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COMPARATIVE STUDY OF IKIRUN AND OSOGBO SLAG ON CONCRETE GRADE 20

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ABSTRACT

This study examined the use of Prism Steel Slag (PSS) and Machine Iron Slag (MIS) as partial replacement of coarse aggregate in concrete. Coarse aggregates were partially replaced with PSS and MIS at 0%, 10%, 20%, 30%, 40% and 50% respectively. A total of 132 concrete cubes of sizes 150 mm x 150 mm x 150 mm were cast and cured in water for 7, 14, 21 and 28 days respectively. Mix ratio of 1:2:4 was adopted with w/c ratio of 0.45 and batching was done by weight. The slump result indicated that the fresh concrete becomes stiff as the percentages of PSS and MIS increases. However, the compressive strengths of concrete cubes increased as the curing ages increases. 50% PSS and 40% MIS can successfully be used as partial replacement of coarse aggregate in the production of concrete grade 20.

Keywords: *Concrete, Coarse Aggregate, Strength, Machine Iron Slag, Prism Steel Slag*

1. INTRODUCTION

Concrete is the most commonly used construction material in the world [1]. It comprises of cementitious materials (cement or pozzolans), water, aggregate (fine and coarse aggregate) and probably admixtures. Saravanan and Suganya [2] reported that aggregates (fine and coarse) account for 75% of concrete volume and play a significant role in properties of concrete. There is focus on the utilization of alternate aggregate materials and significant research has been made on the use of several materials as substitute for conventional aggregates in concrete.

The demand for conventional aggregates (fine and coarse) is on the increasing side leading to an increase in the cost of concrete production. Therefore, there is need for the utilization of this by-product (slag) in concrete production in Nigeria as cost of natural aggregates (fine and coarse aggregate) is becoming higher. Thus, waste materials such as coconut shell, palm kernel shell, iron slag and steel slag aggregate as alternatives in concrete production will address environmental pollution and lead to sustainable construction.

Slag is an industrial by-product generated from pig iron and in steel production. Primarily, slag consists of magnesium, manganese, calcium and aluminium silicates in various combinations. The cooling process of slag is the main reason for generation of different types of slag's required for various purposes [3].

In Nigeria and many countries of the world, steel is mainly produced from melting of metal scrap and hundreds of tonnes of slag are produced yearly. Most often, slags are dumped around the steel producing company and not much research has been reported on the utilization of steel slag for concrete production in Nigeria [4].

Utilization of slag (iron or steel) is economical because the costs of steel slag are just about 50% of that of normal aggregates [5]. According to Abrol, *et al.* [6], steel slag has longer life span and it is more durable than natural aggregates, and when used in asphalt layer, steel slag offers a better non-skid-able pavement surface. In a study by Kothai and Malathy

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[7], utilization of slag promotes the conservation of natural resources. However, Palod, *et al.* [8] reported that steel slag possesses high mineralogical composition and has higher density than other binders.

Raza, *et al.* [9] investigated the strength analysis of concrete by using iron slag as a partial replacement for coarse aggregate in concrete. The study revealed that 30% replacement of coarse aggregate with iron slag aggregate gives optimum compressive strength. A study by Thangaselvi [10] shows that compressive strength of concrete increased up to 60% replacement of coarse aggregate with steel slag but decreased at 80% replacement. Nonetheless, Qurishee *et al.* [11] researched on the use of slag as coarse aggregate and its effect on mechanical properties of concrete. It was reported that compressive strength of concrete made by replacing coarse aggregate with slag is higher than normal concrete.

Anifowose *et al.* [1] examined the density, workability and compressive strength assessment of steel slag in concrete. The study revealed that concrete produced with slag possesses higher compressive strength than the control mix.

This study focused on comparing the compressive strengths of grade 20 N/mm^2 concrete produced with steel slags from Prism Steel Mills Ltd, Ikirun, Nigeria and iron slags from Nigeria Machine Tools, Osogbo, Nigeria using water to cement ratio of 0.45.

2. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland cement (OPC), Dangote cement brands of 42.5R which conforms to NIS 444-1 [12] and water that meets specification of NIS 554 [13] was used for production of concrete specimens. The aggregates used were natural sand (fine aggregate) that passes through sieve 5 mm and crushed stone (granite) of maximum size 19 mm both of which conforms to BS 882 [14].

The slags (iron and steel) used in this research were collected from Nigeria Machine Tools Ltd and Prism Steel Mills Ltd along Osogbo – Ikirun Road, State of Osun, respectively. The slags were crushed into smaller sizes manually and allows passing through BS sieve size 25 mm and retained on sieve size 5 mm. Slag from Prism Steel Mills Ltd was denoted as PSS (Prism Steel Slag) while that of Nigeria Machine Tools was denoted as MIS (Machine Iron Slag).

2.2 Methods

This research focussed on using iron slag and steel slag as partial replacements of coarse aggregate in concrete grade 20. The replacement levels of crushed stone (granite) with PSS and MIS were 0%, 10%, 20%, 30%, 40% and 50% respectively. A total of 132 concrete cubes (12 cubes for control mix, 60 cubes for PSS concrete and 60 cubes for MIS concrete) of sizes 150 mm x 150 mm x 150 mm (12 cubes for each percentage replacements) were cast and cured in water for 7, 14, 21 and 28 days respectively. A mix ratio of 1:2:4 was adopted and batching was done by weight with water-cement ratio of 0.45 (this is higher than the minimum quantity of 0.35 specified by BS 8500:1 [15]) and cement content of 340 kg/m^3. Aggregate impact value (AIV) and Los Angeles Abrasion Value (LAAV) were determined on coarse aggregate, PSS and MIS while specific gravity and fineness modulus were determined on fine aggregate, coarse aggregate, PSS and MIS respectively. Slump tests were carried out to determine the workability of fresh concrete used.

At the end of each curing ages, the densities of the cubes were determined, and the cubes were crushed using a compression testing machine of 2000 kN capacity at Soil and Concrete Laboratory, Federal Polytechnic Offa, Nigeria.

3. RESULTS AND DISCUSSION

3.1 Aggregate Impact Value and Los Angeles Abrasion Test

Aggregate impact value (AIV) gives a measure of the resistance of an aggregate to an unexpected shock or impact [16]. While Los Angeles Abrasion Value (LAAV) is the resistance to degradation of aggregates using the Los Angeles testing machine [17]. The AIV and LAAV of the aggregates (coarse aggregate, PSS and MIS) used are presented in Table 1 and the tests were done in accordance with BS 812-112 [16] and ASTM C131/C131M [17].

Table 1: AIV and LAAV of Aggregates

Sample	AIV	LAAV
Coarse Aggregate	11.8%	26%
PSS	6.4%	15%
MIS	16.8%	21.2%

The AIV and LAAV results meet the requirement of 30% maximum value specified by BS 812-112 [16] and ASTM C131/C131M [17] respectively for aggregate to be used in concrete. However, BS 812-112 [16] reported that if AIV of an aggregate is above 30%, the result should be treated with caution.

3.1 Specific Gravity Test

The specific gravity of the aggregates (fine aggregate and coarse aggregate, PSS and MIS) was conducted in accordance with BS 1377-2 [18] and ACI Education Bulletin [19]. The results obtained are presented in Table 2.

Table 2: Specific Gravity of Aggregates used

Test Samples	Specific Gravity
Fine Aggregate	2.53
Coarse Aggregate	2.60
PSS	2.69
MIS	2.64

The range of specific gravity of aggregates as specified by ACI Education Bulletin [19] ranges from 2.30 to 2.90. The results of specific gravity of the fine aggregate, coarse aggregate, PSS and MIS in Table 2 are within the acceptable limits for aggregates.

3.2 Fineness Modulus

The fineness modulus (FM) was conducted in accordance with BS 812-103.1 [20]. From the particle size distribution test, the following fineness modulus as shown in Table 3 was obtained.

Table 3: Fineness Modulus of Aggregates used

Test Samples	Fineness modulus
Fine Aggregate	2.7
Coarse Aggregate	5.2
PSS	5.9
MIS	6.1

ACI Education Bulletin [19], reported that fineness modulus is most commonly computed for fine aggregates, and the value of FM generally ranges from 2.3 to 3.1. Hence, the fineness modulus of coarse aggregate is required for some proportioning methods. The result of fineness modulus in Table 3 falls within the acceptable limits for fine aggregates.

3.3 Slump Test

Slump test was carried out to determine the workability of fresh concrete and the test was done in accordance with ASTM C192/C192M [21]. Table 4 shows the slump test results for the PSS concrete and MIS concrete.

Table 4: Slump Test Results of PSS and MIS Concrete

Fresh Concrete Properties	Slag	Percentage Replacement					
		0%	10%	20%	30%	40%	50%
Slump (mm)	PSS	45	50	45	42	40	37
	MIS	45	43	40	39	38	35

True slump was exhibited by the concrete and the slump height values (Table 4) reduce as the percentage of coarse aggregate replacement with PSS and MIS increases. This is an indication that the fresh concrete becomes stiff as the percentages of PSS and MIS increases.

3.4 Density Test

The mean densities of concrete cubes made with different replacement level of slag for ages 7, 14, 21 and 28 days curing (hydration period) respectively are given in Figure 1 and Figure 2. The density test conforms to BS EN 12390-7 [22].

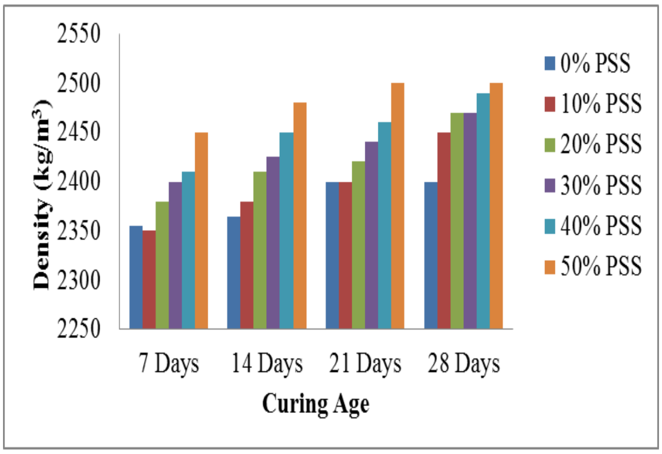

Figure 1: Density against PSS Concrete Cubes

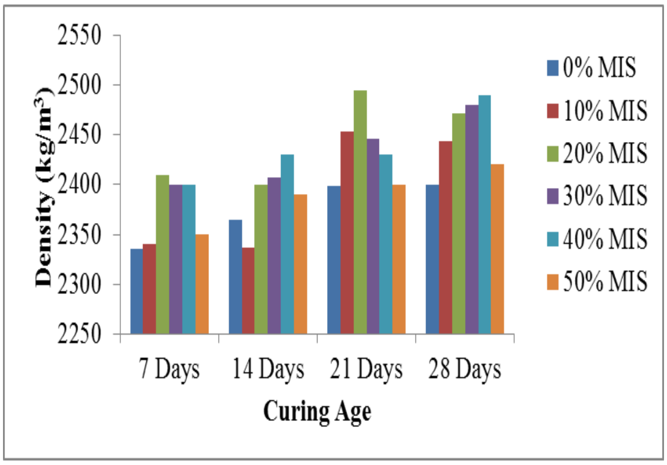

Figure 2: Density against MIS Concrete Cubes

All concrete cubes produced falls within the range of 2000 kg/m^3 to 2600 kg/m^3 specified by BS EN 206-1 [23] for normal concrete.

3.5 Compressive Strength Test

The compressive strength test on the PSS and MIS concrete cubes respectively was done in accordance with BS EN 12390-3 [24]. Figure 3 and Figure 4 shows the compressive strength results of the concrete cubes.

The compressive strength results show that the control mix (0%) is lesser than concrete with 10%, 20%, 30%, 40% and 50% replacement of crushed stone (granite) with PSS and MIS respectively. The 7 days compressive strength results of 0% is lower than the minimum required compressive strength of 13.5 N/mm^2 for concrete grade 20 as specified by BS 8110-2 [25] while the strength of 10%, 20%, 30%, 40% and 50% of crushed stone with PSS and MIS respectively met the minimum required compressive strength of 13.5 N/mm^2 for grade 20 concrete. At 28 days, the strength of 10%, 20%, 30%, 40% and 50% of crushed stone with PSS and MIS respectively was above the specified value of 20 N/mm^2 for grade 20 concrete specified by BS 8110-2 [25]. However, it was observed that the compressive strength of PSS concrete increases with respect to curing age as the percentage increases from 0% to 50% while the compressive strength of MIS concrete decreased at 50% replacement. The mean compressive strengths and standard deviations are presented in Table 5 while the T-statistic value, degree of freedom, P-value and the mean difference are presented in Table 6.

From Table 6, the P-values are all less than the significance value. It can be concluded that the average compressive strengths are significantly different from characteristics strength of 20 N/mm^2 at the different percentages of replacement on the 28th day of curing.

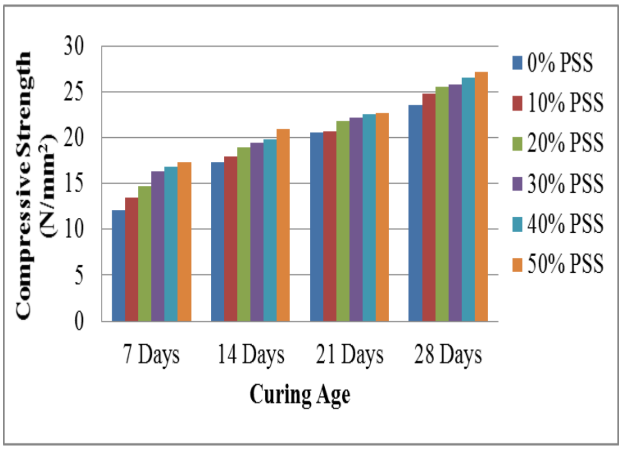

Figure 3: Average Compressive Strength of PSS Concrete

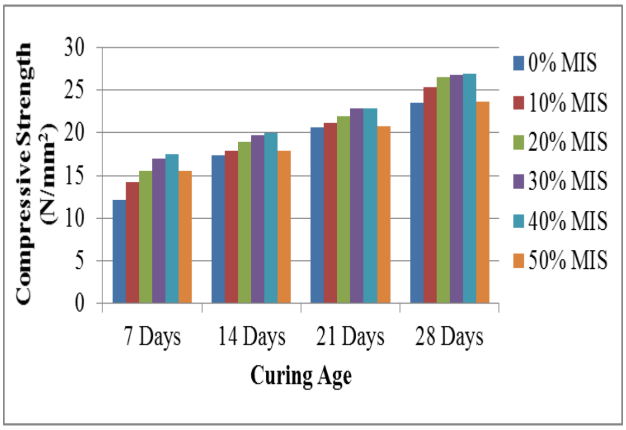

Figure 4: Average Compressive Strength of MIS Concrete

Table 5: Mean and Standard Deviations of PSS and MIS Concrete

Slag	N	Mean	Standard Deviation	Standard Error Mean
PSS 0%	3	23.5500	.51468	.29715
PSS 10%	3	24.8700	.12288	.07095
PSS 20%	3	25.5500	.23302	.13454
PSS 30%	3	25.8300	.22539	.73578
PSS 40%	3	26.6000	.33645	.19425
PSS 50%	3	27.2000	.18735	.10817
MIS 0%	3	23.5500	.51468	.29715
MIS 10%	3	25.4000	.33422	.19296
MIS 20%	3	26.5500	.44911	.25929
MIS 30%	3	26.7900	.18358	.10599
MIS 40%	3	26.9500	.06083	.03512
MIS 50%	3	23.7000	.34044	.19655

Table 6: T-Test for Average Compressive Strength of PSS and MIS Concrete

Slag	t	Degree of freedom	P-value	Mean Difference
PSS 0%	11.947	2	.007	3.55000
PSS 10%	68.644	2	.000	4.87000
PSS 20%	41.253	2	.001	5.55000
PSS 30%	44.802	2	.000	5.83000
PSS 40%	33.977	2	.001	6.60000
PSS 50%	66.564	2	.000	7.20000
MIS 0%	11.947	2	.007	3.55000
MIS 10%	27.985	2	.001	5.40000
MIS 20%	25.261	2	.002	6.55000
MIS 30%	64.064	2	.000	6.79000
MIS 40%	197.899	2	.000	6.95000
MIS 50%	18.824	2	.003	3.70000

4. CONCLUSION

The following conclusions were drawn from the study:

i. True slump was exhibited by the concrete in the fresh concrete mix and the slump height reduced as the percentage of coarse aggregate replacement with slag (PSS and MIS) increased.
ii. The compressive strength result of the control mix is lower than PSS concrete and MIS concrete for the replacement levels investigated in this research. The compressive strength of concrete cubes increased with respect to curing ages as the percentage of PIS increased from 0% to 50% while the compressive strength of MIS concrete increased up to 40% replacement and thereafter began to decrease.
iii. 50% of PSS can be used to replace coarse aggregate in concrete while 40% of MIS would be better in concrete for structural work.
iv. Nigerian slag (PSS and MIS) can successfully be used as a partial replacement of coarse aggregate (crushed stone) in concrete for concrete grade M20 structural work.
v. Utilization of slag in concrete production should be adopted in Nigeria for sustainable construction. Hence, partial replacement of coarse aggregate (crushed stone) with slag will minimize environmental pollution of rock blasting.

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