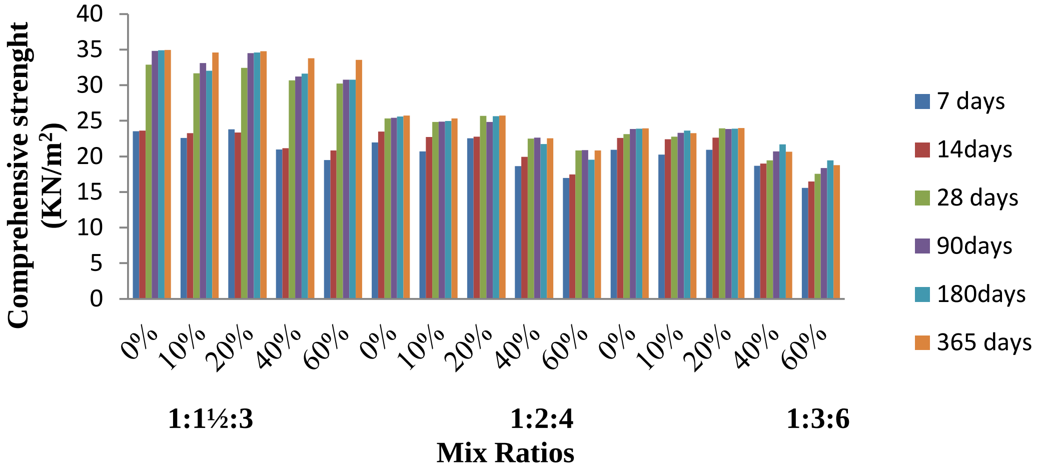
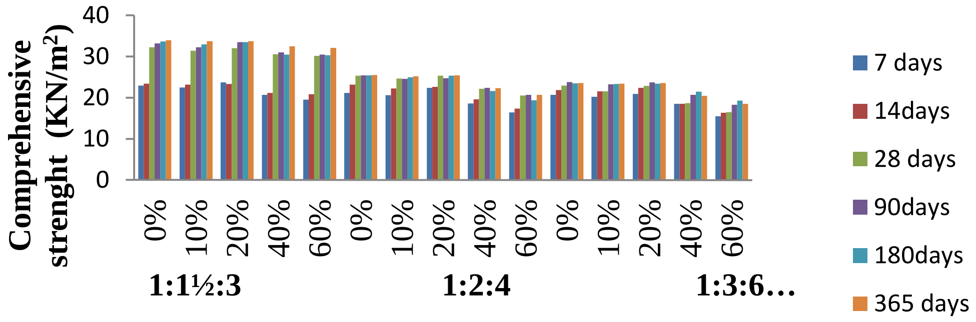


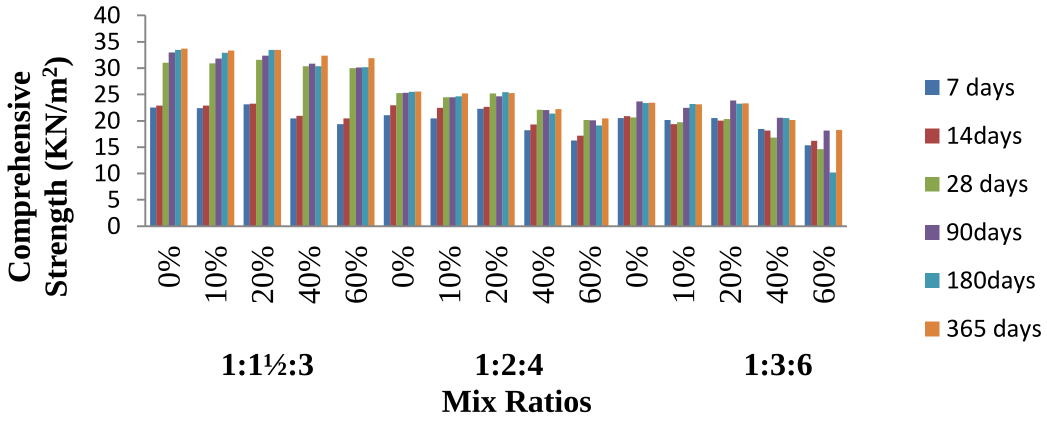
Figure 5: Particle size distribution graph for sharp sand



a. MAS 37.5 mm



b. MAS 20 mm



c. MAS 12 mm

Figure 6: Effect of mix ratios 1:1½:3, 1:2:4 and 1:3:6 on the compressive strength of concrete.

Table 3: Statistical Analysis of the Effect of Mix Ratios (1:1½:3, 1:2:4 & 1:3:6) on the Compressive Strength of Concrete.

(a) MR: 1:1½:3

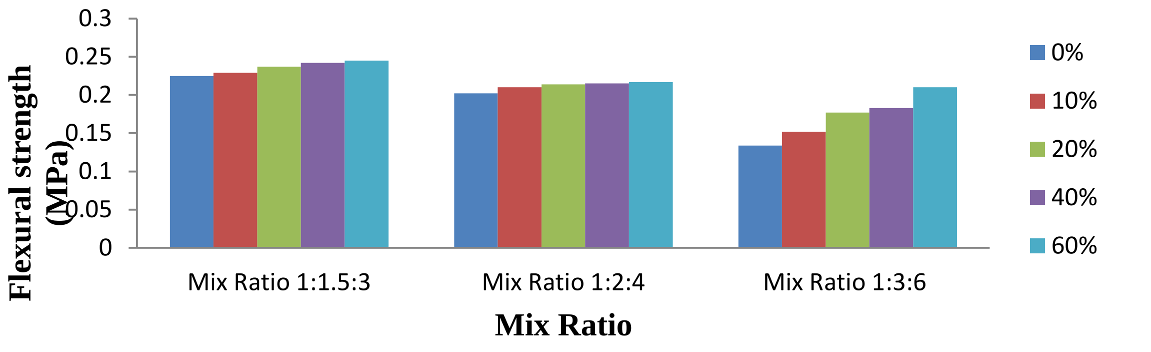
ANOVA	F-test	P-value	Remark
Analysis of Variance for A (0%)	1.01	0.453	Significant
Analysis of Variance for B (10%)	1.21	0.326	Significant
Analysis of Variance for C (20%)	1.04	0.437	Significant
Analysis of Variance for D(40%)	0.89	0.517	Significant
Analysis of Variance for E (60%)	0.79	0.577	Significant

(b) MR: 1:2:4

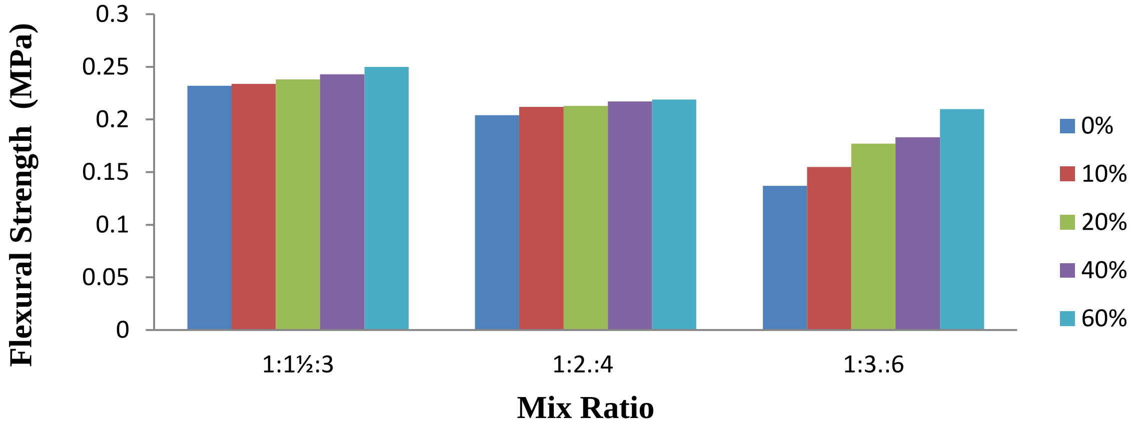
ANOVA	F-test	P-value	Remark
Analysis of Variance for A (0%)	1.20	0.367	Significant
Analysis of Variance for B (10%)	1.20	0.364	Significant
Analysis of Variance for C (20%)	0.97	0.475	Significant
Analysis of Variance for D(40%)	0.81	0.515	Significant
Analysis of Variance for E (60%)	0.75	0.601	Significant

(c) MR: 1:3:6

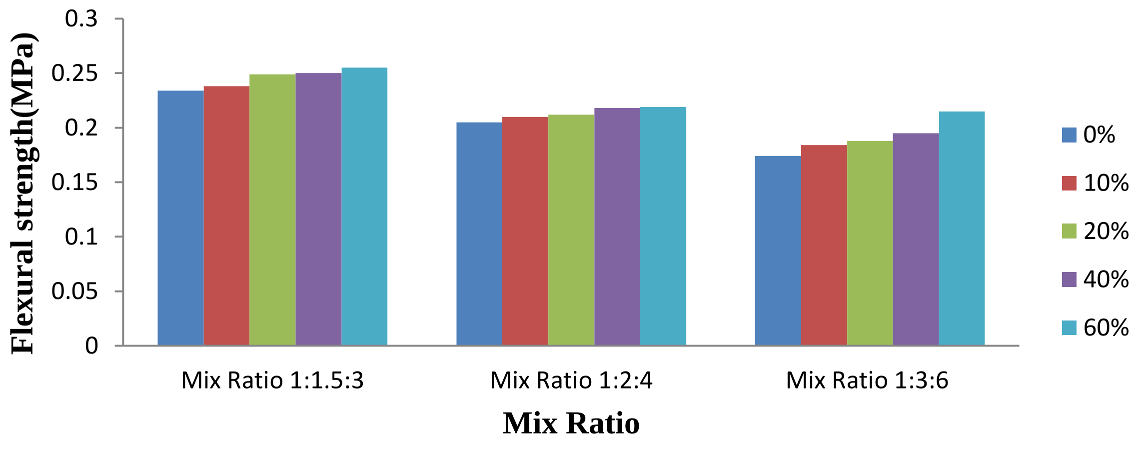
ANOVA	F-test	P-value	Remark
Analysis of Variance for A (0%)	1.25	0.347	Significant
Analysis of Variance for B (10%)	1.15	0.388	Significant
Analysis of Variance for C (20%)	1.04	0.439	Significant
Analysis of Variance for D(40%)	0.79	0.574	Significant
Analysis of Variance for E (60%)	0.48	0.788	Significant



a. WCR of 0.65



b. WCR of 0.60



c. WCR of 0.55

Figure 7: Effect of mix ratios 1:1½:3, 1:2:4 and 1:3:6 on the flexural strength of concrete.

4.0 CONCLUSION

From the findings of the tests conducted, the following conclusions are drawn:

1. Both aggregate (RISS and granite) contains silicon oxide (quartz) as the common mineral that makes both aggregate to be relatively non reactive which also makes RISS aggregate a suitable alternative to granite aggregate in concrete production.
2. Aggregate crushing value test conducted on the aggregate (RISS and granite) classified both aggregate as exceptionally strong which can withstand crushing force.
3. Aggregate impact value test conducted on both aggregate (RISS and granite) indicated that both aggregate can be used for heavy duty concrete flooring, concrete pavement floor and any other concrete works.
4. The sieve analysis depicted well graded, strong and dense aggregate for RISS and granite aggregate which can be use to produce strong, durable and dense concrete.
5. Compressive strength test conducted on concrete cubes produced with RISS and granite aggregate differentiated the concrete into their respective recommended usage into heavy reinforced concrete/precast concrete works, reinforced concrete and mass concrete.
6. Flexural strength test conducted on the concrete beams produced showed that mix ratio 1:1½:3 has the greater values of flexural strength which was followed by mix ratio 1:2:4 and lastly by 1:3:6 mix ratio; it was also concluded that concrete produced with RISS aggregate (treatment beams) has higher flexural strength than concrete produce with granite aggregate referred to as control beams.

7.0 IMPLICATIONS OF THE STUDY

RISS aggregate in concrete works can be used to differentiate concrete into their recommended usage based on the mix ratios adopted; flexural strength increases along with the mix ratios, mix ratio 1:1½:3 has greater flexural strength than 1:2:4 mix ratio which also has greater flexural strength than mix ratio 1:3:6.

8.0 DECLARATION OF COMPETING INTREST

The authors declare that their is no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

9.0 RECOMMENDATIONS

Based on the investigation of the effects of mix ratios on the strengths of concrete produce with RISS aggregate the following recommendations are made:

i. Concrete can be produce with RISS aggregate using different mix ratios for different civil engineering works

ii. Concrete produce with RISS aggregate can be used where high flexural strength is required such as in concrete payment.

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