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RESEARCH ARTICLE - ENGINEERING (MISCELLANEOUS)

Effect of Steel Fibers and Iron Filings on Concrete Properties with Partial Replacement of Cement by Fly Ash

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Abstract

Concrete is one of the most used construction materials., Mineral admixtures with pozzolanic characteristics, like silica fume, fly ash, ground granulated blast-furnace slag, and metakaolin, are often used to replace Portland cement in construction projects partially. Concrete faces persistent challenges, such as low tensile strength, brittleness, and a propensity to crack. This comprehensive study explores the improvement of partial substitution of Portland cement concrete properties with fly ash and reinforced with steel fibers and iron filings. In total, 45 cubes (150 mm) and prisms (100x100x500 mm) were tested using an M25 mix, varying the steel fiber volume fractions at 0%, 0.5%, and 1.0%. These specimens were subjected to given curing periods, after which compressive and split tensile strength tests were conducted to assess their performance. For comparison, plain concrete specimens of the same mix were also tested. Also, iron filings were incorporated into the concrete mix at three different percentages (0%, 0.5%, and 1%) to assess their influence on compressive and tensile strengths after 28 days. The results demonstrate that the addition of steel fibers significantly enhances the mechanical properties of concrete. After 28 days, compressive strength increased by 8.5% to 24%, tensile strength improved by 15% to 49.43%, and flexural strength increased by 38.5% to 85%. Similarly, the inclusion of iron filings improved compressive strength by 9.78% initially, followed by a decrease of 13.84% at higher content. Tensile strength increased by 24.05% to 34.43%, while flexural strength improved by 21% to 29.7%. However, both steel fibers and iron filings slightly reduced workability, with slump values ranging from 63 mm to 92 mm depending on the material and its proportion. The outcomes provide a comparative analysis of the effect of steel fibers and iron filings on the mechanical characteristics of concrete, and present valuable understandings for optimizing concrete behavior in construction applications.

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Keywords: Fly Ash; Hardened Concrete; Fresh Concrete; Steel Fiber; Iron Filings; Crack Resistance; Mix Design.

1. Introduction

Steel fiber-reinforced concrete is an innovative composite material consisting of cement, aggregates, water, and tactically integrated steel fibers. These fibers meaningfully mitigate the inherent brittleness of concrete, improving its toughness, compressive and tensile strength, flexural capacity, shock resistance, and fatigue durability. By performing as applicable crack arrestors, the steel fibers reinforce the concrete, stopping the propagation of cracks and contributing to a further resilient and durable structure. These outcomes are in a durable composite with improved crack resistance, greater ductility, and distinct behavior when cracking [1].

Portland cement, fine and coarse aggregates, and irregularly distributed steel fibers as additional ingredients make up steel fiber-reinforced concrete (SFRC). SFRC only fails during tension when the steel fibers are disrupted or separated from the cement matrix [2]. SFRC has excellent flexural and tensile strength, fatigue and shock resistance, ductility, and crack arresting competencies. So, steel fibers have been widely used in numerous professional fields, including construction, architecture, and irrigation [3].

Steel fibers, which come in a variety of configurations like straight, crimped, and hooked, act as tougheners and crack arrestors, enhancing the material's performance. Steel fiber-reinforced concrete (SFRC) overcomes the inherent drawbacks of regular concrete, primarily its brittleness and poor tensile strength.

These steel fibers are positioned strategically within the concrete matrix to greatly improve its overall toughness, flexural strength, and tensile strength. Because of this sophisticated combination, SFRC is a valued asset in construction since it boosts the material's resistance to impact, spalling, and cracking. The exceptional resistance of steel fiber-reinforced concrete (SFRC) to extreme weather conditions, including freeze-thaw cycles and exposure to harsh chemicals, is crucial to its overall performance.

Nomenclature & Symbols			
M25	Mix Design with 25 Mpa	Fcu	Compressive Strength for Cube
SFRC	Steel Fiber-Reinforced Concrete	Ft	Tensile Strength
IQS	Iraqi Specifications	Fr	Flexural Strength
f'c	Compressive Strength for Cylinder		

One of the primary challenges facing modern society is environmental protection. Key features of this issue include reducing energy consumption, minimizing the utilization of natural raw materials, and decreasing waste production. These subjects are gaining significant attention in the context of sustainable development today [4,5].

The disposal of non-biodegradable waste materials requires a lot of work, time, and money and poses a serious environmental risk to living things. Recycling is one of the most efficient ways to deal with this garbage. One such waste product that can be recycled and utilized in a variety of engineering and construction domains is iron filings, which are extremely tiny bits of iron that resemble fine powder [6].

Fly ash is a fine, glassy powder that is extracted from the gases that are created when coal is burned to generate electricity. A large portion of the millions of tons of fly ash produced annually by power stations is usually dumped in landfills. Fly ash, on the other hand, improves the strength of concrete and makes it easier to pump, making it a more affordable alternative to Portland cement. Fly ash is also used in the manufacturing of structural fillers, paving materials, bricks, and blocks.

Fly ash and free lime combine through pozzolanic action to create the same cementitious chemicals as are created when Portland cement is hydrated. In the early phases of curing, fly ash concrete experiences a delayed strength gain due to this chemical reaction. In recent years, some cement manufacturers have begun incorporating fly ash into their cement production, resulting in what is known as "Pozzolana Portland Cement." However, the overall use of fly ash remains low, with most of it still being disposed of in landfills.

Fly ash, or pulverized fuel ash, is the residue captured by mechanical dust collectors or electrostatic precipitators from the exhaust gases of thermal power plants[7].

This study aims to examine the effects of incorporating fly ash as a partial replacement for Portland cement on the properties of concrete. Additionally, it investigates the impact of reinforcing with steel fibers or iron filings and provides a comparative analysis of the resulting mechanical and workability properties.

2. Related Works

2.1. Steel fiber

The impact of coarse aggregate size on the fresh and hardened characteristics of concrete containing steel and synthetic fibers was investigated by Al-Baghdadi and associates. Their findings indicate that larger maximum aggregate sizes significantly enhance the influence of the fibers [8]. According to Ramob et al., the use of a variety of fiber types in mortar, pastes, or concrete can stop fractures from spreading and getting wider at different points in their load-deflection or stress-strain behavior [9].

Yao et al. employed steel with polypropylene fibers and steel with carbon fibers at the same volume fraction (0.5%).Due to the symmetrical modulus and synergistic interaction between the reinforcing fibers, they found that using a mixture of steel and carbon provided the concrete with the highest levels of strength and bending stiffness. They also found that the fibers, when used in a hybrid form, result in superior composite performance [10].

The effect of adding steel fiber on the material's strength characteristics has been further studied in Lightweight Foamed Concrete (LFC). The preparation of three different LFC mixes—a trial mix (LFC-TM), a control mix (LFC-CTR), and a mix with 30 kg/m³ of steel fiber (LFC-30SF)—was made more difficult by this study. Based on a performance index graph, the ideal water-to-cement ratio for both the control and fiber-reinforced mixes was 0.56 when they were cast. Tests on fresh density, flow table, and inverted slump were performed to evaluate the fresh characteristics of the LFC mixes. At 7, 28, and 56 days of curing, the mechanical characteristics, such as compressive strength, splitting tensile strength, and flexural strength, were assessed. The findings showed that the use of steel fiber considerably increased LFC's flexural, splitting tensile, and compressive strengths. However, it was also observed that adding steel fiber improved the fresh LFC's uniformity and flow ability while decreasing its stability. This indicates that whereas steel fiber adds to LFC's mechanical strength, it also affects its properties in its fresh condition, highlighting the need to balance workability and strength when designing LFC blends [11].

2.2. Iron fillings

Alzaed evaluated the feasibility of incorporating iron filings into the concrete mix. After 28 days, the mechanical qualities were measured using four different percentages of iron filings: 0%, 10%, 20%, and 30%. According to the results, adding iron filings to the concrete mix steadily increased its compressive strength, whereas adding more than 10% of iron filings did not influence its tensile strength [12].

The strength characteristics of concrete made using iron filings as a partial substitute for sand at values of 0% (control mix), 10%, 20%, and 30% were examined experimentally by Olutoge. The findings showed that replacing 10% and 20% of the sand with iron filings enhanced the concrete's compressive strength by 3.5% and 13.5%. At the 30% replacement level, however, there was an 8% drop.

Similarly, as compared to the control mix, the split tensile strength of concrete rose by 12.7% and 1% for the 10% and 20% replacement levels, respectively, but slightly dropped by 1.7% at the 30% replacement level. These findings suggest that, depending on the performance requirements, iron filings should replace 10% to 20% of the weight of sand (fine aggregates) in the manufacture of concrete. [13].

2.3. Fly ash

Concrete samples with 15%, 30%, and 45% fly ash replacement ratios were evaluated at 7 and 28 days to determine their compressive strength. The results were compared to concrete specimens without fly ash at the same ages by Case, J. and R. [14]. The results demonstrate that, in comparison to fly ash-free concrete, fly ash-containing concrete becomes stronger over time but does so more slowly. The maximum strength of the 28-day-old specimens exceeded that of concrete without fly ash, indicating that there is an ideal fly ash replacement ratio where the highest compressive strength can be attained.

One of the main goals, according to Bendapudi S.C.K. and Saha P. [7], is to use less Portland cement, which can be successfully achieved by substituting some of it with other cementitious materials. Fly ash, a byproduct of burning coal, is one of the most well-known and efficient substitutes. About 75 million tons of fly ash are produced in India each year, which poses a serious disposal problem for the environment.

It is evident from the above that all previous studies added steel fibers and iron filings to normal concrete or added one of these two components to concrete with different properties. The significance of the current research lies in utilizing eco-friendly concrete containing a waste material as a substitute for cement, comparing its performance to concrete enhanced with steel fibers or iron filings.

3. Experimental Procedure

The procedures for carrying out our experiment will be described in this section. Fly ash is typically used to replace 30% of Portland cement; in mass concrete applications, even larger percentages are utilized. The amount of cement removed is equal to or greater than the weight of fly ash that is substituted.

3.1. Materials and mixing

3.1.1. Cement

Ordinary Portland cement is used in this study [15]. Chemical and physical properties are listed in Tables 1 and 2.

Table 1. Chemical properties of Ordinary Portland cement

Composition	Chemical properties	Weight (%)	According to (IQS N0.5/2019)
Lime	CaO	62.57	----
Alumina	Al_2O_3	3.96	----
Silica	SiO_2	23.95	----
Magnesia	MgO	2.44	<5.00
Iron	Fe_2O_3	4.52	----
Sulfate	SO_3	2.11	<2.50
Loss on ignition	L.O.I	1.30	4.0
residue Insoluble	I.R	1.42	1.5
The factor of Lime saturation	L.S.F	0.83	0.66 -1.02

Table 2. Physical properties of cement

Physical properties		Values	According to Iraqi specifications (I.O.S.5/2019)
Time of setting (Vicats method)	Early setting (hr:min)	4:23	≤ 00:45
	Last setting (hr:min)	5:35	≤10:00
Fineness m^2/Kg		312	≥250
Compressive strength, MPa	3 days	25.7	≥15:00
	7 days	29.68	≥23:00
(Autoclave)		% 0.17	≤0.8

3.1.2. Fly Ash

Fly ash comes in two primary varieties: Class F and Class C. Both varieties exhibit comparable behaviour in concrete, going through a "pozzolanic reaction" with the lime (calcium hydroxide) that is created when cement and water react chemically. This technique creates calcium silicate hydrate, which is the same binder used in cement. In addition to the pozzolanic reaction with the lime from cement hydration, some Class C fly ashes have sufficient lime to demonstrate self-cementing qualities. The chemical composition of fly ash is shown in Table 3. Fly ash from the Iskenderun power station, Turkish hard coal, was employed in this investigation. It met DIN EN 450-Fly Ash for Concrete requirements as shown in Fig. 1.

Table 3. Fly Ash chemical composition

Composition	Chemical properties	Weight (%)
Lime	CaO	0.97
Alumina	Al_2O_3	17.66
Silica	SiO_2	65.55
Magnesia	MgO	0.74
Iron	Fe_2O_3	5.92
Sulfate	SO_3	0.18
Loss on ignition	L.0.I	3.10
Sodium oxide	Na2O	1.36
Potassium oxide	K2O	2.93

Fig. 1. Fly Ash

3.1.3. Coarse aggregate

The crushed gravel (20 mm) maximum size conforming to "Iraqi Specification No.45/1984 [16], was utilized in this study as shown in Fig. 2. Grading and physical properties of coarse aggregate are listed in Tables 4 and 5, respectively.

Table 4. Grading of coarse aggregate

Size of sieve	Passing %	
	Coarse aggregate	According to (IQS No. 45/1984 standards)
Percentage of Passing	100.00	100.00

Table 5. Physical properties of coarse aggregate

Physical properties	Amount	(IQS No. 45/1984 standards)
Specific gravity	2.66	-
Sulfate content SO3	0.6%	-
Absorption	0.043%	0.1%

Fig. 2. The coarse aggregate

3.1.4 Fine aggregate

Natural sand with a maximum size of 4.75 mm was used and conformed to [17] as shown in Fig. 3. Classification and characteristics of sand are shown in Tables 6 and 7 respectively.

Table 6. Classification of sand

The sieves	Passing (%)	
	sand	According to (IQS No. 45/1984 standards)
Sieve size (10) mm	100.0	100.0
Sieve size (4.75) mm	91.0	90.0-100.0
Sieve size (2.36) mm	82.0	75.0-100.0
Sieve size (1.18) mm	75.0	55.0-90.0
Sieve size (0.6) mm	53.0	35.0-59.0
Sieve size (0.3) mm	22.0	8.0–30.0
Sieve size (0.15) mm	5.0	100.0

Table 7. Characteristics of sand

Physical Characteristics	Results of Test	Limits of (IQS No. 45/1984 standards)
Specific gravity	2.64	-
(SO_3) Content	0.08%	≥0.5
Absorption	0.75%	-
Sieve size	Passing %	
	Coarse aggregate	According to “Iraqi Specification No.45/1984”
14 mm	100.0	100.0

Fig. 3. Fine aggregate

3.1.5. Water

Locally available tap water, free from impurities, chemicals, and organic matter, was used in this study.

3.1.6. Iron fillings

In this study the iron fillings were obtained from the workshop’s areas in Baghdad, as shown in Fig. 4. Sieve analysis of iron filings is shown in Table 8.

Table 8. Sieve Analysis of Iron Filings

Size	Pass percentage	(IQS No. 45/1984 standards)
4.75	100	90-100
2.36	99.32	75-100
1.18	87.18	55-90
0.6	36.26	35-59
0.3	10.3	8-30
0.15	3.25	0-10

Fig. 4. Iron filings

3.1.7. Steel fibers

This study utilizes hooked-end steel fiber (65/35) to facilitate comparison as shown in Fig. 5. Three different dosage levels of steel fiber are recommended for evaluation: 0%, 0.5%, and 1%. The physical characteristics of the steel fiber are detailed in Table 9 according to the manufacturer, while Table 10 outlines the proportions and composition of the concrete mixtures.

Fig. 5. The shape of the steel fibers

Table 9. Characteristics of fibres

Type	Diameter(d) (mm)	Length(l) (mm)	Aspect ratio l/d	Yield strength (Fy) (MPa)
Hooked fiber (KF 65/35)	0.52	37	71	900.0 – 2200.0

3.2. Mixing procedure

3.2.1. Mixing specimens with steel fibers

The components were mixed using a revolving mixer. The process began by thoroughly combining the sand, cement, fly ash and gravel, followed by the gradual addition of water as necessary. Steel fibers were then integrated into the fresh concrete at specified dosages of 0.0%, 0.5%, and 1.0% by volume. After initial mixing and collection, the mixture was thoroughly homogenized. The prepared mixes were divided into different sample groups, including 150 mm cubes, cylinders with a diameter of 10 cm and a length of 20 cm, prisms measuring 10x10x50 cm, and direct examination samples with dimensions detailed in Fig. 6.

The test samples were cured by submerging them in a water tank for one day and 28 days. After curing, the samples were degassed and allowed to dry for a day before testing. The bending strength was evaluated using a uniaxial load device, while the flexural strength was tested on 10x10x50 cm prisms, applying the load across three equal sections of the prism length. Table 10 provides the mix proportions for all samples.

3.2.2. Mixing for specimens with iron filling

The procedure began with preparing and weighing the materials in the laboratory, followed by casting the required cubes and cylinders for testing. The concrete mixture, depicted in Fig. 6 was first blended without water. To ensure that the mixture was homogenized with the designated iron filings dosages of 0.0%, 0.5%, and 1.0% by volume of concrete, water was then added gradually while the mixer was operating. Prisms sized 10x10x50 cm, cylinders with a diameter of 100 mm and a length of 200 mm, and 150 mm cubes were used in this investigation. At 28 days, a total of 36 cubes were cast to test the concrete's compressive strength, and at the same age, a matching number of cylinders were used to test the tensile strength. The mix proportions for each sample are shown in Table 10.

Table 10. Mix proportions for all mixes

Mix design	Cement (kg/m3)	Fly ash (kg/m3)	Fine Aggregate (kg/m3)	Coarse Aggregate (kg/m3)	Water (kg/m3)	Steel fiber Vf%	Iron filling Vi%
1	350	….	700	1400	151	0	0
2	290	105	717	1024	190	0.5	....
3	283	105	653	1200	178	1	....
4	290	105	717	1024	190	....	0.5
5	283	105	653	1200	178	....	1

Fig. 6. Experimental work and mixing

4. Fresh Concrete Testing

Table 11 shows the results of the slump test for partial replacement concrete with fly ash and reinforcing with steel fiber and iron filling. A slump test was conducted on three concrete mixtures: one plain concrete mixture and two fiber-reinforced concrete mixtures. Experimental results show that concrete containing 1% iron filings exhibited the highest slump value, followed by concrete with 0.5% iron filings, concrete with 0% iron filings, and finally the control sample. These slump values indicate that the workability of all four concrete mixes fall within the plastic range. Notably, the mix with 1% iron filings achieved the greatest slump value compared to the other mixes.

Table 11. Slump test

Mix Type	Slump result (mm)
0%	30
0.5% steel fiber	80
1% steel fiber	92
0.5% iron filling	63
1% iron filling	69

5. Hardened Concrete Testing

5.1 The strength of compression

The average compressive strength values for three cylindrical samples from each mixture, tested with different fiber contents (0%, 0.5%, and 1%), after 28 days are shown in Tables 12 and 13 as well as Figs. 7 and 8. The results show that the compressive strength of concrete increases as the fiber content rises. In particular, the compressive strength of cylinders with hook-end steel fibers increased by 8.5% and 24.11%. Because hook fibers slow the spread of cracks, they were more successful in increasing the compressive strength of specimens with iron fillings at the same fiber volume fractions (0%, 0.5%, and 1%). In contrast to the abrupt failure seen in typical concrete samples, the failure mode in fiber-reinforced samples was also more gradual. Because of minor compositional variations, the hydration reaction between fly ash and water happens significantly more slowly than the interaction between cement and water, which results in slower strength development for fly ash-containing concrete than for fly ash-free concrete.

Table 12. Mechanical properties of fiber reinforced concrete

Mix design	**Ratio of steel fiber (Vf)**	**f'c 28 days (MPa)**	**Ft 28 days**	**Fr 28 days**	**Density kg/m3**
1	0	22.15	2.61	3.61	2305
2	0.5	24.03	3	5	2476
3	1	27.49	3.9	6.7	2510

Table 13. Mechanical properties of concrete with iron filling

Mix design	**Ratio of iron filling (Vi)**	**Fcu 28 days**	**f'c 28 days (MPa)**	**Ft 28 days**	**Fr 28 days**	**Density kg/m3**
1	0	25.37	20.30	2.37	2.74	2200
2	0.5	27.85	22.28	2.94	3.315	2320
3	1	21.86	17.49	3.186	3.554	2350

Fig. 7. The compression strength test

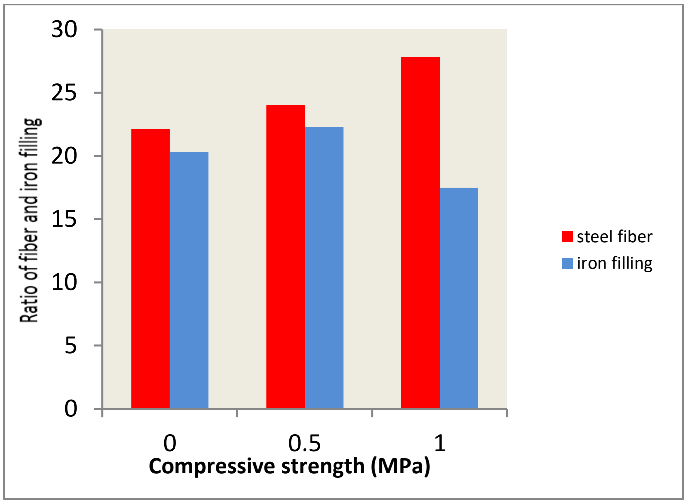

Fig. 8. Changes of compressive strength for steel fibers and iron filling mixes

5.2. Splitting strength

The impact of steel fibers and iron filings on tensile strength is illustrated in Tables 12 and 13 and Fig. 9. The fiber-reinforced samples demonstrated a higher tensile strength, making them less prone to cracking compared to regular concrete and concrete containing iron filings. The failure in fiber-reinforced samples was gradual, whereas it was sudden in both normal concrete and iron-filing concrete samples. Samples with iron filings also exhibited higher tensile strength and were less likely to crack compared to regular concrete. The tensile strength increased by approximately 15% and 49.43% when fibers were added. The enhanced tensile strength is attributed to the friction bond between the fibers and the concrete mixture, which allows the steel fibers to yield by being pulled out rather than breaking under tensile stress. The mode of failure is shown in Fig. 10.

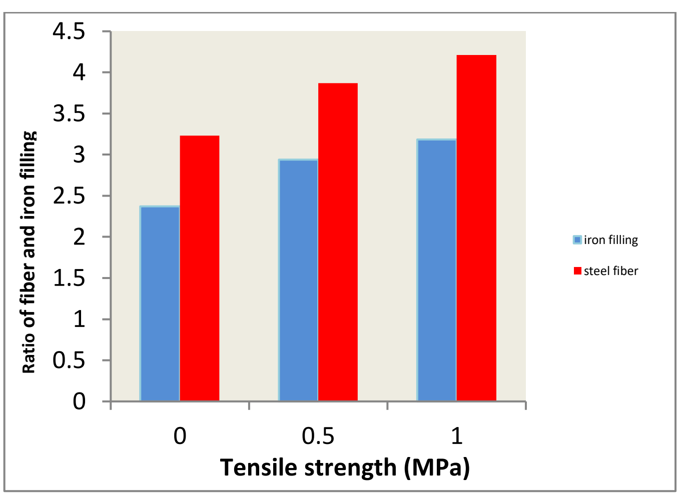

Fig. 9. Changes in tensile strength for steel fibers and iron filings

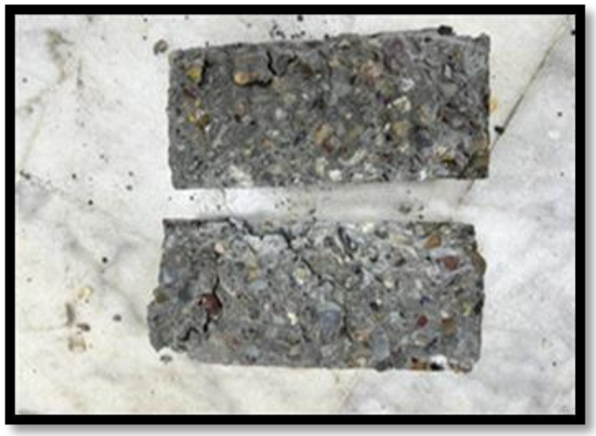

Fig. 10. The splitting strength test

5.3. Flexural strength

The possibility of steel fibers spreading evenly throughout the concrete decreases marginally with increasing fiber length, as seen in Tables 12 and 13, and Fig. 11. This may be because there are fewer steel fibers in the mixture overall, which causes their dispersion to be more erratic. As shown in Table 10, the addition of steel fibers considerably increased the flexural strength by 38.5% and 85.6% in comparison to the control sample. The flexural strength of the concrete can be greatly increased by adding fibers before the matrix cracks and before the interfacial bond between the matrix and fibers is broken. Steel fibers and iron filings were used in conjunction for prism testing. Because steel fibers have a much higher tensile strength than concrete, they can be drawn out during prism fracture without the concrete completely breaking. In general, concrete's flexibility and durability are enhanced by adding more steel fibers. Table 10 shows how different kinds of steel fibers affect the concrete's bending strength. Because the steel strands were retrieved without snapping, a prism reinforced with steel fibers did not completely disintegrate when bent. Unlike the behavior seen in prisms without reinforcement, this phenomenon is probably caused by the steel fibers' high tensile strength, which contrasts with the concrete's lower tensile strength.

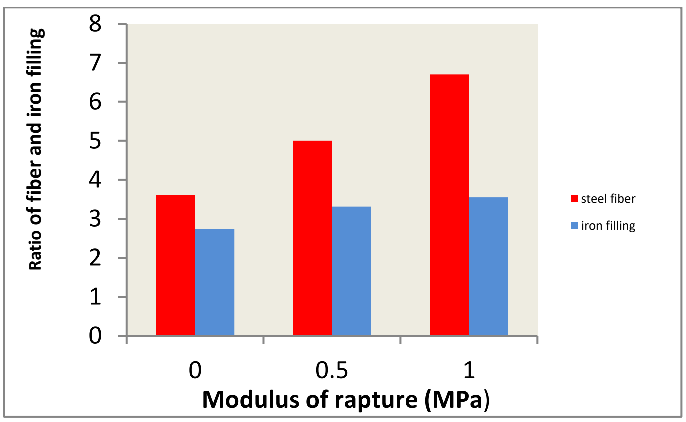

Fig. 11. Changes of Flexural strength for steel fibers and iron filling

5.4. Dry density

Density refers to the mass per unit volume of hardened concrete expressed in kilograms per cubic meter. This test was conducted according to B.S. 1881, part 114-1983 [18]. For this test, the specimen was a cube with dimensions (150x150x150) mm. Tables 12 and 13 and Fig. 12 display the density of fiber and iron filling concrete specimens.

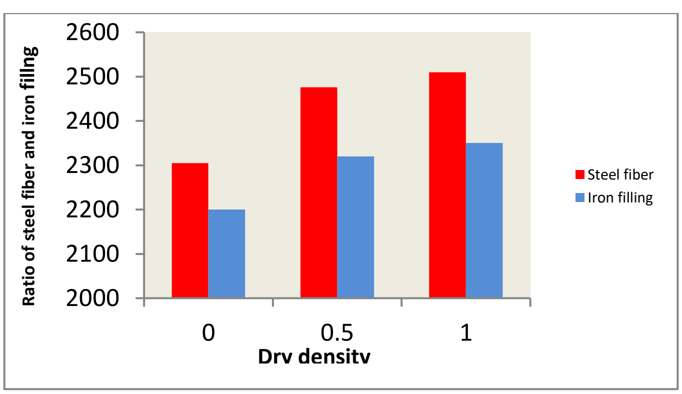

Fig. 12. Changes of Dry Density for steel Fibers and iron filling

6. Conclusion

This study highlights the differential impacts of steel fibers and iron filings on the mechanical properties of concrete with partial replacement of cement with fly ash, offering valuable insights for future material optimization.

- The concrete's compressive, tensile, and flexural strengths were greatly increased by the insertion of steel fibers. The addition of fibers resulted in a 24.11% increase in compressive strength. The tensile strength increased by 49.43% and peaked at 1% fiber content, indicating a significant improvement. Similarly, flexural strength steadily rose as fiber content increased, reaching a maximum improvement of 85.6%. These enhancements can be ascribed to steel fibers' capacity to strengthen the concrete's overall toughness, improve load distribution, and bridge cracks. Higher fiber content resulted in a decrease in workability, as shown by lower slump values, but it also significantly increased compressive and tensile strengths.
- Steel fibers, owing to their uniform distribution within the concrete matrix, proved to be highly effective in improving the tensile properties, underscoring their role as a robust reinforcement material.
- The addition of iron filings increased the concrete's density by filling voids, resulting in density increases of 5.45% and 6.82%. However, despite this densification, the compressive strength of the concrete was lower compared to that of steel fiber-reinforced concrete.
- As the proportion of iron filings in the concrete rose, a notable improvement in its mechanical qualities was seen. Tensile and flexural strengths increased by 34.43% and 29.7%, respectively, while compressive strength increased by a maximum of 9.75%. These improvements are probably due to the concrete matrix's densification and the iron filings' natural toughness, which improved load distribution and crack resistance.

All things considered, the results indicate that steel fibers provide a more successful reinforcement approach than iron filings, especially in applications that call for increased tensile and flexural strength. Steel fibers are a desirable option for advanced concrete applications where strength and durability are crucial due to their superior mechanical performance, which is fueled by their distribution and high tensile capacity. The synergistic effects of mixing these materials should be further explored in future studies to maximize the trade-off between mechanical performance and workability.

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References

[1] L. Das and Md. Kumruzzaman, "Strengthening concrete; unbridling the potential of steel fiber reinforcement," 7th International Conference on Mechanical Engineering and Renewable Energy, Chattogram, Bangladesh, Nov. 2023.
[2] ACI Committee 544, "State-of-the-Art Report on Fiber Reinforced Concrete," ACI 544.1 R-96, American Concrete Institute, 1996.
[3] V. S. Vairagade and K. S. Kene, "Introduction to steel fiber reinforced concrete on engineering performance of concrete," Int. J. Sci. Technol. Res., vol. 1, no. 4, pp. 139-141, 2012.
[4] A. Lyons, Materials for Architects & Builders, United Kingdom: Butterworth-Heinemann Publishers, 2004.
[5] A. M. Neville, Properties of Concrete, 5th ed., 2011.
[6] M. N. AL-Hashimi and W. S. Najim, "Performance of concrete containing iron fillings," J. Univ. of Babylon for Eng. Sci., vol. 26, no. 6, 2018.
[7] S. C. K. Bendapudi and P. Saha, "Contribution of fly ash to mortar and concrete properties," Int. J. Earth Sci. Eng., vol. 4, pp. 1017-1023, 2011.
[8] H. M. Al-Baghdadi, F. H. Al-Merib, A. A. Ibrahim, R. F. Hassan, and H. H. Hussein, "Effects of coarse aggregate maximum size on synthetic/steel fiber reinforced concrete performance with different fiber parameters," Buildings, vol. 11, no. 1, p. 158, 2021.
[9] D. Ramob D., A. S. Silva, F. D. A. Silva, and R. D. T. Fillho, "Flexural behavior of hybrid steel fiber reinforced self-consolidating concrete," vol. 67, 2014.
[10] W. Yao, J. Li, and K. Wu, "Mechanical properties of hybrid fiber-reinforced concrete at low fiber volume fraction," Cement and Concrete Research, vol. 33, pp. 27-30, 2003.
[11] S. K. Lim, W. Y. Wong, M. K. Yew, and H. Y. Chong, "Strength properties of lightweight foamed concrete with steel fibre," J. Inst. Eng. Malaysia, 2024.
[12] F. A. Olutoge, M. A. Onugba, and A. Ocholi, "Strength properties of concrete produced with iron filings as sand replacement," Br. J. Appl. Sci. Technol., vol. 18, no. 3, 2016.
[13] A. N. Alzaed, "Effect of iron filings in concrete compression and tensile strength," Int. J. Recent Develop. Eng. Technol., vol. 3, pp. 1-6, 2014.
[14] [14] R. Case, J. Duan, and T. G. Suntharavadivel, "On effects of fly ash as a partial replacement of cement on concrete strength," Appl. Mech. Mater. J., 2012.
[15] Central Agency for Standardization and Quality Control, Portland Cement, IQS No.5/2019, Planning Council, Baghdad, Iraq, 2019.
[16] Central Agency for Standardization and Quality Control, Aggregate from Natural Sources for Concrete, Iraqi Specification No. 45/1984, Planning Council, Baghdad, Iraq, 1984.
[17] E. S. Berney IV and D. M. Smith, "Mechanical and physical properties of ASTM C33 sand," Geotechnical and Structures Laboratory, U.S. Army Engineer Research and Development Center, 2003.
[18] British Standard, Methods for determination of density of hardened concrete, BS 1881-114:1983, 1983.