Effect of using waste-iron on the mechanical properties of concrete

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Abstract

The aim goal of this research was to study the effect of using the waste-iron which product from milling processes on the mechanical properties of concrete. The tests performed to evaluate waste-iron concrete are compressive strength, splitting tensile strength and flexural strength tests. Sixty cubes of concrete for the compressive strength, sixty cylinders of concrete for the tensile strength, and Sixty prisms of concrete for the flexural strength tests with different volume fractions of waste-iron (1%, 2%, 3% and 4%) were prepared. The specimens were tested at 7, 14 and 28 days age. The results show that the concrete mixes with waste-iron have a higher compressive strength, tensile strength and flexural strength than the plain concrete mixes. Concrete containing volume fractions 3% ratio of waste-iron has the maximum value of compressive strength, tensile strength and flexural strength. The primary effect for adding the waste-iron to the concrete is to improve the post-cracking behavior.

Keywords: plain concrete, waste-iron, Slump test, compressive strength, tensile strength and flexural strength.

تأثير أستعمال برادة الحديد على الخواص الميكانيكية للخرسانة

الخلاصة

الهدف من هذا البحث هو دراسة تأثير اضافة برادة الحديد الناتجة من عملية التفريز الى الخرسانة ودراسة تأثيرها على الخواص الميكانيكية للخرسانة ، لقد تمت دراسة مقاومة الإنضغاط ومقاومة الشد ومقاومة الإنثناء. في هذه الدراسة تم صب ٦٠ مكعب لفحص مقاومة الإنضغاط و٦٠ أسطوانة لفحص مقاومة الشد و٦٠ موشور لفحص مقاومة الإنثناء بنسب حجمية مختلفة من برادة الحديد (١%، ٢%، ٣%، ٤%) ، هذه الفحوصات تمت بأعمار مختلفة للخرسانة ٧ و ١٤ و ٢٨ يوم.

أظهرت النتائج بأن الخلطات الحاوية على برادة الحديد لها مقاومة أنضغاط ومقاومة شد انشطاري ومقاومة أنثناء أعلى في الخلطات الحاوية على برادة الحديد. الخرسانة الحاوية على برادة الحديد بنسبة ٣% أعطت اعلى زيادة في مقاومة الإنضغاط ومقاومة الشد ومقاومة الإنثناء. والتأثير الأكبر لبرادة الحديد هي زيادة مقاومة التشقق للخرسانة.

Introduction

The main goal of this research is to improve the mechanical properties for the concrete by using the recycle material, waste-iron. The reuse of waste is important from multiple points of view: it helps to save and sustain natural resources which cannot be replenished, it decreases the pollution of the environment and it helps to save and recycle energy in production processes.[8]

The concrete industry has begun adopting a number of methods to achieve goals [9] and [١] investigated the use of steel slag as an aggregate for concrete mixes; based on the short-term results and the crushing strengths; “slagcrete” appeared to have potential in the construction industry. Ghailan, [7] Utilized an industrial solid waste produced from the iron and steel industry. It was physically treated, fully inspected and incorporated into concrete coarse aggregate. The results confirmed that concrete mixes made with the waste material gave a higher modulus of rigidity, higher rebound number and higher chemical resistance towards the exposure to acids/ salts solutions as compared with conventional concrete mixes. [12] demonstrated that using waste iron filings as partial replacement of fine aggregate in concrete mixes offers higher strength values than that for the plain mixes.

Iron represents one of the major constituents of industrial solid waste are likely to include iron and steel manufacturing plants, as well as small and medium –sized workshops. Although there are no reliable data on the quantities of these wastes generated in Iraq. There are clear signs of a sharp increase in their accumulated quantities as discarded solid wastes due to the absence or poor functioning of systems for the collection, treatment and disposal of these wastes. The main goals of this study were to investigate the following:-

- Improve the properties of concrete by using the cheaper method, using the waste iron.
- The feasibility of reusing waste iron in concrete mixes in order to reduce the environmental impact resulting from waste iron disposal.

1. Materials

2.1 Cement:-

Type I Portland cement was used in this investigation, chemical analysis of the cement was carried out according to ASTM C150 and Iraqi standard No.5/1984. The chemical composition and physical properties of the cement are determined by the structural lab in the Engineering collage at Thi-Qar University. The chemical composition and physical properties presented in Table 1 and 2 respectively.

Table 1.Chemical composition of cement

Compounds	% (by weight)	Limit of Iraqi specification No. 5/1984
Lime	64.43	-
Silica	21.14	-
Alumina	5.78	-
Iron oxide	3.59	-
Sulfite	2.35	< 2.8%
Magnesia	1.52	< 5%
Loss of ignition	0.89	< 4%
Lime saturation factor	0.92	0.66 – 1.02
Insoluble residue	0.34	< 1.5
Main compounds (Bogue's equation) % by weight		
Name of compounds		
Tricalcium silicate	50.83	
Dicalcium silicate	22.30	
Tricalcium aluminate	9.25	
Tetra calcium aluminoferrite	10.90	

Table 2:- Physical properties of cement

Properties	Limit	Limit of Iraqi specification No.5/1984
Fineness (m^2/kg)	269.50	230 (min)
Initial setting time (min)	3:20	0:45 (min)
Final setting time (h)	4:15	10:0 (max)
Soundness	0.19	0.8 (max)
3 days age compressive strength (Mpa)	24.96	15 (min)
7 days age compressive strength (Mpa)	30.80	23 (min)

2.2 Coarse aggregate

Natural crushed stone aggregate with bulk density of 1545 kg/m^3 and was used in this study. The properties and gradation of the coarse aggregate are shown in Table (3).

Table 3:- Properties and gradation of the coarse aggregate

No. Sieves (mm)	Percentage of Passing	Limit of Iraqi specification No. 45/1984
37.5	100	100
20	98	95-100
10	46	30-60
4.75	3	0-10
So_3 %	0.085	≤ 0.1

2.3 Fine aggregate:-

Natural sand of desert origin the properties and gradation of the fine aggregate in the third zone are shown in Table (4).

Table 4:- Properties and gradation of the fine aggregate

No. Sieves (mm)	Percentage of Passing	Limit of Iraqi specification No. 45/1984
9.5	100	100
4.75	97	90-100
2.36	87	85-100
1.18	79	75-100
0.6	65	60-79
0.2	22	12-40
0.15	3	0-10
So_3 %	0.482	≤ 0.5

2.4 Waste iron:-

Waste iron was obtained from the Engineering workshops in the Engineering collage at Thi-Qar University. This type of waste iron is normally generated in tremendous quantities from the milling operation in these workshops. A sample of the waste iron utilized in this study was shown in Fig. 1. The shape of this waste iron was spiral and it had a range length of 4cm. the aspect ratio is 1:8. The effect on workability is the aspect ratio (*l/d*) of the fibers. The workability decreases with increasing aspect ratio, in practice it is very difficult to achieve a uniform mix if the aspect ratio is greater than about 100.[15]

The chemical composition of the waste iron was determined by the state Company for Geological Survey and Mining in Iraq. The chemical composition and physical properties of the waste iron are presented in Tables 5 and 6, respectively.

Table 5:- Chemical composition of waste iron

Compounds	% (by weight)	Test method
Fe_2O_3	93.14	Titration with potassium dichromate using biphenyl amine as the indicator
Al_2O_3	<0.03	Auto color analyzer

Table 6:- Physical properties of waste iron. [2]

Properties	Limit	Test method
Fineness modulus	2.65	F.M=Accumulative percentage retained/100
Specific gravity	4.50	Somayaji, 1995
Density (kg/m^3)	1946.70	ASTM C29-87
Color	Black-gray	

Fig. (1) Waste-iron produced from milling process

2. Experimental Work:-

2.1 Mix Proportions:-

Two types of concrete mixes were prepared according to the British standard in this study reference concrete mixes consisted of sand (715 kg/m^3), gravel (1020 kg/m^3), cement (380 kg/m^3) and a water-to-cement ratio of 0.53. The other concrete mixes were made with waste iron with different volume fractions (1%, 2%, 3% and 4%). Both types of concrete mixes were cured for 7, 14, and 28 days.

2.2 Preparation of concrete specimens :-

Sixty cubes of concrete were molded for test the compressive strength. Sixty cylinders of concrete were molded for test the tensile strength. Sixty prisms were casted for testing the flexural strength. Casting, compaction and curing were conducted according to B.S. 1881-111:1997. Concrete casting was accomplished in three layers of 50 mm each. Each layer was compacted using a vibrating table for (1-1.5) min according to B.S. 1881-116:1997. until no air bubbles emerged from the surface of the concrete mold. The specimens were then left at room temperature. After 24 hours the concrete was removed from the molds, marked and submerged in fresh, clean water and then tested at a specified age. The slump test was carried out according to B.S. 1881-102:1997.

2.3 Testing of concrete specimens:-

The most common concrete tests carried out in this study are the Compressive Test, Tensile Test and Flexural Test.

3.3.1 Slump Test

Slump test was carried out according to B.S. 1881-102:1997.

3.3.2 Compressive Strength Test

Concrete 150mm cubes, compressive test machine hydraulic test machine (MATEST) was used to complete this test. Sixty cubes with 0, 1%, 2%, 3% and 4% volume fraction of waste iron; four cubes for each ratio and for each curing periods 7, 14 and 28 days were used for this test. The compressive strength was carried out according to B.S. 1881-128:1997. .

3.3.3 Splitting tensile Strength Test

Sixty cylinders (150x300) mm with different volume fractions 0, 1%, 2%, 3% and 4% volume fraction of waste iron, four cylinders for each ratio and for each curing periods 7, 14 and 28 days were tested. Splitting tensile strength was carried out according to B.S. 1881:1997.

3.3.4 Flexural Strength Test

Flexural test machine was used to complete this test. Sixty prisms (100 x 100 x 500mm) with different volume fractions (0, 1%, 2%, 3% and 4%) of waste iron were prepared, four prisms for each ratio and for each curing periods 7, 14 and 28 days. The specimens were cured; then tested according to B.S. 1881-128:1997.

3. Results and Discussion

The performance of the waste-iron was evaluated by determining the compressive strengths, tensile strengths and flexural strengths of the concrete specimens containing different volume fractions of waste-iron.

4.1 Workability of mixes

The results of the slump tests are presented in Table 7. The results demonstrate the tendency of the slump to decrease below the reference mix by 4.32%, 13.11%, 17.84%, and 29.60% for concrete mixes with different volume fractions 1%, 2%, 3% and 4% waste-iron respectively. This tendency might be due to the heterogeneity and shapes of the waste-iron particles, which lead to lower fluidity of the mixes.

Table 7: Slump of waste iron concrete mix

% Waste iron	0	1%	2%	3%	4%
Slump (cm)	7.4	7.08	6.43	6.08	5.21
Percentage decrease in slump	0	4.32	13.11	17.84	29.60

4.2 Compressive Strength

Compressive strength test results show that the compressive strength of waste-iron specimens increased with the increasing the ratio of waste-iron for all curing periods. Table 8 presents the increasing ratios of the compressive strengths of these mixes.

Table 8: Compressive strength of waste iron concrete mix

Volume fraction of waste iron	Comp. strength at 7 days (MPa)	Increasing ratio in 7 days	Comp. strength at 14 days (MPa)	Increasing ratio in 14 days	Comp. strength at 28 days (MPa)	Increasing ratio in 28 days
0	25.05	0.00	28.85	0.00	31.15	0.00
1	27.87	11.25	31.37	8.75	34.57	10.97
2	29.47	17.64	33.02	14.47	37.89	21.65
3	31.53	25.87	34.33	18.98	40.26	29.24
4	30.76	22.78	33.94	17.65	38.79	24.52

The results show that using waste-iron on the compressive strength of concrete for all curing periods relative to the reference mix. The effect of this type of waste-iron was similar to that for steel fiber reinforcement. The result shows that adding the waste-iron in the concrete result the increasing in compressive strength at all curing periods. The highest compressive strength was that in the concrete mixes made of volume fraction 3% of waste-iron fiber at 28 days curing period, which is 29.24% higher than the reference mix at the same curing period. In the volume fraction 4% of waste-iron had lower increasing in compressive strength than in the volume fraction 3% of waste-iron, this caused by the percentage decrease in slump was higher in the volume fraction 4% of waste-iron and this lead to decreasing the compact factor. However, the waste-iron does substantially increase the post-cracking ductility, or energy absorption of the material.[17]. The results shown in Fig.(3).

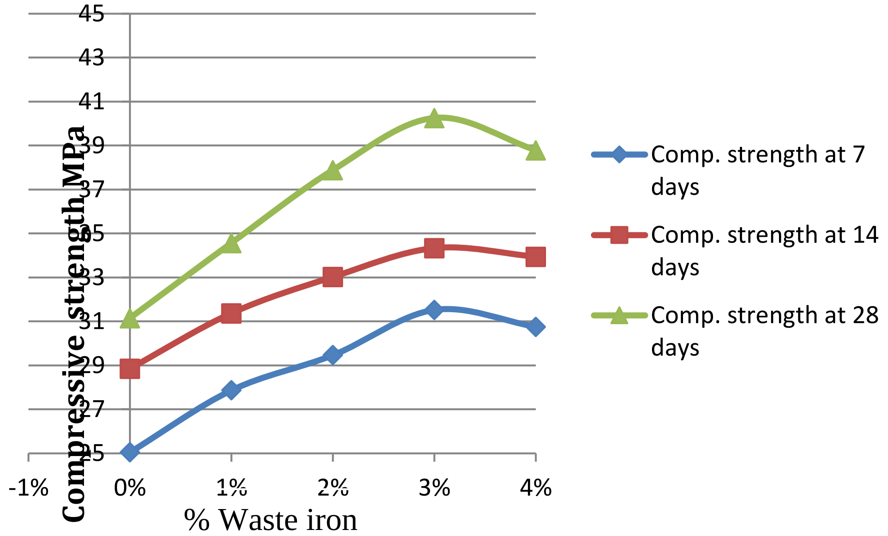

Fig.(3). Compressive strength of waste iron concrete mixes

(a) **(b)**

Fig.(4) Concrete specimens after failure in compressive strength test

(a) without waste-iron. (b) with waste-iron

4.3 Tensile Strength

The result of the tensile strength tests show that the tensile strengths of the waste-iron specimens increased with the increasing the ratio of waste-iron at all curing periods. Table (9) and Fig. (5) presents the tensile strengths of these mixes.

Table 9: Splitting tensile strength of waste iron concrete mix

Volume fraction of waste iron	Splitting tensile strength at 7 days (MPa)	Increasing ratio in 7 days	Splitting tensile strength at 14 days (MPa)	Increasing ratio in 14 days	Splitting tensile strength at 28 days (MPa)	Increasing ratio in 28 days
0	1.89	0.00	3.12	0.00	4.95	0.00
1	2.15	13.54	3.49	11.74	5.62	13.56
2	2.22	17.49	3.64	16.54	5.87	18.69
3	2.32	22.83	3.76	20.37	6.35	28.24
4	2.31	21.97	3.7	18.45	6.16	24.43

The result of the splitting tensile strength tests show that the tensile strengths of the waste-iron specimens increased with all the ratio of waste-iron at all curing periods.

Concrete containing 3% of waste-iron shows maximum tensile strength in comparison with other mixes. Concrete containing 4% of waste-iron had lower increasing in tensile strength than that containing 3% of waste-iron. This attribute to the decrease in the workability which leads to a decrease in the compact factor. For more or less randomly distributed fibers, the increase in strength is much smaller.[10]. However, adding the waste-iron is probably not worthwhile in tensile strength. However, as in compression, waste-iron does lead to major increases in the post-cracking behavior.[16].

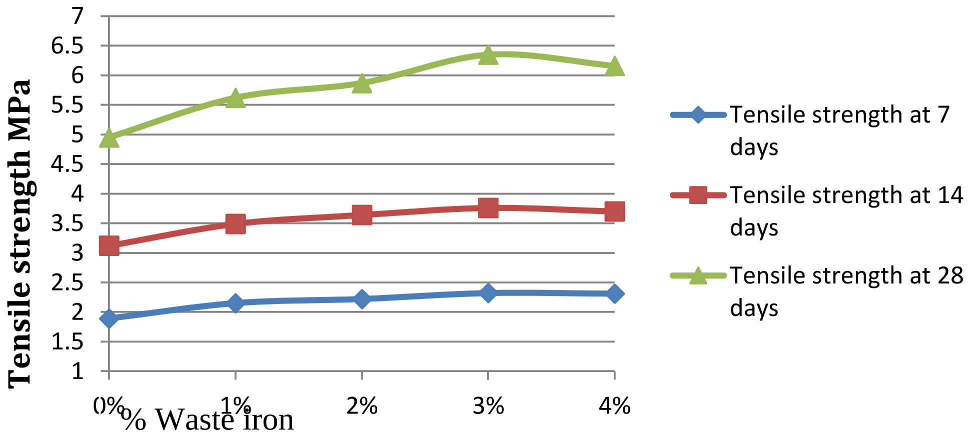

Fig.(5). Splitting tensile strength of waste iron concrete mixes

4.4 Flexural Strength

The result of the flexural strength tests show that the flexural strengths of the waste-iron specimens increased with all the ratio of waste-iron at all curing periods. For fiber reinforced concrete, the increase in flexural strength is particularly sensitive, not only to the fiber volume, but also to the aspect ratio of the fibers. The higher aspect ratio leading to larger strength increases.[18]. The maximum increase in flexural strength was for concrete containing 3% of waste-iron. Concrete specimens containing 4% of waste-iron had the lower increase in flexural strength than that containing 3% of waste-iron. This may be due to the decrease in workability which leads to decrease the compact factor of the concrete mix. Fibers are added to concrete not to improve the strength, but primarily to improve the toughness, or energy absorption capacity. [10]. Table (10) and Fig.(5). Presents the flexural strengths of these mixes.

Table 10: Flexural strength of waste iron concrete mix

% waste iron	Flexural strength at 7 days (MPa)	Increasing ratio in 7 days	Flexural strength at 14 days (MPa)	Increasing ratio in 14 days	Flexural strength at 28 days (MPa)	Increasing ratio in 28 days
0	2.1	0.0	4.5	0.0	6.1	0.0
1	2.32	10.4	5.2	15.2	8.8	44.3
2	2.98	42.1	6.77	50.4	11.6	90.2
3	3.64	73.2	8.08	79.5	12	96.7
4	3.32	58.1	7.26	61.4	10.2	67.2

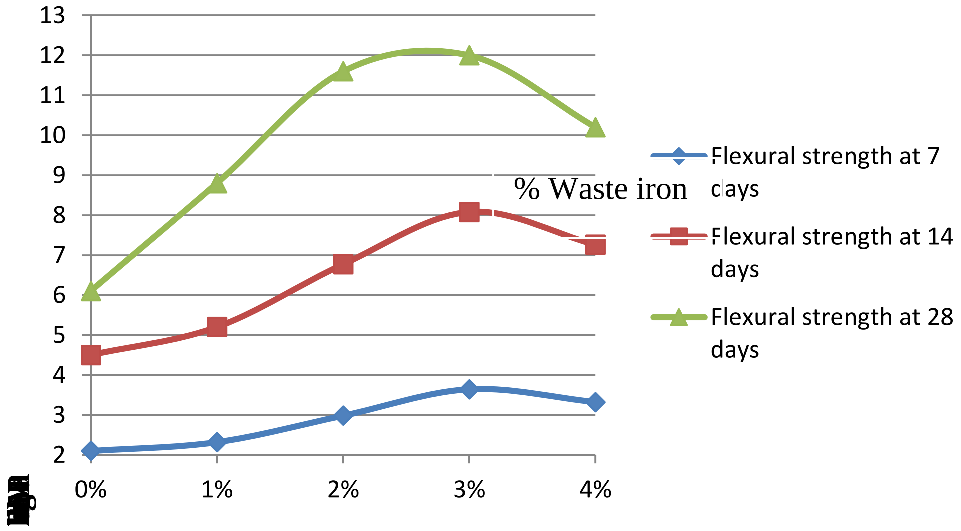

Fig.(6). Flexural strength of waste iron concrete mixes

Conclusion

The results of this investigation show that the use of waste-iron which product from milling processes performed efficiently to improve most properties:

1. The compressive strengths of waste-iron concrete mixes at all curing periods tend to increase relative to the reference mix. The highest compressive strength was that in the concrete mixes made of volume fraction 3% of waste-iron fiber at 28 days curing period, which is 29.24% higher than the reference mix at the same curing period.
2. The tensile strengths of waste-iron concrete mixes at all curing periods tend to increase relative to the reference mix. The highest tensile strength was that in the concrete mixes made of volume fraction 3% waste-iron fiber at 28 days curing period, which is 28.24% higher than the reference mix at the same curing period.
3. The flexural strengths of waste-iron concrete mixes at all curing periods tend to increase relative to the reference mix. The highest flexural strength was that in the concrete mixes made of volume fraction 3% ratio of waste-iron fiber at 28 days curing period, which is 96.7% higher than the reference mix at 28 days curing period.
4. The slump values of the waste-iron concrete mixes decrease with increasing the content of the waste-iron. In spite of this decline in the slump values of the concrete mixes, they remain easy to work. In practice it is very difficult to achieve a uniform mix if the aspect ratio is greater than about 100
5. Adding the waste-iron increases in the post-cracking behavior.
6. The color of the waste-iron concrete products did not change due the black-gray color of waste-iron.

4. References

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