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Strength Characteristics of Concrete Produced by Replacing Fine Aggregates with Iron Filings and Marble Dust

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Abstract:- **The decline in the availability of natural aggregates and the high cost of construction materials has necessitated the quest for alternative materials. This study investigates the combined effect of using marble dust (MD) and iron filings (IF) as a partial replacement for fine aggregates (sand) in concrete production. Concrete cubes measuring 150 X 150 X 150 mm^3, were cast, using a mix ratio of 1:2:4 and a water/cement ratio of 0.5. The specimens were tested for workability and compressive strength at 0% (control mix), (2.5% IF, 7.5% MD), (5% IF,15% MD), (7.5% IF,22.5% MD), (10% IF,30% MD) replacement of sand (by weight) with IF and MD after curing in water for 28 days. The test results showed that the best gain in compressive strength was with (2.5% IF, 7.5% MD) replacement. At this replacement level, the compressive strength exhibited a 9.6% decrease compared to control cube strength. Regardless of the observed decline in the concrete strength produced, the concrete strength at 28days still relate favorably well with the control cube, and also meet the strength requirement of a good structural concrete.**

Keywords:- *Iron Filings, Marble Dust, Partial Replacement, Compressive strength, Waste.*

I. INTRODUCTION

Concrete is one of the most widely used materials for infrastructural development globally. With the continuous global population growth, there is an increased demand for infrastructure, leading to an increased demand for concrete**.** The quantity of concrete used globally surpasses other construction materials such as wood, steel, glass, plastics, aluminum, and iron combined [3]. It is composed mainly of aggregates (fine and coarse), cement and water. The most expensive constituent in concrete is cement and in terms of quantity, fine and coarse aggregate are the most demanding [4]. Hence, it is important to find locally available materials that would replace these aggregates wholly or partially in concrete without compromising strength. The choice of the materials however depends factors such as strength, economy, and availability. Currently, lots of waste and industrial by-products materials are being used to replace sand in concrete [5]. Research has revealed that this waste has some properties that are appropriate to produce concrete up to a certain limit [3]. Consequently, several studies have been carried out to examine the optimal replacement in concrete which will not impact negatively the engineering properties of concrete[3]. Such waste includes iron filings (IF), marble dust (MD), coconut shells, plastic, palm kernel shells, foundry sand and various sea shells.

Marble is one of the most important materials used in buildings since earliest times, most importantly for decorative purposes. Nonetheless, its powder got from finishing the marble has adverse effects on the environment. MD is produced from sawing and polishing of blocks of marble. Approximately 25% of the processed marble turns into dust. Moreso, approximately 7,000,000 tons of marble have been produced in the world [5]. In most part of Nigeria, the marble powder is kept open or disposed off in open sites and this poses serious environmental threat. Iron filing (IF) a waste from steel processing is produced locally in large amounts from steel workshops and factories. This industrial waste product equally has a negative effect on the environment when improperly disposed and for this reason its usage is concrete production is researched. Its usage in concrete production have been researched into separately and reported to have produced concrete of good strength and durability at certain percentage of application. However, its combined usage in concrete production have not been reported and this necessitated this research. Some of researches performed in this field can be summarized as follow:

Replacing sand with waste MD upto 10% by weight of fine sand can increase the tensile strength and compressive strength of concrete [7]. In a research carried out by Felix K et al. (2010) [8] and Patel, A.N (2013) [9], MD was used to partially replace sand and cement at 0%, 25%, 50%, 75% and 100% with 10% fly ash, 10 %slag, 7.5% silica fume and 1% superplasticizer in concrete. It was revealed that its usage has beneficial effect on mechanical properties of concrete. Ofuyatan O M et al (2019) [10] carried out a study on the utilization of marble dust powder in concrete the performance of the concrete was tested 7, 21, 28 and 56 curing days. The results revealed that MD powder replacement with cement increased in strength up to 25% for both compressive and tensile strength of concrete. In a similar research carried out by Rai B et al. (2011) [11] on the effect of using MD to partially replace cement as well as

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other conventional fines. Their results revealed that increased MD ratio led to an increased workability and compressive strengths of the concrete produced. In a similar research carried out by [12] to assess the effect of using steel slag on hardened concrete it was reported that steel slag aggregate concrete attained higher values of compressive, tensile and flexural strength compared to natural aggregate concrete. Manso J et.al. (2004) [13] Manso J et.al. (2004) [14] in their study on the use of electric arc furnace slag as partial replacement of aggregate in concrete concluded in their findings that arc furnace slag can be used to improve concrete properties. Elamin A.A (2015)[15] studied the consequence of replacing fine aggregate by 30% IF on properties of concrete. It was discovered that with the addition of IF, the concrete possesses the geometry conditions measuring the weakening characteristics of a shielding material.

II. MATERIALS AND METHODS

2.1 *Cement*

Dangote Portland-Limestone Cement, CEM II/B-L, Grade 42.5, manufactured in conformity to Nigerian Industrial Standard (NIS) 444-1:2003, which is equivalent to BS EN 197-1:2000 [16] was employed for this investigation.

2.2 *Aggregates*

Natural river sand with a 3.75mm maximum size was used as a fine aggregate, and natural rounded stone with a 19mm maximum size as a coarse aggregate. The waste used for this research was sourced at Ilaro Ogun State Nigeria. The coefficient of curvature and coefficient of uniformity of iron fillings waste and marble dust were determined. The iron filings used for this research was sourced from workshops in Ilaro environs, Ilaro Yewa South Local Government Ilaro, Ogun State, Nigeria. The marble dust was obtained in landfills at Eruwa, Oyo State, Nigeria. The physical and chemical properties of the iron filings and marble are shown in Tables 1,2,3and 4.

Table 1: Chemical properties of marble powder [1]

Property	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	CL
Results	42.14	14.08	2.69	1.94	2.77	0.91	0.63	0.04

Table 2: Physical properties of marble powder [1]

Property	**Result**
Specific surface area (cm^2/gm)	11.4×10^3
Bulk density (kg/m)	520
Specific gravity	2.5
Color	Light gray

Table 3: Chemical properties of iron fillings [2]

Property	Carbon	Silicon	Iron	Magnesium	Sulphur	Phosphorus	Manganese
Results	3.53	2.67	93.40	0.05	0.01	0.03	0.31

Table 4: Physical properties of iron fillings [2]

Property	**Result**
Fineness modulus	2.24
Density	1946kg/m^3
Specific gravity	3.95
Color	Black – grey

2.2 *Samples and Selection*

For the purpose of this investigation. The standard mold by dimension (150 mm^3 x 150 mm^3 x 150mm^3 was used in the casting of cubes. The replacement was done at 0% (control mix), (2.5% IF, 7.5% MD), (5% IF,15% MD), (7.5% IF,22.5% MD), (10% IF,30% MD), replacement of sand (by weight) with iron filings (IF) and marble dust (MD). Compressive strength tests were carried out on three cubes for each percentage replacement after 7, 14, 21 and 28 days of casting.

2.3 *Experimental Procedures*

The specimens were cured in water as shown in Fig 1. Casting and curing of the specimens were conducted in accordance to B.S. EN 12390 [17,18]. The various investigations carried out on the materials and concrete cube cast includes: Sieve analysis, specific gravity, Bulk & Dry densities, Slump test (workability), water absorption and Compressive strength test. The tests of compressive was conducted in accordance to B.S. EN 12390 [19,20,21]. A Matest Digital Testing Machine was used for the compressive tests as shown in Fig. 1.

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(a) Cubes during testing

(b) Cubes during curing stage

Figure 1: Concrete cubes after curing and during test.

2.4 *Concrete Mix Design and Proportion*

The materials cement, sand and coarse aggregate were batched by weight using a mix proportion of 1:2:4 cement-sand-coarse aggregate ratio, and a water/cement ratio of 0.5.

II. RESULTS AND DISCUSSION

3.1 Sieve Analysis Test Results

The particle-size distribution curve shows the range of particle sizes present in a soil so as to ascertain whether the particle distribution is in compliance with recognized standards. The sand used for this research have a maximum size of 4.75mm and a fineness modulus of 3.214 coefficient of curvature of 1.42 and coefficient of uniformity of 3.78. The sand is well graded indicating its appropriateness for construction purposes. Moreso, it falls within the acceptable range for fine aggregate in concrete. The result of the sieve analysis is presented in Figure 2.

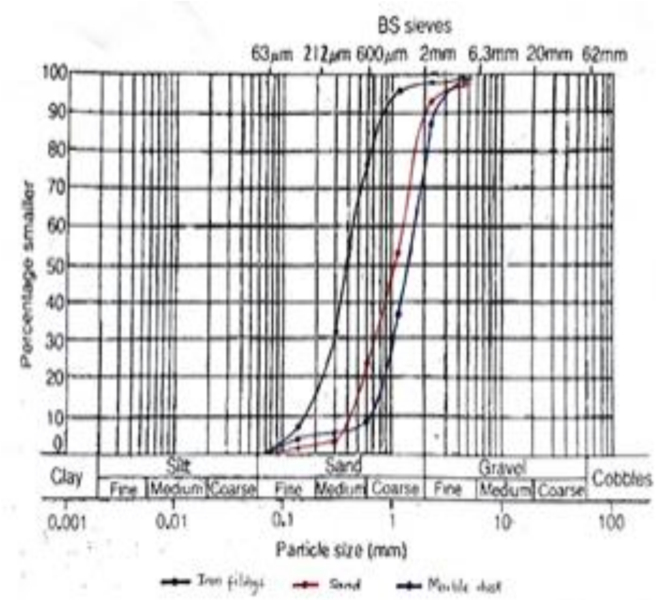

Figure 2: Particle size distribution of sand, IF and MD

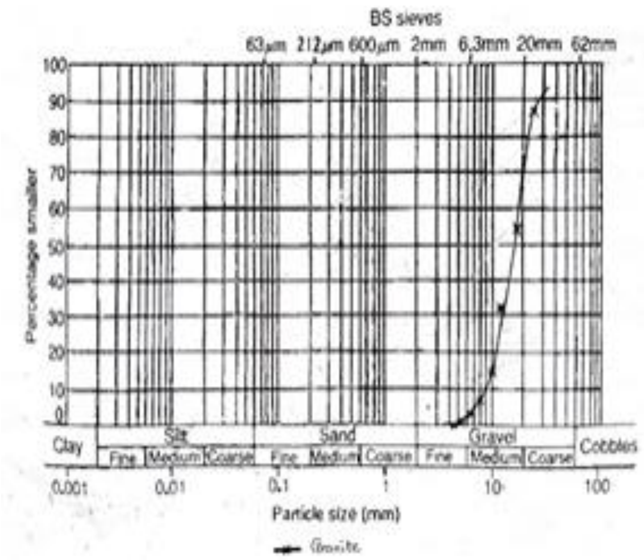

Figure 3: Particle size distribution of granite

Crushed granite coarse aggregates of 20mm maximum size having a specific gravity of 2.75 was used. It has a coefficient of curvature of 1.42 and coefficient of uniformity of 3.7. The gradation is shown in Figure 3. From the graph shown above the gravel is well graded.

3.2 Density of Concrete

Density obtained from concrete mix sample (control) gives an average of 2426.66kg/m^3. Concrete sample with (2.5% IF and 7.5% MD) have a value of 2585 kg/m^3. The concrete sample (7.5% IF and 30% MD) have an increased density value of 2589.63kg/m^3.

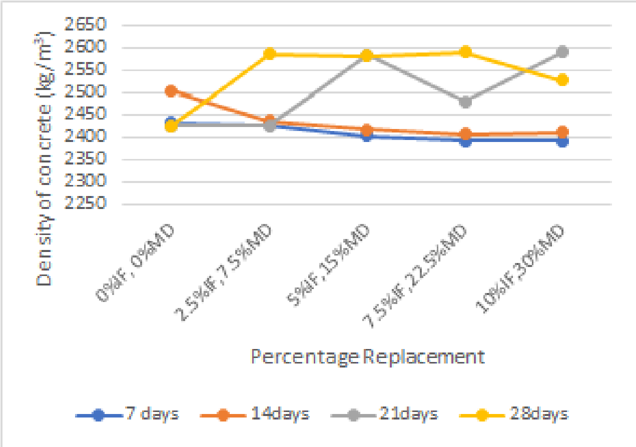

Figure 4: Variation of density of concrete with varying percentage replacement of fine aggregates with IF and MD.

It can be clearly seen as presented in figure 4, that the density of concrete produced increased with increase in quantity of material replaced. However, the results obtained from concrete samples of all replacement can be classified as normal concrete.

3.3 Slump Test

From the results shown in figure 5 it is seen that there was no significant increase or decrease in the workability of the concrete as compared to the control mix.

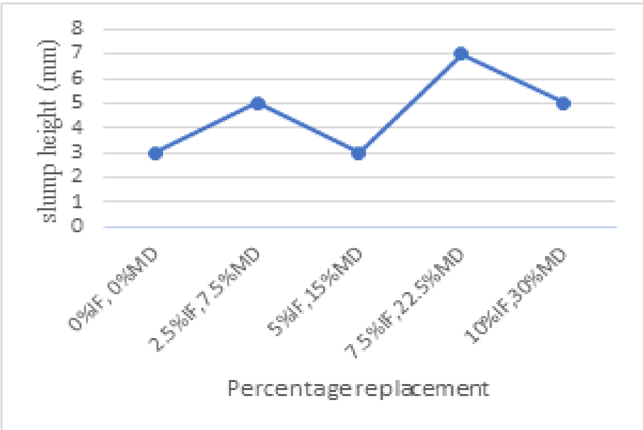

Figure 5: Variation of slump of concrete with varying percentage replacement of fine aggregates with IF and MD

Hence, it can be concluded that the inclusion of IF and MD in concrete does not significantly improve or reduce the workability of concrete as can be seen from the results.

3.4 Water Absorption Test

This test was carried out as a measure of Durability of the various concrete cubes derived from the different concrete mixes. According to BS 1881-122:1983. The water absorption capacity of the concrete at all ages of curing is shown in Figure 6.

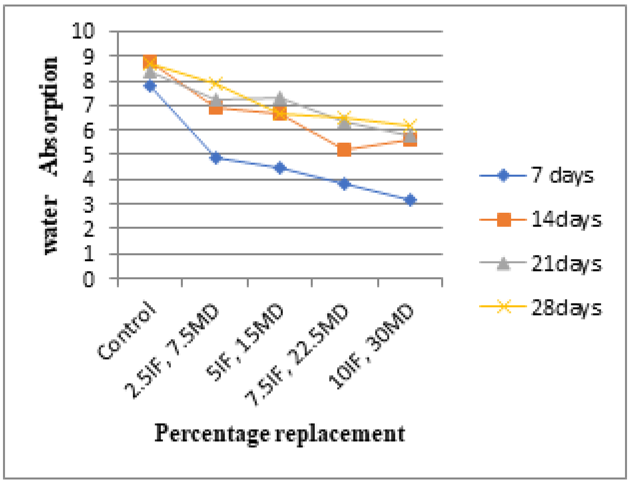

Figure 6: Variation of water absorption of concrete with varying percentage replacement of fine aggregates with IF and MD

It decreases with increase in IF and MD in concrete. The result submits that the best possible performance, mainly for durability of the IF and MD modified concrete is practicable at 10% application.

3.5 Compressive Strength

The compressive strength test was carried out on the hardened concrete in order to study the resistance of the concrete cubes cast to compressive load. This test was done in accordance with BS 1881-116:1983 and the result of this test is shown in figure 7.

It was observed that the mix at 10% (2.5%IF,7.5%MD) replacement of sand with IF and MD, showed a 9.6% decrease in the compressive strength of concrete as compared with the control mix. At 20% replacement, there was a 14% decrease in the concrete compressive strength as compared with the control mix. With increase in the content of IF and MD there was noticeable decrease in compressive strength of the hardened concrete at 28days age of curing.

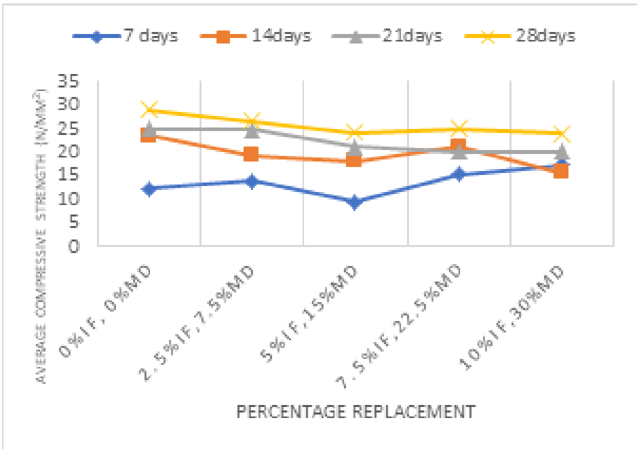

Figure 7: Variation of compressive strength at various curing age with varying percentage replacement of sand with IF and MD.

Despite the observed decrease in the strength of concrete produced compared to the control, the concrete strength at 28days still relate favorably well with the control cube, and also meets the strength requirement of a good structural concrete.

IV. CONCLUSION

It is expected that concrete produced by incorporating waste should exhibit an improved workability, strength and durability of concrete properties or should have comparable properties with respect to reference or control concrete. The results of the research work show that concrete produced with IF and MD as partial replacement of sand shows an insignificant increase or decrease in the workability of the concrete as compared to the control mix, this implies that a good concrete can be produced with inclusion of IF and MD. The density of concrete replaced with IF and MD is considerably close to conventional concrete. The result revealed that up to 10% (2.5% IF 7.5% MD) the modified concrete develops an early strength gain corresponding to a 0.13% increase at 7days, however at 28days there was an observed 9.6% decrease in the compressive strength of concrete compared to the control mix. At 20% replacement, there was a 14% decrease in the concrete compressive strength as compared with the control mix. With increase in the content of IF and MD there was a noticeable decrease in compressive strength of the hardened concrete. Regardless of the observed decline in the concrete strength produced, the concrete strength at 28days still relate favorably well with the control cube, and also meet the strength requirement of a good structural concrete. In terms of durability, concrete produced with IF and MD may have consequences on water retaining structures owing to its high-water absorption capacity. The use of IF and MD in concrete production would lead to improved environmental waste management and its usage may be employed in low traffic road pavements, stone pitching, embankment, base for flexible pavements and minor concrete works in general.

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