Mechanical Evaluation of Sustainable Concrete Used in a Concrete Pavement that Production from Iron Filling Waste

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Abstract. In this research used iron filling as partial replacement fine aggregate at percent 5,10, and 15% by weight of fine aggregate and maintaining the ratio of water to cement at 40% and study observe that produces concrete with high compressive strength, tensile and flexural strength at replacement percent I10% and production of concrete with a lower coefficient of thermal expansion with continued replacement and thus obtaining the maximum distance between expansion joints at the rate of addition of I15%.

Keywords: Concrete; iron filling; coarse aggregate; tensile strength; flexural strength; compressive strength.

1. INTRODUCTION

The pavement construction must be able to provide a surface with good riding quality, sufficient skid resistance, good light-reflecting properties, and low noise pollution. The ultimate goal is to make sure that transmitted stresses caused by wheel load are sufficiently decreased so that they won't surpass the subgrade's bearing capability. The only materials utilized to build roads in ancient times were stone, gravel, and sand, with water acting as a binding agent to level the surface and give it a polished appearance. iron filings are produced as byproducts of metal cutting, grinding, filing, or milling finished iron products, particularly in workshops and foundries, Thus, recycling if in any useful way acts as an alternate method of waste disposal while also lowering the expenses and issues associated with waste disposal, which in turn improves the accomplishments of significant environmental protection and the creation of affordable concrete [1-5].

Experimental study of concrete made with granite and iron powders as partial replacement of sand. use iron powder and granite powder to replace sand by weight were used 5, 10,15, and 20% .researcher observed that substituting 10% of sand by weight with granite powder increased in compressive strength was 30% compared with the reference mix and increasing in flexural strength when adding the iron powder to mix observe an increase in compressive strength and flexural strength [1]. Using iron filling to replace sand with percent 10, 20, and 30% the result obtain an increase in compressive strength of concrete in percent 10%,20%, and the amount increased by 3.5 and 13.5% respectively Depending on the desired characteristic called for in the concrete, it is best to replace 10 to 20% by weight of sand (fine particles) in the concrete mix with iron filings [6]. Mohammed Noori uses three different mixes of percentages from iron filling 5,10, and 15% as partial replacement sand by weight, which results gives an increase in compressive strength and increase in tensile [7]. Recovered resources are correctly assessed before being used as building materials, the construction sector has a significant capacity to absorb a range of industrial leftovers. Iron, a by-product of iron ore, is the most frequently used metal in the world, making up over 95% of all metals consumed annually. An average of 2 billion metric tons of raw ore are produced annually worldwide. The total recoverable iron ore resources in India are around 9602 million tons of hematite and 3408 million tons of magnetite. The use of iron ore is rising by 10% globally [8].

After reviewing the previous research, an idea was formed about the use of iron filling as a partial substitute for fine aggregate, as it contributes to ridding the environment of accumulated materials resulting from iron industries forming as required, as well as about the percentages of adding that material, as it was found that the best percentage range from 10-20%, giving better result in improving the mechanical properties of concrete. The main objective is to use iron filling in concrete that is used in concrete pavement and find the optimal proportion of iron filling addition as an alternative to coarse aggregate and compare it with the reference mixture. Evaluation of wet density, compressive strength, tensile and flexural strength by adding the sustainable material.

2. MATERIALS

2.1 Aggregate

In this research, crushed gravel from the Al-Nabai quarry was used, with a maximum size of 19 mm. coarse conforms to the specification [9]. The sand used in the mixture Standards demand sand. possessing qualities as an example limited particle distribution, inertness, density, hardness, water absorption limit, metal type, endurance, and absence of toxic chemicals Laboratory-treated fine aggregate from Najaf quarries was used with a maximum size of 4.75mm is confirmed.

2.2 Cement

Iraqi Sulphate Resistant Cement (SRC) Type V, manufactured by a local supplier in Tasluja Cement Factory under the brand name Al-Jesr Cement, was used in all mixes in this study. The cement must be preserved from exposure to environmental conditions such as moisture and stored in a dry place, which was following the Iraqi specification [10] No. 5/1984 (IQR, 1984).

2.3 Water

Its PH value of 7.01 satisfies IS 456-2000's specifications. Additionally, it is utilized for specimen curing and mixing concrete.

2.4 Iron Filling

In filling used in the study Iron filings resulting from pieces of iron from the torna machine located in the Industrial district in Najaf, the iron filling was used as a partial replacement fine aggregate. See Figure 1.

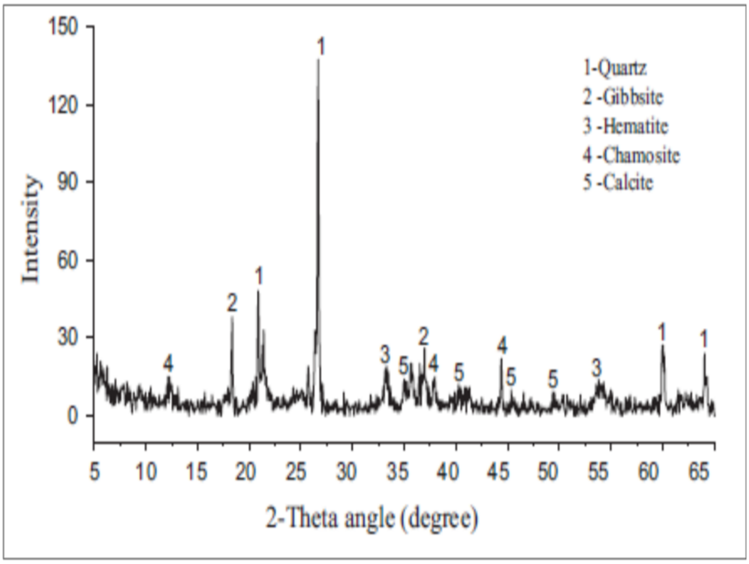

Figure 1: XRD analysis of iron ore [11].

2.5 Mixing Procedure

The goal of this project is to make sustainable concrete from iron filling as a substitute for fine aggregate and study the effect of addition on concrete mechanical features.The percentage of iron filling with replacement rates of 5,10, and 15% as a replacement for coarse aggregate, and compared with the reference. The concrete mixture was made by adding iron filings as a partial substitute for fine aggregate at rates of 5, 10, and 15%, comparison of the tests with the reference mixture, as shown in Table1.

Table 1: Mixes design proportions of concrete mix (kg/m^3).

Mix number	Weight ratio	Ratio by weight	Cement content (kg/m^3)	Coarse aggregate (kg/m^3)	Iron filling (kg/m^3)	Fine aggregate (kg/m^3)	w/c
0	1:1.6:2.85	0	400	1140	0	640	0.4
$I_{5\%}$	1:1.6:2.85	5%	400	1140	32	608	0.4
$I_{10\%}$	1:1.6:2.85	10%	400	1140	64	576	0.4
$I_{15\%}$	1:1.6:2.85	15%	400	1140	96	544	0.4

3. TESTING

3.1 Wet Density

The density of fresh concrete can be found by calculating the weight of concrete compacted in a container of known dimensions to the volume of the container according to the specification [12].

3.2 Slump Test

It is an assessment of the workability of fresh concrete Performed according to standards [13].

3.3 Compressive Strength

The compressive strength test was performed according to the specification [14] B.S 881 Part 3 for molds with dimensions of 150×150×150 mm. Three samples are tested for each sample after treatment with water for 28 days. The examination was carried out in the laboratory of the College of Engineering.

3.4 Tensile Strength

An indirect tensile strength test for concrete was conducted for an average of three models for each proportion with dimensions of the tube (100×200) mm for 28 days ages and according to the specification [15].

3.5 Flexural Strength

This is a measurement that shows a material's resistance to deforming when subjected to a load. By loading rectangular material samples tested in a 2-point loading rig, the quantities required to compute flexural strength are experimentally determined. The stress on test specimens that have been bent outermost fibers at the point of failure serves as an indicator of a material's bending strength. Flexural strength tests were performed on prism specimens. The prisms were cast with dimensions of 400×100×100 mm, and an average of three models were taken for each proportion for curing at 28 days' age, according to the specification [16].

3.6 Test Method for a Coefficient of Linear Thermal Expansion of Concrete

Samples are cast with their dimensions 76.2×76.2×285 mm (3×3×1.2) in according to the specification CRD C39-81 The samples were first cured in water for three days before being tested using the CRD method to reduce the effect of drying shrinkage. The samples were then cured in a water bath at 5°C for 24 hours before being stored in a 60°C water bath. The length was then determined. After that, the specimens were returned to the 5°C water bath and stored for 24 hours. The length was then measured once more. calculated by dividing the change in length by the change in temperature, This method covers the determination of the coefficient of linear thermal expansion of concrete test specimens by determinations of length change due to temperature changes. Because the thermal coefficient of concrete varies with moisture conditions, being a minimum when saturated or oven dry and a maximum at about 70 percent saturated.

4. RESULTS

4.1 Slump and Wet Density Test

In table 2 results after conducting the precipitation test, a decrease in the values was found, reaching an addition rate of 15%, where the workability is equal to the reference mix. The roughness and coarse aggregate occlusion of the iron ore tailing particles cause this effect, which significantly improves cohesion in the tailing mixes. Iron ore tailings also absorb more water than unprocessed sand [17].

Table 2: Slump test results.

Mix	Slump (cm)
Ref.	5
5%	2.6
10%	4.6
15%	5

Table 3 illustrates the results When replacing sand in proportions with iron filings, it causes the production of dense concrete compared to the reference mixture, it causes the production of heavier concrete, and this is since the density of sand is less than the density of iron.

Table 3: Wet density test results.

Mix	Wet density (kg/m^3)
Ref.	23.955
5%	24.163
10%	25.050
15%	26.1

4.2 Compressive Strength

After 28 days of treatment, a compressive strength test was performed, when adding iron filings as a substitute for sand, there was an increase in the compressive strength values. The highest values were at the 10% replacement ratio as shown in Figure 2. All compressive strength results of the replacement ratios tested were compared with BS 881 Part 3 [18]. There was about 26.5% increase in the compressive strength compared to the reference mixture [7]. Concrete with 25% iron ore tailings regularly exceeded reference concrete in terms of compressive strength at all ages [19].

4.3 Tensile Strength

After 28 days of treatment, a tensile strength test was performed, When adding iron filings as a substitute for sand, there was an increase in tensile strength values, and the highest values were at the 10% replacement ratio, as it was about 47.8% compared to the reference mixture. In one investigation, excellent tensile strength was produced in a designed cementitious composite employing iron ore tailing as aggregate [20]. Figure 3 shows results of tensile strength.

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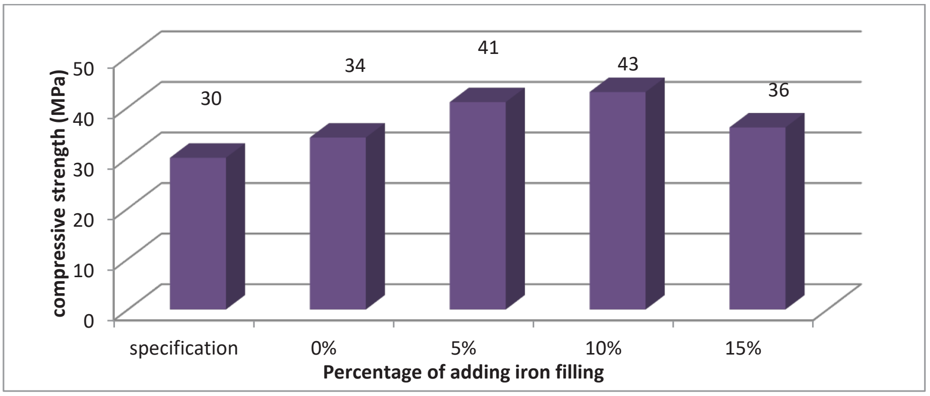

Figure 2: Results of compressive strength.

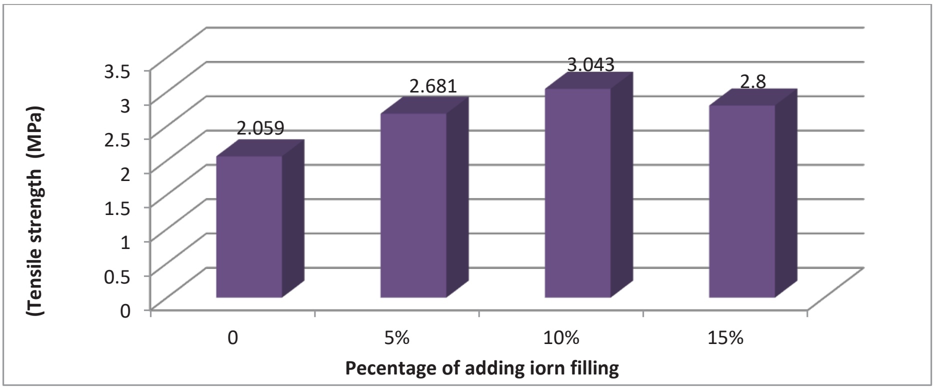

Figure 3: Results of tensile strength.

4.4 Flexural Strength

After 28 days of treatment, a flexural strength test was performed When adding iron filings as a substitute for sand, there was an increase in flexural strength, According to the study, adding the tailings slightly raised the value of flexural strength [21], see Figure 4.

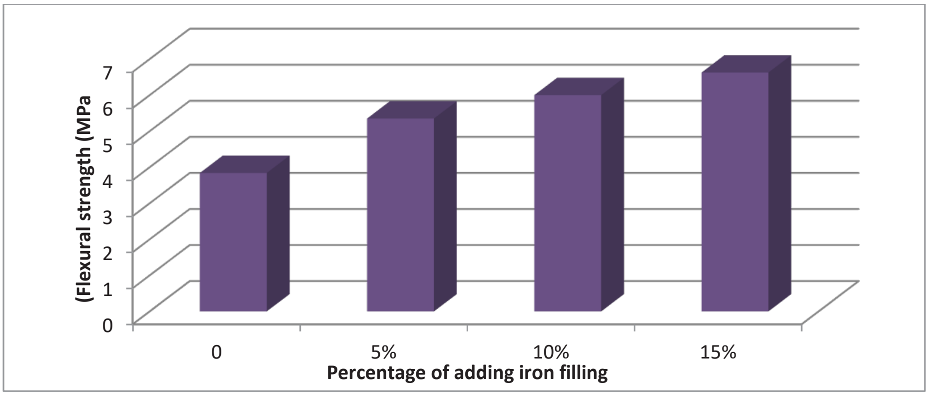

Figure 4: Results of flexural strength.

4.5 Coefficient of Thermal Expansion

The results show a decrease in the values of the thermal expansion coefficient with the continuous addition of iron filings replacement rates, and the maximum value of the decrease was at the replacement rate of 15%, which gives the maximum possible length through which the concrete expands for a distance within the expansion gauge in the joint according to the strain of the joint material, see Tables 4 and 5. The values can be calculated from the equation below [22]:

$$\alpha C = (Rh - Rc)/(G\Delta T) \quad (1)$$

Where
α_C =Coefficient of linear thermal expansion of concrete 10˚/deg F(deg C).
R_h = length reading at higher temperature in . or mm.
R_c =length reading at a lower temperature in . or mm.
ΔL= $[(CL(\alpha_C \times DT_D+Z))/S]\times 100$ [23].
ΔL= The joint opening caused by temperature change and drying shrinkage of the PCC, in.
S= allowable strain of joint sealant material most current sealants are designed to withstand the strain of 25 to 35 percent thus 25 percent may be used as a conservative value.
α_C= The thermal coefficient of Portland cement concrete F°.
Z= The drying shrinkage coefficient of the PCC slab, which can be neglected for a resealing project, in/in.
L= joint spacing, in.
DT_D =The temperature range, F° and
C=The adjustment factor due to subbase /slab friction restraint Use 0.65 for stabilized subbase, 0.80 for a granular base.

Table 4: Relationship between shrinkage and indirect tensile strength of Portland cement concrete.

Indirect tensile strength (psi)	Shrinkage (in./in.) Z
300 or less	0.0008
400	0.0006
500	0.00045
600	0.0003
700 (or greater)	0.0002

Table 5: Results of the coefficients of thermal expansion for concrete and joint spacing.

Mixes	Coefficient of thermal expansion (c)	Joint spacing (m)
Reference (0)	4.08×10^{-5}	5.09
$I_{5\%}$	1.6×10^{-5}	8.8
$I_{10\%}$	0.95×10^{-6}	16.72
$I_{15\%}$	0.44×10^{-6}	17.06

5. CONCLUSIONS

Based on the results of current stud, the following points can be drawn out:

- From the results of the test noticed can adding iron filling as a partial replacement for fine aggregate at a percentage of 10%.
- Increase in compressive strength when adding iron filling at percent 10% about 26.5%.
- Increase in tensile strength when adding iron filling at percent 10% about 47.8%.
- Increase in flexural strength gradually when increase adding percentage of ion filling.
- Increased space between separators compared to the reference mixture at a 15% replacement ratio.

REFERENCES

[1] Ghannam S, Najm H and Vasconez R. Experimental study of concrete made with granite and iron powders as partial replacement of sand. Sustain. Mater. Technol. 2016; 9(1): 1-9.
[2] Karkush MO, Yassin S. Improvement of geotechnical properties of cohesive soil using crushed concrete. Civil Engineering Journal. 2019 Oct 7;5(10):2110-9.
[3] Karkush MO, Yassin SA. Using sustainable material in improvement the geotechnical properties of soft clayey soil. Journal of Engineering Science and Technology. 2020 Aug;15(4):2208-22.
[4] Karkush MO, Ali HA, Ahmed BA. Improvement of unconfined compressive strength of soft clay by grouting gel and silica fume. InProceedings of China-Europe Conference on Geotechnical Engineering: Volume 1 2018 (pp. 546-550). Springer International Publishing.
[5] Ali NA, Karkush MO. Improvement of unconfined compressive strength of soft clay using microbial calcite precipitates. Journal of Engineering. 2021 Feb 27;27(3):67-75.
[6] Olutoge F, Onugba M, Ocholi A. Strength properties of concrete produced with iron filings as sand replacement. British Journal of Applied Science & Technology. 2016 Jan 10;18(3):1-6.
[7] AL-Hashimi MN, Najim WA, Hameed AM. Performance of concrete containing iron fillings. Journal of University of Babylon for Engineering Sciences. 2018 Apr 10;26(6):384-92.

[8] Bangalore Chinnappa G, Karra RC. Experimental and statistical evaluations of strength properties of concrete with iron ore tailings as fine aggregate. Journal of Hazardous, Toxic, and Radioactive Waste. 2020 Jan 1;24(1):04019038.

[9] Iraqi specification No.45. Aggregate from natural sources for concrete. Central agency for standardization and quality control, Planning council, Baghdad, Iraq, translated from Arabic edition

[10] Iraqi specification No.5. Portland Cement", Central agency for standardization and quality control. Planning council, Baghdad, Iraq, translated from Arabic edition. 1984.

[11] Shettima AU, Hussin MW, Ahmad Y, Mirza J. Evaluation of iron ore tailings as replacement for fine aggregate in concrete. Construction and Building Materials. 2016 Sep 1;120:72-9..

[12] BS EN 12350-6. part 6 Testing fresh concrete Density. 2019.

[13] AASHTO TI19 Testing fresh concrete Slump.

[14] B.S 881 Part 3 Testing hardened concrete compressive strength of test specimens. General Specifications for Roads and Bridges.

[15] BS EN 12390-6.Testing hardened concrete. Tensile splitting strength of test specimens. 2009.

[16] BS EN 12390-5. Testing hardened concrete Flexural strength of test specimens. 2019.

[17] Sabat, V.; Shaikh, M.; Kanap, M.; Chaudhari, M.; Suryawanshi, S.; Knadgouda, K. Use of Iron Ore Tailings as a Construction Material. Int. J. Concept. Mech. Civ. Eng. 2015; 3(1): 1–6.

[18] Shettima, A.U.; Hussin, M.W.; Ahmad, Y.; Mirza, J. Evaluation of Iron Ore Tailings as Replacement for Fine Aggregate in Concrete. Constr. Build. Mater. 2016; 120(1): 72–79.

[19] Huang, X.; Ranade, R.; Ni, W.; Li, V.C. Development of Green Engineered Cementitious Composites Using Iron Ore Tailings as Aggregates. Constr. Build. Mater. 2013; 44(1): 757–764.

[20] Oritola, S.; Saleh, A.L.; Mohd Sam, A.R. Performance of Iron Ore Tailings as Partial Replacement for Sand in Concrete. In Proceedings of the Applied Mechanics and Materials; Trans Tech Publications: Bäch, Switzerland. 2015; 735(1): 122–127.

[21] CRD-C39-81Army Corps of Engineering Test Method.

[22] AASHTO Guide for Design of Pavement Structure. American Association of State Highway and Transportation Officials, Washington,D.C., USA. 1993.

[23] Rogers M. Highway Engineering, 2nd Edition ,Blackwell Publishing Ltd. 2008.