Investigating the Characteristics of Concrete Modified with Iron Waste

By:

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Abstract

Due to its potential to increase strength and its favourable environmental effects, using iron waste in place of some of the sand in concrete has gained a lot of attention recently. This study looks at the possibilities of substituting different amounts of iron waste for fine aggregate in concrete with the main objective of strengthening it. The concrete was designed with a certain mix ratio in mind, with the goal being to achieve the required compressive strength of 33 MPa after 28 days of curing. Examining the impact of iron waste on the compressive and flexural tensile strengths of concrete was one of the main goals of the laboratory experiment. Thus, profiles of strength growth were generated by the inquiry.

Keywords: Concrete Strength, Fine Aggregate Replacement, Industrial Iron Waste.

1. Introduction

Concrete, which is made of cement, sand, gravel, and water, is currently one of the building materials most commonly utilised worldwide. It is possible to add more ingredients to the mixture. Air entrainment can be intentionally created by the use of additives or air-entraining cement, as concrete usually includes entrapped air (Dixon et al., 1991). Fine sand is one of the most utilised materials in concrete production. As a result, in recent years, many emerging countries have struggled to provide the need for natural sand to fund infrastructure development (Raman, Safiuddin & Zain, 2007). As a result, a variety of waste materials have the ability to take the place of sand in concrete, providing better workability, plasticity, and strength for longer durability (Ghannam, Najm & Vasconez, 2016).

Technological developments have raised environmental concerns in addition to raising human living standards when it comes to the influence of waste products on the environment (Joshi, 2013). Even though industrialization is a major force behind economic expansion, it has also resulted in serious problems with contamination of the environment. There are serious environmental problems as a result of industry' large waste material discharge. Recycling these waste products is increasingly becoming a necessary practise for environmental protection in order to reduce harm to the ecosystem (Jayaraman, Shenbagamn & Senthilkumar, 2017). In this situation, recycling more materials offers a desirable substitute for disposing of garbage. Potential pollution problems and related expenses can be decreased, and in certain situations, environmental harm can be lessened while environmental protection is achieved, through the use of garbage. However, plans for utilisation should be properly matched with concerns of energy and environmental effect in order to achieve the most efficient use of available resources (Bahoria et al., 2013). Alzaed (2014) investigated how iron filings, one component of the concrete mixture, affected the strength of the concrete. In order to ascertain any potential differences in the compression and tensile concrete strengths at twenty-eight days, the iron filing was added to the concrete mix in four different percentages in the paper. Many standard cubes and cylinders were made and tested for the investigation. It was found that adding iron filing to the concrete mix enhanced the material's compressive strength progressively while having no influence on its tensile strength at ratios higher than 10%. Two formulae were therefore proposed that could be used to predict the amount of rising that would be associated with each proportion of iron filing added to the concrete mixture. In order to investigate the possibilities of partially substituting fine aggregate in concrete mixtures with iron powder (IP) and granite powder (GP), Ghannam et al. (2016) conducted an experimental study. Compared to other ratios, it was discovered that 10% by weight was the most efficient way to replace sand in concrete with granite powder in order to increase the material's compressive and flexural strength. According to the test findings, when sand substituted 10% of the GP in concrete, the compressive strength improved by over 30% as compared to regular concrete. For the flexure, similar outcomes were also discovered. Furthermore, it was noted that adding up to 20% of iron powder by weight in place of sand in concrete increased the material's compressive and flexural strengths.

An industrial byproduct that is created when steel is manufactured at a steel production is iron waste. This waste product can be used in concrete to partially replace sand. The purpose of this study is to determine whether iron waste may be utilised in place of some fine aggregate in concrete and to note whether doing so increases the material's flexural and compressive strengths when used in the right amounts. The experimental research taken into consideration for this study showed that when iron waste was added to sand in certain amounts, the mechanical characteristics of concrete improved. Additionally, this by-product's impact on the environment and health risks will be reduced by recycling it and using it in concrete. Sand use in the building sector will decrease if iron waste is used in its place, protecting more of this natural resource.

2. Experimental study

Preparing concrete cubes and beams with and without iron waste replacement was part of the experimental programme. Portland cement, sand, coarse aggregates, iron waste, and water make up the concrete mixture. The cubes were ready to measure the compressive strength of the concrete, and the beams were outfitted to measure the flexural strength.

3. Research Strategy

3.1 Materials

Cement, fine aggregates (sand), coarse aggregates (gravel), iron waste, and water were the materials employed in this investigation. The required testing for the materials were performed in accordance with ASTM standards. One material that may bind other things together is cement. The physical characteristics of regular Portland cement were discovered and contrasted with the ASTM C 150 code specification, which is displayed in Table 1. The outcomes align with the requirements of the code specification.

Table 1: Cement characteristics according to the code standard.

No	Parameters	Values	Code Specification ASTM C150
1	Fineness	0.045	0.01 – 0.06
2	Specific gravity	3.12	around 3.15
3	Consistency	29 %	26% – 30 %
4	Initial Setting time (minutes)	72	≥ 45
5	Final Setting time (minutes)	295	≤ 375

Finely divided material particles make up the naturally occurring granular substance known as sand. The fine material was retained mostly on sieve # 200 (75 m) after passing through sieve #4 (4.75 mm). The sand's bulk density is 1647 kg/m3, specific gravity is 2.67, and fineness modulus is 2.6. One of the primary ingredients of concrete composite materials is coarse aggregate. The largest size of coarse material that was utilised was 12.5 mm. The gravel's bulk density is 1600 kg/m3, specific gravity is 2.74, and fineness modulus is 6.2.

Waste iron is one of the by-products. The environment will be impacted by the waste material's disposal. Steel plants in Iraq's Kurdistan region have boosted the amount of this material during the last few years. Iron waste might be utilised in place of the sand concrete mixture to lessen the environmental impact of waste materials. The bulk density, specific gravity, and fineness modulus of the iron waste are 3.56, 2168 kg/m3, and 2.3, respectively. It should be highlighted that the density of the iron waste and sand will likely have different effects on the concrete's density. Additionally, the waste material gathered in a Bazyan-related steel industry (Sulaymani Province). This waste material will be produced in greater amounts, which will have an impact on the environment. Utilising this substance to enhance the qualities of concrete is therefore essential. For the mixing and curing processes, clean water is utilised. It is important to apply the utilised water in accordance with the mix proportion design.

3.2 Research Work Plan

The strength of concrete may be increased by substituting iron waste with sand, as previously mentioned. Compressive and flexural tensile strengths of the concrete were thought to be examined in order to determine that an experimental approach was applied. With respect to this, the study is set up to begin with the preparation of regular concrete using only cement, sand, aggregate, and water as the control. In order to achieve the desired compressive and flexural tensile strengths, iron waste is then substituted for a portion of the fine aggregate sand. Nine cubes and nine beams were put together for every percent. In total, 108 cubes and flexural beams were tested for compressive and tensile strength of concrete.

In order to create a strong and long-lasting concrete, it is crucial to determine the mix proportions. Using Dixon et al. (1991)'s standard mix design, the mixture was designed to give concrete a compressive strength of 33 MPa after 28 days of curing. The mix proportion was prepared as (1:2.12:2.37).

3.3 Performing Tests

A useful test to determine the consistency of fresh concrete and determine its workability is the concrete slump test. Slump tests in accordance with (ASTM C143) were conducted in this respect for every mix ratio. The slump test is shown in Figure 1(a). Concrete cubes and beams were subjected to compression and flexural testing, respectively. The ability of a material or structure to bear loads that tend to diminish size is known as its compressive strength.

The concrete uniaxial compressive strength UCS test samples were produced in accordance with (ASTM C39-2015). Meanwhile, samples for flexural tensile strength FTS were prepared in compliance with (ASTM C293-2010). At the third locations along the 300 mm span, a 100 x 100 x 500 mm plain concrete beam was loaded in flexure until the tension face split and the beam collapsed. Under normal circumstances, the samples were cured for 7, 14, and 28 days. Following that, the specimens were put through their testing. The samples were subjected to tests for flexural strength by KN and compressive strength by MPa. Figures 1(b) and (c) depict the results of the compression and flexural tests, respectively.

(a) (b) (c)

Figure 1: Presents (a) Slump Test, (b) Compressive Strength, and (c) Flexure strength specimen tests.

4. Results

The results demonstrate that as iron waste rose, the slump progressively and marginally lessened. This indicates that the concrete's durability is good and its workability is within an acceptable range. The slump test for every mixing ratio is shown in Figure 2.

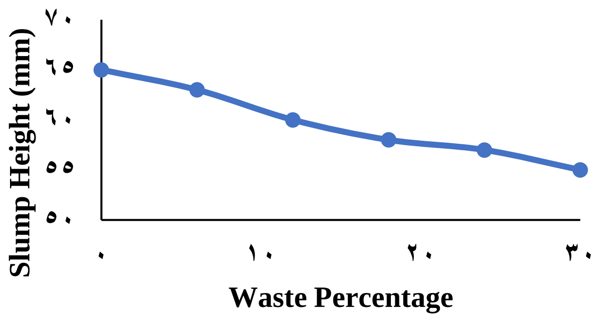

Figure 2. Results of slump tests.

To gain a comprehensive understanding of the influence of varying waste content, the study conducted compressive strength assessments at three distinct time points: specifically, seven, fourteen, and twenty-eight days. As depicted in Figure 3, the graphical representation elucidates a consistent trend of increasing compressive strength with incremental additions of iron waste in the concrete blend. Notably, the findings underscore the attainment of optimal strength at a 12% waste content. Beyond this threshold, an inverse relationship is observed, as a higher percentage of iron waste in the concrete mixture corresponds to a diminishing compressive strength. Significantly, the study's results reveal that, after a curing period of twenty-eight days, the concrete formulation containing 12% waste manifested a substantial 15% increment in compressive strength compared to the control concrete, which was devoid of any iron waste admixture.

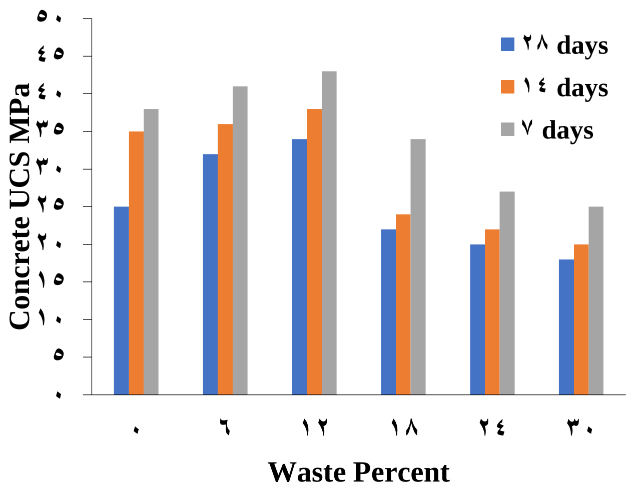

Figure 3. Concrete UCS test results.

Flexural samples with varying ratios of waste were examined to determine the strength of concrete with regard to flexural tensile strength. As the waste percentage approaches 12%, the flexural tensile strength progressively rises, as seen by the data displayed in Figure 4. The graphic makes it evident that flexural tensile strength decreases as waste increases by much above 12%. Consequently, it may be concluded that iron powder has a limited potential to strengthen concrete by replacing sand. Therefore, it can be said that using waste materials improves the structural qualities of concrete while simultaneously helping to preserve the environment.

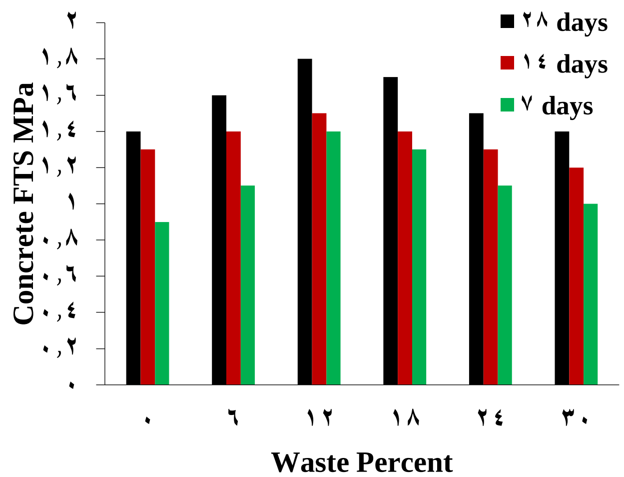

Figure 4. Shows FTS flexural tensile strength test results.

5. Conclusion

In conclusion, increasing industrial iron waste causes a minor and progressive decline in the workability of the concrete. Concrete became stronger as it took longer to cure. As the waste ratio was raised to 12%, there was a modest increase in both UCS and FTS of concrete. It is noteworthy that, in comparison to normal concrete, 12% waste in the concrete produced 15% greater concrete compressive strength after 28 days of curing. Remember that the mix ratio was primarily intended to provide 33 MPa at 28 days; but, by adding 12% of the waste, around 35 MPa, or more can be achieved at 7 days. Therefore, it might be advised to utilise 12% iron waste in the concrete if the goal is for the concrete to attain its maximum compressive strength in the shortest amount of time.

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