



Strength Properties of Concrete Produced With Iron Filings as Sand Replacement

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experimental study was carried out to investigate the strength properties of concrete produced with iron filings as partial replacement for sand. Concrete specimens (cubes, cylinders and prisms) were cast and tested for compressive, split-tensile and flexural strengths at 0% (control mix), 10%, 20% and 30% replacement of sand by weight with iron filings after curing in water for 28 days. The results obtained showed that the compressive strength of concrete increased for the 10% and 20% replacement levels of sand with iron filings by 3.5% and 13.5% respectively while there was a decrease of 8% for the 30% replacement level. The split-tensile strength of concrete for the 10% and 20% replacement levels increased by 12.7% and 1% respectively and decreased marginally by 1.7% for the 30% replacement level when compared to the control mix. The flexural strength of concrete increased by 11.1% and 4.8% for the 10% and 20% replacement levels respectively while it decreased marginally by 1.6% for the 30% replacement level as compared to the control mix. An optimum of 10% and 20% replacement by weight of sand (fine aggregates) with iron filings in concrete mix is recommended for concrete production depending on the desirable property required in the concrete.

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1. INTRODUCTION

Availability of natural aggregates is gradually dwindling and natural aggregates are also becoming costly. The depletion of natural reserves of sand used in the construction industry and the disposal of agricultural and industrial wastes in the environment has been of great concern to mankind in the last few decades due to the environmental impact arising from these activities. In the last decade, there has been increased global agitation on the need for green construction. Therefore, the use of agricultural and industrial wastes such as iron filings in concrete production would lead to improved environmental waste management and profitable utilization of industrial wastes, resulting in a greener world.

Sarsaam [1] evaluated the influence of nano-materials (limestone dust, coal fly ash and iron filings) addition as partial replacement of cement on the properties of concrete pavement. The results obtained indicate that the addition of limestone dust and coal fly ash lead to reduced flexural strength while the addition of iron filings led to an increased flexural strength.

Elamin et al. [2] studied the effect of replacing each component of concrete by 30% iron filings on concrete attenuation properties. The results revealed that with the addition of iron filings, the concrete becomes heavy and has the desired gamma absorption capabilities and possess the geometry conditions measuring the attenuation characteristics of a shielding material.

Alzaed [3] evaluated the effect of iron filings on concrete compressive and tensile strength. Iron filings were used to partially replace cement in concrete. Results obtained revealed that there was increase in the concrete compressive and tensile strengths respectively.

Prema et al. [4] carried a research to evaluate the effect of replacing sand in cement concrete with iron ore tailing. Their results showed the strength properties of the modified concrete increased over the control mix.

Adeyanju and Manohar [5] carried out an experimental study on the thermal properties of Iron Filings and Steel Fibre Reinforced Concrete (SFRC) for solar/thermal energy storage applications. Results obtained reveal that the steel fibres and iron filings have influence on the thermal and mechanical properties of concrete.

Thus, iron filings and SFRC is suitable for better solar/thermal energy storage due to an increase in storage capacity over plain concrete.

Ismail and Al-Hashmi [6] evaluated the possibility of using waste iron in concrete as partial replacement of fine aggregates. Their investigation revealed that the concrete mixes produced with waste iron had higher compressive and flexural strengths when compared to plain mixes.

Neeraja and Gopal [7] investigated the combined behaviour of ferrous slag and polypropylene fibre in concrete. Granulated ferrous slag was used to partially replace sand while polypropylene was used as a micro-reinforcement. It was observed that with the replacement of sand with ferrous slag, up to 20%, the compressive strength increased and further increment may lead to reduction of the compressive strength. Also, the split tensile property of the concrete increased constantly due to the addition of polypropylene fibre.

In this present contribution, the strength properties of concrete produced with iron filings as sand replacement have been investigated.

2. MATERIALS AND METHODS

2.1 Materials

The following materials were sourced and used in the study:

2.1.1 Cement

Locally available Portland-Limestone Cement, CEM II/B-L, Grade 42.5, (purchased in Ibadan, Nigeria), manufactured in conformity to Nigerian Industrial Standard (NIS) 444-1 [8], which is equivalent to BS EN 197-1 [9] was used for this research.

2.1.2 Sand

Sharp river quartzite sand that is free of clay, loam, dirt and any organic or chemical matter, and maximum size of 4.75mm with a specific gravity of 2.65, water absorption of 0.9% and a fineness modulus of 2.41 was used for this research. The sand has coefficient of curvature of 0.97 and coefficient of uniformity of 2.50; hence, it is poorly graded sand. The sand was sourced from Ibadan environs, Ibadan, Nigeria.

The gradation of the sand used is shown in Table 1.

2.1.3 Iron filings

The iron filings used for this research was sourced from workshops in Ibadan environs, Ibadan, Nigeria. The iron filings has water absorption of 1.5%, coefficient of curvature of 0.98 and coefficient of uniformity of 2.21, hence, it is a poorly graded. A sample of the iron filings used for this study is shown in Fig. 1. The gradation of iron filings, as well as its physical and chemical properties are shown in Tables 1, 2 and 3 respectively.

2.1.4 Coarse aggregates

Crushed granite coarse aggregates of 20 mm maximum size having a specific gravity of 2.75; free from impurities such as dust, clay particles and organic matter, etc, was used. It has a coefficient of curvature of 1.60 and coefficient of uniformity of 1.73; hence, it is poorly graded. The granite was sourced from a quarry in Abeokuta, Nigeria.

2.1.5 Water

Fresh, colourless, odourless and tasteless potable water that is free from injurious amounts of oils, alkalis, salts, sugar organic matter or any other substances, was used for this research.

Table 1. Gradation of fine aggregates

Sieve size (mm)	% passing (sand)	% passing (iron filings)
4.750	100.00	100.00
2.360	99.70	99.68
0.600	74.80	95.36
0.425	57.04	59.24
0.212	18.80	14.52
0.150	8.28	6.76
0.075	1.72	1.26
Pan	0.00	0.00

Table 2. Physical properties of iron filings

Properties	Value	Test methods
Fineness modulus	2.24	F.M. = Accummlative percentage retained/100
Specific gravity	3.95	BS 812-2 [10]
Colour	Black-grey	-
Density	1946 Kg/m ³	BS 812-2 [10]

Table 3. Typical chemical composition of iron filings [11]

Elements	Composition (%)
Carbon	3.53
Silicon	2.67
Magnesium	0.05
Sulphur	0.01
Phosphorus	0.03
Manganese	0.31
Iron	93.40



Fig. 1. Sample of iron filings used

2.2 Experimental Investigation

Experimental investigations were carried out to evaluate the strength properties of grade M30 concrete mixes in which fine aggregates (sand) was partially replaced with iron filings. The compressive, split-tensile and flexural strength of the specimens after replacing the fine aggregates by 0% (control), 10%, 20% and 30% with iron filings (by weight) was investigated after 28 days of curing.

The concrete cubes (100 mm X 100 mm X 100 mm), concrete cylinders (Φ100 mm X 200 mm) and concrete prisms (100 mm X 100 mm X 500 mm) were cast for conventional mix as well as other mixes.

2.2.1 Mix proportioning

The concrete mix design was proposed to achieve the compressive strength of 30N/mm² after curing for 28 days in the case of cubes, cylinders for split-tensile strength and prisms for flexural strength. The concrete mix proportion

used was 1:2:4 and a water/cement ratio of 0.5. Table 4 shows the mix proportions of waste modified concrete mixes.



Fig. 2. Samples of specimens water cured



Fig. 3. Specimens undergoing flexural test

2.2.2 Casting and testing of specimens

Three specimens each of waste modified and control concrete were cast for compressive, split-tensile and flexural strength tests respectively. The specimens were cured in water as shown in above Fig. 2. Casting, compaction and curing of the specimens were conducted in accordance to B.S. EN 12390 [12-13]. The tests of compressive, split-tensile and flexural strengths were also conducted in accordance to B.S. EN 12390 [14,15,16]. The strength tests were conducted at the Material Testing Laboratories of Civil Engineering Department and Agricultural and Environmental Engineering Department, University of Ibadan, Ibadan, Nigeria. A Matest Digital Testing Machine was used for the compressive and split-tensile tests while a Universal Testing Machine (UTM) was used for the flexural strength test. Above Fig. 3 shows a prism specimen being tested using the UTM. The average strength (compressive, split-tensile and

flexural) of three specimens were recorded at 28 days of curing.

3. RESULTS AND DISCUSSION

The results obtained for the compressive, split-tensile and flexural tests respectively are presented and discussed as follows:

3.1 Compressive Strength

The compressive strength tests results are presented in Table 5. The results showed that as iron filings was used to replace sand by 10% and 20%, the compressive strength of concrete increased above the control mix (0% iron filings) by 3.5% and 13.5% respectively while the compressive strength for the 30% iron filings mix decreased by 8% as compared to the control mix. The increase experienced by the 10% and 20% iron filing mixes could be attributed to the strength and toughness of iron filings as well as its pozzolanic properties justified by Alzaed [3]. The decrease in compressive strength of 30% iron filings mix could be attributed to the lower fineness modulus of iron filings which leads to higher demand for cement in the concrete matrix. The decrease could also be due to the higher water absorption capacity of iron filings which makes less water available for the hydration of cement in the concrete matrix.

3.2 Split-tensile Strength

The split-tensile strength tests results are presented in Table 6. The results showed that as iron filings was used to replace sand by 10% and 20%, the split-tensile strength of concrete increased above the control mix (0% iron filings) by 12.7 % and 0.9% respectively while the split-tensile strength for the 30% iron filing mix decreased by 1.7% as compared to the control mix. The increase in split-tensile strength experienced by the 10% and 20% iron filings mixes could be attributed to the strength and toughness of iron filings as well as its pozzolanic properties. Also, the ductility of iron filings could have led to the increase in the split-tensile strength. The decrease in compressive strength of 30% iron filings mix could be attributed to the lower fineness modulus of iron filings which leads to higher demand for cement in the concrete matrix. The decrease could also be due to the higher water absorption capacity of iron filings which makes less water available for the hydration of cement in the concrete matrix.

Table 4. Mix proportions of waste modified concrete mixes

Mix I.D.	% iron filings	Cement (Kg/m ³)	Sand (Kg/m ³)	Iron filings (Kg/m ³)	Coarse aggregate (Kg/m ³)	Water/cement ratio
C	0	9.00	18.00	0.00	36.00	0.5
R1	10	9.00	16.20	1.80	36.00	0.5
R2	20	9.00	14.40	3.60	36.00	0.5
R3	30	9.00	12.60	5.40	36.00	0.5

Table 5. Compressive strength of concrete cubes

% iron filings	Compressive strength (N/mm ²)
0	34.8
10	36.0
20	39.5
30	32.0

Table 6. Split-tensile strength of concrete cylinders

% iron filings	Split-tensile strength (N/mm ²)
0	2.36
10	2.66
20	2.38
30	2.32

3.3 Flexural Strength

The flexural strength tests results are presented in Table 7. The results showed that as iron filings was used to replace sand by 10% and 20%, the flexural strength of concrete increased above the control mix (0% iron filings) by 11.1 % and 4.8% respectively while the flexural strength for the 30% iron filings mix decreased by 1.6% as compared to the control mix. The increase in flexural strength experienced by the 10% and 20% iron filing mixes could be attributed to the strength and toughness of iron filings as well as its pozzolanic properties. There is also the possibility of iron filings acting as micro-reinforcements in the concrete matrix, hence increasing the flexural strength. The decrease in flexural strength of 30% iron filings mix could be attributed to the lower fineness modulus of iron filings which leads to higher demand for cement in the concrete matrix. The decrease could also be due to the higher water absorption capacity of iron filings which makes less water available for the hydration of cement in the concrete matrix.

Table 7. Flexural strength of concrete prisms

% iron filings	Flexural strength (N/mm ²)
0	6.3
10	7.0
20	6.6
30	6.2

4. CONCLUSION

Based on the results obtained from this experimental investigation, the following conclusions can be drawn:

1. There is a possibility for the replacement of sand (fine aggregate) with iron filings in the production of concrete.
2. The use of iron filings in concrete production would lead to improved environmental waste management and profitable utilization of industrial wastes.
3. Iron filings can be used for production of heavyweight concrete.
4. Compared to the control mix, the compressive strength of concrete increased for the 10% and 20% replacement levels of sand with iron filings by 3.5% and 13.5% respectively while there was a decrease of 8% for the 30% replacement level.
5. The split-tensile strength of concrete for the 10% and 20% replacement levels increased by 12.7% and 1% respectively and decreased marginally by 1.7% for the 30% replacement level when compared to the control mix.
6. The flexural strength of concrete increased by 11.1% and 4.8% for the 10% and 20% replacement levels respectively while it decreased marginally by 1.6% for the 30% replacement level as compared to the control mix.
7. Thus, an optimum of 10% and 20% replacement by weight of sand (fine aggregates) with iron filings in concrete

mix is recommended for concrete production depending on the desirable strength property required in the concrete.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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