

Experimental Investigation on High Performance Green Concrete (HPGC) Produced with Iron Filings

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Abstract: The acronym "HPGC" refers to "high performance green concrete." This breakthrough is significant because it moves the industry closer to its goal of replacing concrete with eco-friendly alternatives that claim superior mechanical qualities, thereby making concrete a more sustainable building material. When working with metal, a fine powdery dust known as "iron filings" is inevitably created. The purpose of this study was to evaluate the usefulness of iron filings as a fine aggregate in building projects. An experiment was conducted to examine the mechanical iron filings' effects on concrete's characteristics utilised as a supplement to sand. Using a range of sand replacement percentages (0% (control mix), 10% (treatment mix), 20% (treatment mix), and 30% (treatment mix)), the compressive, split-tensile, and flexural strengths of 35 concrete specimens consist of cubes, cylinders, and prisms were tested after 28 days of treatment in water. The findings indicated that the mechanical qualities of HPGC were enhanced when iron filings were used in place of sand, but that the concrete's slump value and workability were diminished. Therefore, only 30% of the sand (fine particles) should be substituted by weight with iron filings in the concrete mix, depending on the desired strength attribute. In this case, the concrete's compressive strength is increased by 13.2%, split-tensile strength by 21.1%, and flexural strength by 49.88%, all by replacing 30% of the sand (fine particles) with iron filings. Therefore, employing iron filings in concrete will help with recycling and waste reduction.

Keywords: High performance, green concrete, iron filings, fine aggregates, mechanical properties.

1. Introduction

Nowadays, making a structure that is less harmful to the environment is one of the top priorities in the construction industry. It's a win-win scenario to use recycled resources in concrete manufacturing and cut down on the amount of toxic waste sent to landfills [1]. The concrete industry has progressively substituted waste and by-product materials for the core components of concrete to produce greener concretes. Fly ash, silica fume, blast furnace slag, and rice husk ash are all examples of pozzolans with silica-rich byproducts that are employed

as supplementary cementitious materials [2]. Recycled aggregate, scrap foundry sand, ceramic, tyre rubber, and glass sands are some further examples of sustainable concrete. In addition, discarded materials including steel, plastic, cotton, and carpet fibres have been added to concrete to make it more resistant to cracking under tensile stress [3].

There is a daily increase in environmental pollution due to the large quantity of trash and materials discarded as a byproduct of production in standard industrial, manufacturing, or mechanical operations. Iron filing is one of the byproducts created when finished iron products are ground, filed, or milled. Small bits of iron or galvanised iron are what make up iron filing, a byproduct of the metalworking industry [4]. They are either taken to dump sites to be disposed of as waste or recycled for use in producing lower quality iron products. One disadvantage of using iron in so many diverse applications is the massive amount of waste iron that is created as a consequence of industrial activity and is then disposed of in landfills and municipal garbage dumps. Finding a new purpose for steel scrap is essential if we are to keep it out of landfills. Sand, commonly known as fine aggregate, is a crucial ingredient in the production of concrete. Between twenty and thirty percent of concrete's total volume is made up of sand [5].

Natural sand prices are rising as a result of the rapid growth of our country's infrastructure. The rapid depletion of sand deposits in riverbeds poses a threat to the natural world. Crushed stone is being used as fine aggregate in place of sand since riverbed sand is in short supply. The quarrying and crushing of mountain stones to make sand adds to air pollution in addition to diminishing one natural resource and hastening the loss of highland flora. In light of these problems, researchers have begun exploring low-cost and widely available synthetic substitutes to natural sand. Researchers have experimented with a number of alternatives to sand, including fly-ash, dust from quarries and crushed stones from limestone quarries, etc [6]. Iron filings are one type of industrial byproduct that can be substituted for sand in concrete. If just 5 percent of the world's 4 trillion kilogrammes of sand were substituted with waste iron filings, the environmental advantages would be significant [7].

The use of iron-containing waste products in the creation of dense concrete has been the subject of study since 2011 [8]. Compressive strength was shown to rise by 17% when 30% iron filing was added to the concrete, according to the research [9]. The report does not elaborate on the methods used or the decision to keep the iron filing content below 30% for compressive strength and 10% for tensile strength. Concrete made using Iron Filings as a sand replacement has its strength and characteristics investigated further [10]. The findings revealed that replacing 10% of the sand with iron filings enhanced the compressive strength of the concrete to 3.5%, increasing the strength by 13.5% while replacing 20% of the sand, and decreasing it by 8% when replacing 30% of the sand. With 10% and 20% substitution, the concrete's split-tensile strength climbed to 12.7%, while it declined by 1% at 30% substitution, compared to the control mix. Fine aggregate can be substituted by iron filings up to a volume ratio of 20%. It was observed that beyond 20% iron filings, both compressive and flexural strength dropped, although the reason for this was not explored. Several Writers [7]. Experiments were conducted on the iron waste until a concentration of 30% was achieved. Compressive and flexural strengths were found to be maximised with an iron filings concentration of 12 percent or higher in the concrete. Above this point, however, it was found that the concrete's strength began to decrease [11].

This contradicts the results of previous research [9, 10] Flexural and compressive strengths were shown to improve up to 30% sand substitution. All of the sand in the concrete was substituted with iron filings in an effort to combat the challenges associated with iron filings reuse and the increasing scarcity of river sand. This is because no previous studies have attempted to increase the iron content of concrete by more than 30% using iron filings. There is a disagreement in the concrete's strength values if more than 12% iron filings are added [7] contrary to the findings of others who showed that strength increased up to 30% iron filings [9,

10]. This research was conducted to investigate the inconsistencies and ambiguities found in earlier investigations.

2. Research Significance

In this experiment, natural fine particles are replaced with 10%, 20%, 30%, and 40% iron filings to see how the addition of iron affects the concrete's compressive, tensile, and flexural strengths. So that the outcome of iron filings on concrete resilience may be examined, both natural and iron filings aggregates are rated similarly. There were three types of tests conducted on the specimens after they had cured in water for 28 days: compressive strength, indirect tensile strength, and flexural strength.

3. Materials and Methods

In the course of the trials, we took use of resources that were easily accessible in the local region. The information is broken up into the sections that are shown below.

3.1 Portland cement

The type of Portland cement that is used, which is referred to as ordinary Portland cement (OPC), is one that is compliant with the requirements of IQS 5/1984.

3.2 Silica fume

During the course of this study, a form of mineral addition known as silica fume was added to the concrete mixtures as a means of enhancing their properties. It is junk from an industry that generates silicon and silicon alloys and is mostly composed of particles of amorphous silica (SiO_2) that cannot be burned. It is junk from an industry that produces silicon and silicon alloys. It has been established that using silica fume as a replacement for cement at a percentage of 10% is effective and functional.

3.3 Fine aggregate

The natural sand that was sourced from Al-Ekhaider was utilised as the fine aggregate, and its thickness was measured to be 4.75 millimetres. The sand was put through a series of washes and cleanings in water before it was put to use. After that, it was scooped out, stretched out, and allowed to dry in the air before being used. According to the findings, the grading of the fine aggregate is sufficient to meet the prerequisites of Iraqi Specification No. 45/1984. This was determined by comparing the results to the requirements.

3.4 Coarse Aggregates

Each and every mixture had coarse aggregates that were made up of gravel from nearby rivers that had been crushed to a maximum size of 12.50 millimetres. The Iraqi standard IQS No.45/ 1984 is followed when determining the grading of coarse aggregates. In 1984, this benchmark was initially developed.

3.5 Potable water

Drinking water with a pH of 7 or lower was used. The amount of water in concrete is what determines its fresh and hardened properties, such as its workability, compressive strength,

permeability, water tightness, durability and weathering, drying shrinkage, and potential for cracking. Other properties that are governed by the amount of water in concrete are its permeability, permeability, water tightness, and water tightness. Permeability is yet another characteristic of concrete that is influenced by the amount of water that is present in the material. Because of these variables, lowering and managing the amount of water that is present in concrete is vital for boosting its constructability and sustaining its service life. These goals can be achieved by reducing the amount of water that is contained in concrete.

3.6 Admixtures superplasticizer

The investigation made use of a third-generation super plasticizer for concrete and mortar, which is a high range water reduction additive. This additive was utilised in the investigation. On the market for consumer goods, this product is marketed under the brand name SikaViscocrete-5930 and is described as an aqueous solution of modified polycarboxylates. It is a High Performance Super plasticizer Concrete Admixture, and the Sika firm in Egypt is in charge of importing it. Sika also manufactures the product. SikaViscocrete-5930 was developed with the primary purpose of meeting the requirements of applications that required the greatest possible levels of performance and durability. SikaViscocrete-5930 satisfies the standards of ASTM C494-99 kinds G and F and does not contain any chlorides as required by this standard.

3.7 Iron Filings

Iron filings originated from the local mechanical workshop where filings, shavings, and crushing of steel and iron are done. The workshop was also the source of the iron filings. For the purpose of ensuring that galvanised iron or steel would not rust when it was mixed with concrete, only the filings that were created as a result of the use of galvanised iron or steel were collected. The iron filings that were used in the experiment are depicted in Figure 1, which may be seen here. It was sieved, and the proportion that was larger than 1.18 mm was employed in this inquiry. Table 1 provides a description of how iron filings are classified according to their sizes.

Table 1. Grading of iron filings

Typical Sieve Size	% Passing
4.75mm	100
2.36mm	98.95
1.18mm	86.11
0.6mm	32.18
0.3mm	9.51
0.15mm	3.17



Figure 1. Iron filings

4. Specimens preparations and test methods

Fifteen cube-shaped, ten cylindrical, and ten prism-shaped specimens of concrete were constructed in accordance with the specifications of the (B.S. 1881, part 116) [12], (ASTM C 496) in order to investigate the effects of using iron filings as a partial replacement for fine aggregate on the behaviour of the concrete. [13], and (ASTM C78) [14] standards for compressive, splitting, and flexural tests. cubical specimens were 100 mm * 100 mm*100 mm, cylindrical specimens were 100 mm in diameter and 200 mm tall and prisms specimens were 100mm*100mm*400mm. For one cubic meter of concrete batch, the mix design contained 486 kg cement ,48.6 kg silica fume, 773 kg fine aggregate 1044 kg coarse aggregate, 6 Liter superplasticizer and 143 kg water. This mixed design should produce an Fcu 60 concrete grade. A water to cement ratio of 0.29 was selected to be used in the preparation of the specimens. Three iron filings dosages by weight of (10, 20,30,40 and 50%) were used. For the sake of comparison, we also made some samples without any iron filings. Researchers looked at the optimum cure time of 28 days. ASTM C192 standards were used for the curing process [15], Immediately after completing, the examples were covered with impervious plastic to prevent the water in the unhardened concrete from evaporating. All specimens were cured in water from the time of moulding until the time of tests, which occurred one day following casting. After 28 days of curing, samples were examined. The specimen preparations are depicted in Figure 2, and the testing procedures are depicted in Figure 3. The Slump The purpose of this was to test the fresh concrete made with iron filings and glass particles to see how well they operate. The procedure followed BS EN 12350 -2 2009 standards [12].



Figure 2. Sample preparations

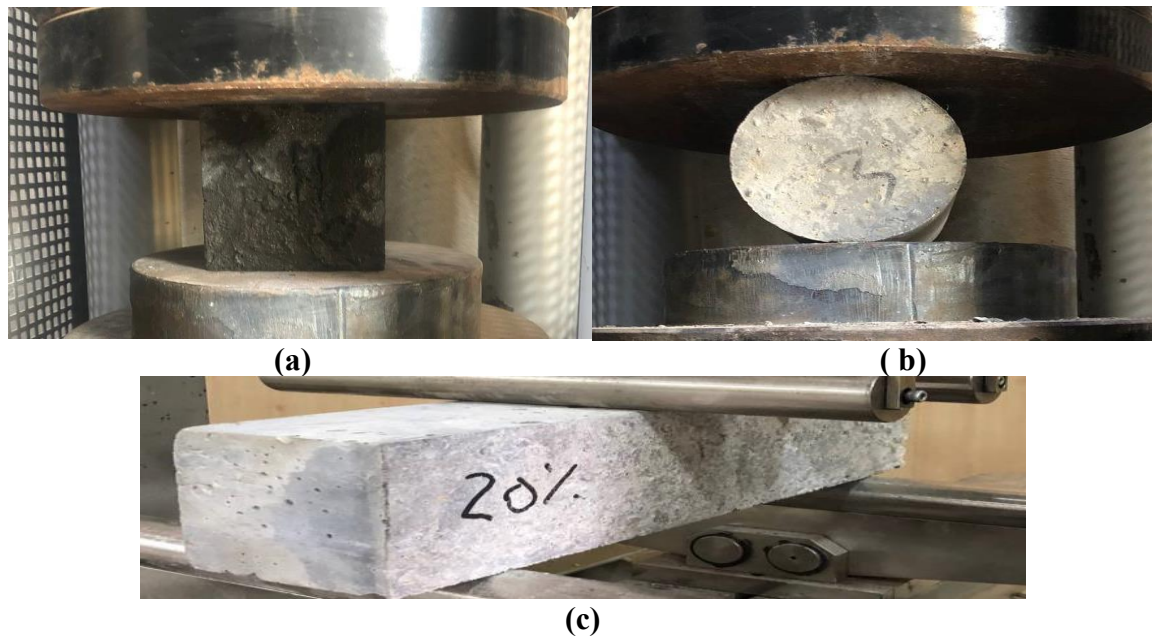


Figure 3. Test methods: a. (Compressive strength test), b. (Tensile strength) and c. (Flexural strength).

5. Experiment results and discussion

5.1. Slump

A slump test was completed to see how workable the concrete would be. Figure 4 shows the outcomes of the slump test. The downturn lessened as a result of an grow in the quantity of iron filings. Perhaps this is due to the increased specific gravity (SG) of iron filings. This is why a higher iron filing % results in less slump. The grow in the amount of discarded iron filings used as fine aggregate correlates with a decrease in the slump amount of the resulting concrete. It's also probable that the grains of iron filings' form contributes to this property. Concrete samples with iron filings as fine aggregate may benefit from the use of superplasticizers, which may make them easier to work with.

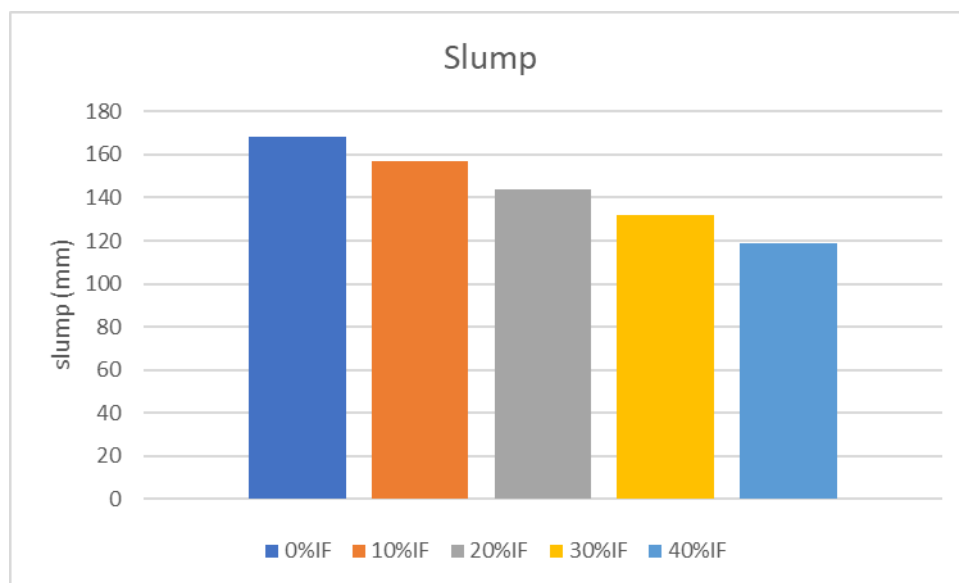


Figure 4. The result of the slump test

5.2. Compressive strength

Compressive strength tests on concrete are performed using cube-shaped specimens with side lengths of 100 mm. The average results are shown graphically in Figure 5. Iron filings were substituted for the natural tiny particles employed in this test, increasing the concrete's compressive strength. However, the maximum increase in strength above the natural value was just 13.2%. After curing, the specimen is placed between metal plates in the compressive testing apparatus shown in Figure 6. The equipment applies a rising force on the sample being analysed. Table 2 displays the results of compressive strength tests conducted when a defective sample was used.

The results revealed that replacing 10%, 20%, 30%, and 40% of the sand in a concrete mix with iron filings increased the compressive strength by 6.1%, 9.9%, 13.2%, and 6.7%, respectively, compared to the control mix (0% iron filings). Iron filings' pozzolanic properties and high strength and hardness may be responsible for the enhanced properties of iron filings blends. This study found that an iron filings/sand mixture of 30% was an adequate replacement for sand in concrete. Therefore, it was logical to expect that iron filings may lower the compressive strength of concrete if they substituted more than 30 percent of the sand in the mixture. Compressive strength is diminished in a mix that contains 40% iron filings, possibly because of the higher need for cement in the concrete matrix caused by the filings' decreased fineness modulus. Because iron filings are able to soak up more water than other aggregates, there is less available in the concrete matrix to be used in the cement hydration process.

Table 2. Compressive strength tests results

% Replacement of fine aggregate	Specimen Size and Type (mm)	Weight (kg)	Density(kg/m ³)	Compressive Strength(N/mm ²)
0%	100(Cube)	2.33	2330	59.10
10%	100(Cube)	2.38	2380	61.69
20%	100(Cube)	2.43	2430	63.94
30%	100(Cube)	2.47	2470	65.89
40%	100(Cube)	2.53	2530	62.04

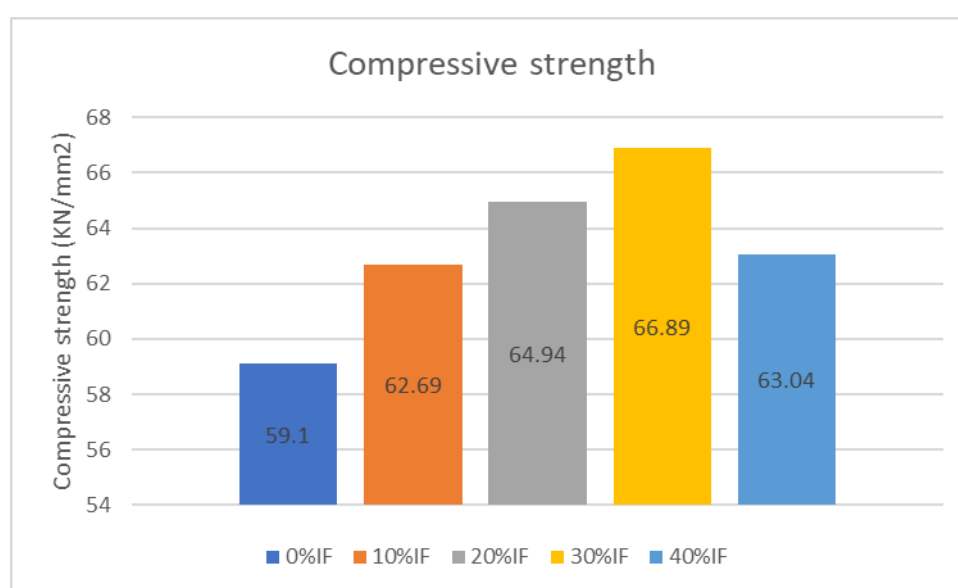


Figure 5. Comparison of cubes with and without iron filings in terms of their compressive strength



Figure 6. Compressive strength test of concrete cubic specimen

5.3. Indirect tensile strength

After curing for 28 days, a test for indirect tensile strength was conducted on cylindrical specimens of 100 mm in diameter and 200 mm in length, as per the ASTM C496-96 standard (Figure 7). Figure 8 depicts the typical outcomes. Figure 8 shows that much like the compressive strength, the tensile strength also rises as more iron filings are used in the replacement process. For instance, if natural fine aggregates were substituted with iron filings at 10%, 20%, 30%, and 40%, the mean value of the indirect tensile strength would drop from 3.895 MPa in the control specimen to 4.52 MPa, 4.21 MPa, 4.515 MPa, and 4.56 MPa, respectively.

The results showed that the split-tensile strength of concrete rose by 16.1%, 17.8%, 21.1%, and 18.4% when iron filings were used to substitute fine aggregate at 10%, 20%, 30%, and 40% compared to the control mix. Due to the high strength and toughness of iron filings also its pozzolanic capabilities, mixtures containing 10, 20, 30, and 40% iron filings showed significant increases in split-tensile strength. Iron filings' ductility may also have contributed to the material's increased split-tensile strength. The decreased fineness modulus of iron filings could be responsible for the increased demand for cement in the concrete matrix, which in turn reduces the compressive strength of a mix containing 40% iron filings. It's also possible that iron filings' greater water absorption ability is to blame, reducing the amount of liquid needed for the hydration of cement in the concrete mix. The outcomes of the split-tensile strength tests are shown in Table 3.

Table 3. Indirect tensile strength tests results

% Replacement of fine aggregate	Specimen Size and Type (mm)	Indirect tensile strength (N/mm ²)
0%	100*200(Cylinder)	3.89
10%	100*200(Cylinder)	4.52
20%	100*200(Cylinder)	4.21
30%	100*200(Cylinder)	4.52
40%	100*200(Cylinder)	4.56

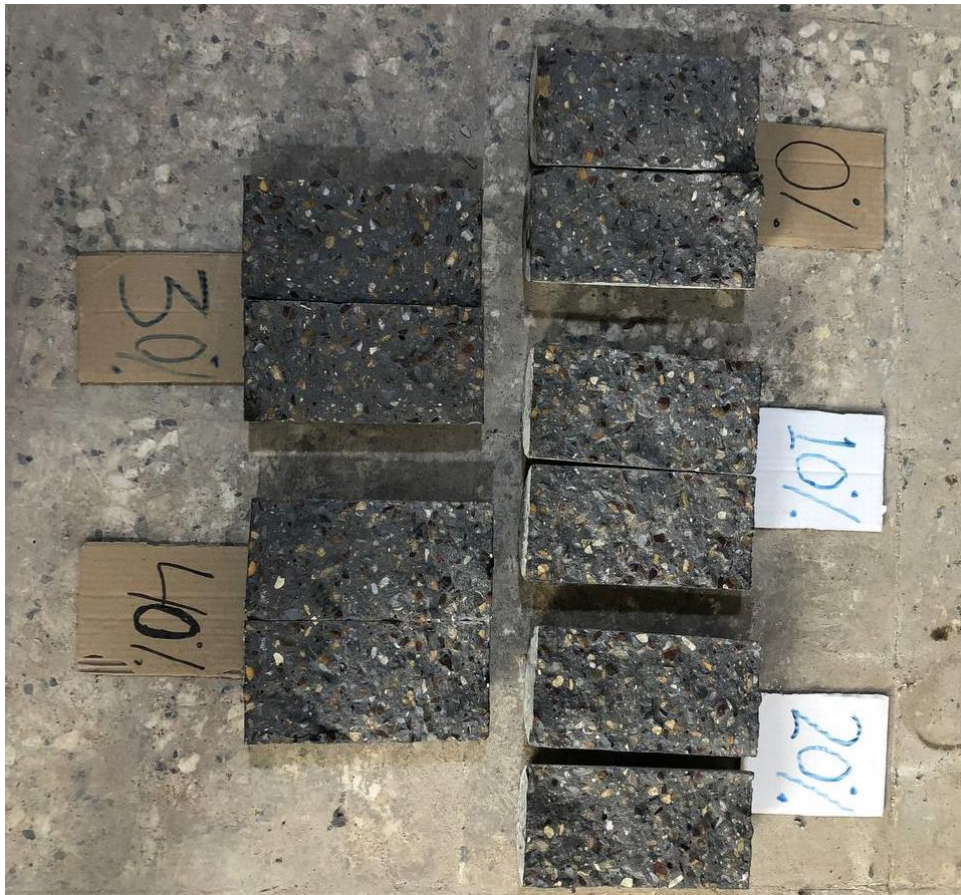


Figure 7. Indirect tensile strength cylinder specimens

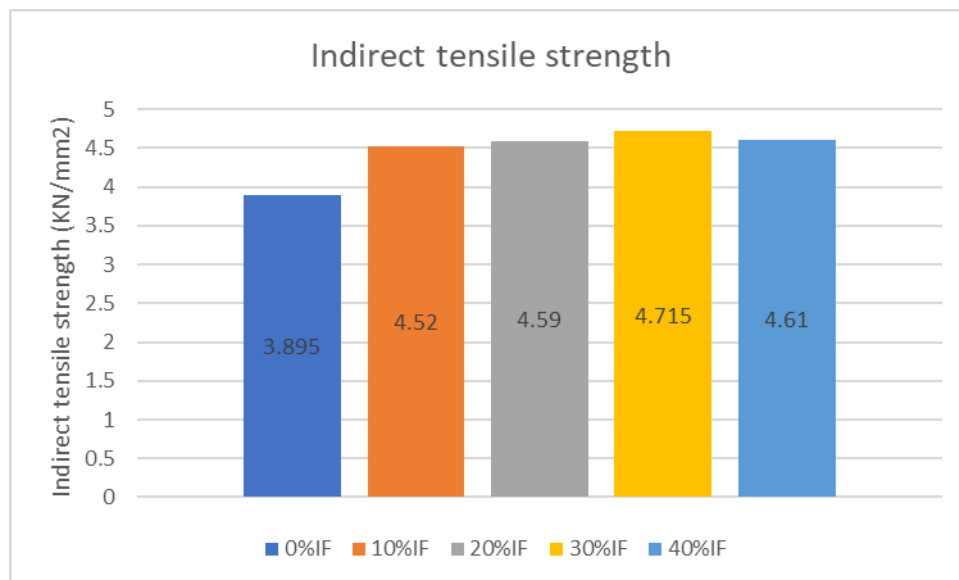


Figure 8. Cylinders with and without iron filings were subjected to indirect tensile strength tests.

5.4. Flexural strength

Beam-shaped specimens 100 mm * 100 mm * length 400 mm were experienced for flexural strength according to ASTM C1018 (Figure 9). The flexural strength was evaluated using a single point of load. In particular, a piece of closed-loop servo-hydraulic dynamic testing equipment with a 2000 kN capacity was used to run the tests. The samples were tested using

procedures designed to limit the spread of strains. The axial strain rate was held constant throughout all of the trials depicted in Figure 3. (c).

Figure 10 displays the typical outcomes of a flexural strength examination. Figure 10 displays the relationship between the percentage of natural aggregates substituted by iron filings and the resulting improvement in flexural strength. When 10%, 20%, 30%, and 40% of the control specimen are swapped out, the flexural strength increases to 4.89, 6.31, and 5.84 MPa, respectively.

Table 4 displays the outcomes of flexural strength tests. Flexural strength increased by 15.68%, 16.15%, 49.88%, and 38.67% when iron filings were used to replace sand at 10%, 20%, 30%, and 40% relative to the control mix (0% iron filings), while it decreased at 40% relative to the 30% iron filings mix. Due to iron filings' strength, toughness, and pozzolanic qualities, the replacement mixes that included iron filings saw a rise in flexural strength. Micro reinforcements made from iron filings are a real possibility in the concrete matrix, enhancing the material's flexural strength in this way Iron filings have a lower fineness modulus, hence more cement is required in the concrete matrix., which may explain why a 30% iron filings mix has lower flexural strength. It's also possible that iron filings' greater water absorption ability is to blame, reducing the amount of water needed for cement hydration in the matrix of concrete itself.

Table 4. Results of flexural strength tests performed on prisms with and without the addition of iron filings

% Surrogate of fine aggregate	Specimen size and type (mm)	Flexural strength (N/mm ²)
0%	100*100*400(prism)	4.21
10%	100*100*400(prism)	4.87
20%	100*100*400(prism)	4.89
30%	100*100*400(prism)	6.31
40%	100*100*400(prism)	5.84



Figure 9. Flexural strength prisms specimens

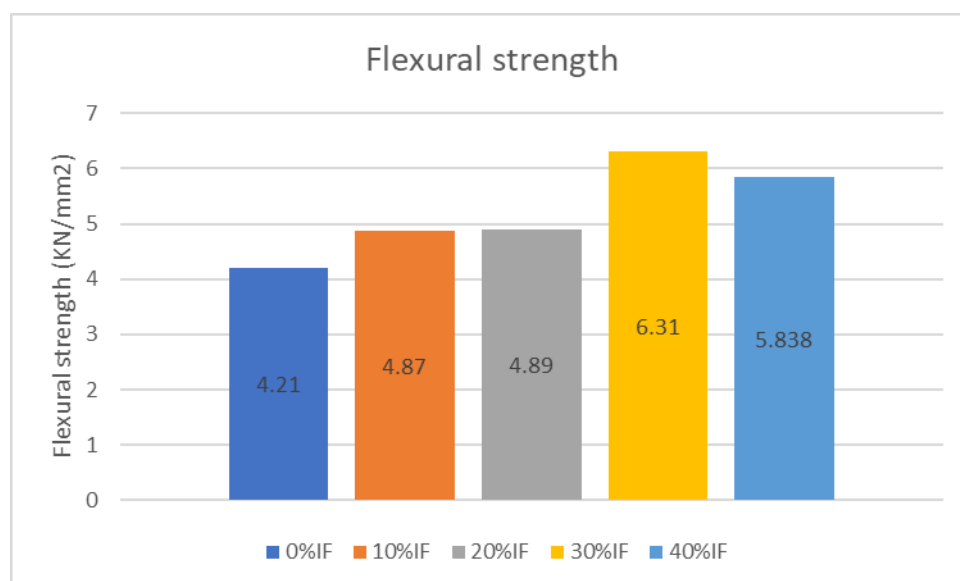


Figure 10. The results of a test to choose the flexural strength of prisms with and without iron filings

6. Conclusion

The following inferences and conclusions are open to consideration in light of the findings that were derived from the experiment that was carried out:

1. Iron filings can be used instead of sand in concrete production since they provide the same purpose (fine aggregate).
2. The manufacturing of concrete with the use of iron filings would result in an improvement in the management of environmental waste and a lucrative utilisation of industrial waste.
3. Iron filings are an ingredient that can be utilised in the manufacturing of heavyweight concrete.
4. When measured against the surveillance mixture, for experimental test of the compressive strength of concrete with iron filings replacing up to thirty percent of the sand showed a thirteen point two percent improvement.
5. The 30% replacement levels increased the concrete's split-tensile strength by 4.7% paralleled to the original control mixture.
6. The concrete's flexural strength rose to 49.9 percent when the replacement amount was raised to 30 percent compared to the original control mixture.
7. Accordingly, a proposal is made regarding based on the perfect strength feature that is needed, suggesting a modification in the weight of fine aggregates in the mixture for concrete by adding iron filings. The replacement's heft had a role in motivating this suggestion.

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