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Effect of Iron Filings in Concrete Compression and Tensile Strength

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***Abstract*— Metals waste materials create serious environmental problems, mainly owing to the inconsistency of the wastes streams. Iron filings are very small pieces of iron that look like a light powder. They are very often used in science demonstrations to show the direction of a magnetic field. The purpose of this paper is to evaluate the possibility of using iron filings as one of the component of concrete mix. Four different percentage of iron filing were added to concrete mix to measure the variation which may be obtained in compression and tensile concrete strengths after 28 days. A 144 standard cubes and cylinders were performed and tested in this study using 0% (control), 10%, 20% and 30% of iron filing in concrete mix. It is concluded that, Concrete compressive strength increased gradually when iron filing added to the concrete mix where the tensile strength had a minor effect if the percentage of iron filing used more than 10%. Two formulas represented these relations are proposed which may be used to anticipated the percentage of increase crossponding to each quantity of iron filing added to concrete mix.**

***Keywords*— Iron filing; Compressive strength; Tensile Strength; waste materials.**

I. INTRODUCTION AND PREVIOUS WORKS

Waste utilization is an attractive alternative to disposal in that disposal cost and potential pollution problems are reduced or even eliminated along with the achievement of resource conservation. Nevertheless, the utilization strategy must be coupled with environmental and energy considerations to use available materials most efficiently. Steel slag, the by-product of steel and iron producing processes, started to be used in civil engineering projects during the past 12 years [1-6]. The second waste from steel is the iron filing, which is produced locally in great amounts from steel workshops and factories. This product has a negative impact on the environment when disposed from this reason the research project started. Most of the previous researches were concerned with steel slag where a rare of it was concerned with iron filing.

Steel slag, due to its high strength and durability has been established in a number of applications in the civil engineering industry. Some of researches performed in this field can be summarized as follow:

Alizadeh et al. [7] carried out a research to evaluate the effect of using electric arc furnace steel slag on hardened concrete. Experimental results indicated that such steel slag aggregate concrete achieved higher values of compressive, tensile and flexural strength and modulus of elasticity, compared to natural aggregate concrete.

Shekarchi et al. [7,8] conducted comprehensive researches on the utilization of steel slag as aggregate in concrete. They concluded that the use of air-cooled steel slag with low amorphous silica content and high amount of ferric oxides is unsuitable to be used in blended cement. On the other hand, utilization of steel slag as aggregate is advantages when compared with normal aggregate mixes.

Maslehuddin et al. [9] presented a comparative study about steel slag aggregate concrete and crushed limestone concrete. In the study, only part of the coarse aggregate was replaced by slag aggregate. The study concluded that the compressive strength of steel slag aggregate concrete was marginally better than that of crushed limestone aggregate concrete. Moreover, the improvement in the tensile strength of steel slag concrete was not significant.

Manso et al. [10,11] presented a study in which electric arc furnace slag was used to obtain concrete of better quality. It was concluded that arc furnace slag can be used to enhance concrete properties. However, according to the authors, special attention must be paid to the fine aggregate of steel slag concrete mixes, which can be obtained by mixing fine slag with filler material.

I.M. Asi [12] presented a study in indirect tensile stiffness modulus test results he concluded that the stiffness modulus values of the mixtures containing steel slag coarse aggregate were higher than mixtures with limestone coarse aggregate at all testing temperatures, especially at 20 ◦C. In terms of creep stiffness, the values of steel slag mixtures are substantially higher than that of the control mixtures.

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The higher creep stiffness of the mixtures with steel slag coarse aggregate indicates better rutting resistance.

Y. Huang et al. [13] studied waste glass, steel slag, tyres and plastics are selected for this study, which reviews standards and literature for technical requirements, as well as the performance of asphalt pavements constructed using such recycled materials. Waste arising and management indicates that although there is a large potential for supplying secondary materials, a few factors have effectively depressed such recycling activities.

Weiguo Shena et al. [14] prepared a new type of steel slag–fly ash–phosphogypsum solidified material totally composed with solid wastes to be utilized as road base material. The mix formula of this material was optimized, the solidified material with optimal mix formula (fly ash/steel slag = 1:1, phosphogypsum dosage = 2.5%) results in highest strength. The strength development, resilience modulus and splitting strength of this material were studied comparing with some typical road base materials, the 28- and 360-day strength of this material can reach 8MPa and 12MPa, respectively, its resilience modulus reaches 1987MPa and splitting strength reaches 0.82MPa, it has higher early strength than lime–fly ash and lime–soil road base material, its long-term strength is much higher than cement stabilized granular materials, the solidified material has best water stability among those road base materials, it can be engineered as road base material with competitive properties.

II. EXPERIMENTAL WORK

Two different tests were conducted in this experimental program. A total of 144 tests conducted to study the effect of additing iron filing as a percentage from cement in concrete mix design. The two main groups of specimens were standard cubes and standard cylinders. The first group of concrete tests performed to study the effect of iron filing in concrete compressive strength, where the second concrete investigation was concerned with studying the effect of iron filing in concrete tensile strength. In each case of study four different percentage of iron filling were used 0% (control), 10%, 20% and 30%.

A. Materials

The materials for the experimental program were procured locally wherever possible. This was to retain the regional flavor of materials and in situ casting practices. Ordinary locally-available Portland cement having a specific gravity of 3.15 was employed in the casting of the specimens. Locally-available sand having a fineness modulus of 2.54 and a specific gravity of 2.62 was used. Crushed granite coarse aggregate of 20 mm maximum size having a fineness modulus of 7.94 and specific gravity of 2.94 was used. Water conforming to the requirements of water for concreting and curing as per IS: 456–2000 was used throughout. The average standard 28-days compressive strength of concrete cubes was approximately 28 MPa with a mix ratio of cement: sand: gravel: water at1:1.8:3.2:0.48.

III. PROCEDURES AND RESULTS DISCUSSION

A. Effect of iron filing in concrete compressive strength

The compression tests were carried out according to B.S. 1881.52 [15], on standard cubes (15 x 15 x 15 cm) as shown in figure 1(a). Concrete mix with iron filing was designed, treated, and controlled under the same conditions of concrete mix without iron filing. The constituents were mixed in a dry state for about one minute to ensure the uniformity of the mix. Mixing water was added gradually and was followed by the addition of workability admixtures. All contents were mechanically mixed for an extra two minutes. The consistency of fresh concrete was measured by the conventional slump test. The temperature degree was measured as well. For each concrete mix, 150-mm cube specimens were prepared for testing in compression after 28 days. To ensure full compaction of concrete, a vibrating table was used during placing of concrete. The cube specimens were demoulded after 24 hours and then submerged under water until tested. Eighteen cubes were cast from each mix and cured in clean water for 28 days. The crushing load was recorded to determine the compressive strength of concrete sample using universal hydraulic testing machine of capacity 2000 KN as shown in figure 1 (b). In this part of study, a total of 72 cubes were tested to study the effect of iron filing in the mechanical properties of concrete. The main variable was considered in this study was the percentage of iron filing. Four different ratios were performed 0% (control), 10%, 20% and 30%. The total numbers of cubes divided in four group each group represented by 18 cubes with different percentage of iron filing. The compressive tested performed for mix at ages 3 days, 7 days and 28 days. In each age of concrete 6 cubes were tested.

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(a) Cubes after curing stage

(b) Cubes during testing

Figure 1 Concrete cubes after curing and during test.

Cube No.	% of iron filing	0%	10%	20%	30%
1	From cement portion in concrete mix	29.30	28.42	29.30	32.45
2		27.11	30.22	30.23	31.52
3		27.97	29.30	31.11	33.74
4		26.20	28.44	31.11	33.30
5		27.97	27.55	30.66	32.00
6		26.64	30.22	32.44	31.55
Average (MPa)		**27.53**	**29.03**	**30.81**	**32.43**

Table 1. Concrete compressive strength results.

The results obtained from the compressive strengths conducted for 24 cubes after 28 days are listed in table1. The average strength for each case of study was indicated in this table. Figure 2 shows a curve plotted to represent the relation between average compressive strength and percentage of IRON FILING in concrete mix. This curve can represent effect of iron filing in concrete after 28 days.

From this curve an equation is formulated to anticipate the compressive strength of concrete mix which may be obtained in case of iron filing add to concrete mix as percentage from cement quantity. The proposed formula can be described as follow:

$$f_{cu} = -7.33 * K^3 + 36 * K^2 + 12.13 * K \quad + F_{cu} \qquad (1)$$

Where

K is the percentage of iron filing

F_{cu} is the designed concrete compressive strength with 0% of Iron Filing.

f_{cu} is the anticipated concrete compressive strength after using K percentage of Iron Filing.

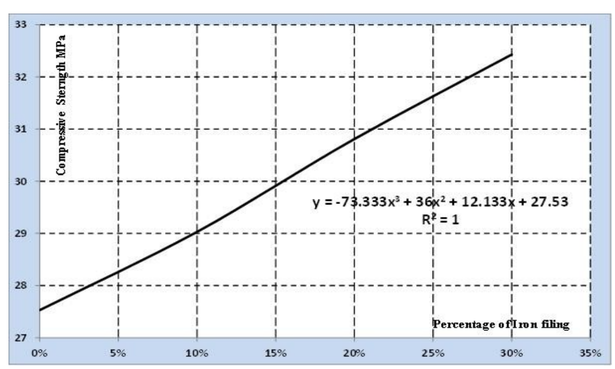

Figure 2 Relation between Compressive strength after 28 days with percentage of iron filing

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B. Effect of iron filing in concrete tensile strength

The following investigation was conducted to study the effect of iron filing as a percentage from cement in concrete tensile. The splitting tensile tests were carried out according to B.S. 1881.52 [15], on standard cylinders, 15 cm in diameter and 30 cm in height as shown in figure 3 (a). Concrete mixes without and with iron filing were designed, treated, and controlled under the same conditions. The constituents were mixed in a dry state for about one minute to ensure the uniformity of the mix. Mixing water was added gradually and was followed by the addition of workability admixture. All contents were mechanically mixed for an extra two minutes. The consistency of fresh concrete was measured by the conventional slump test. The temperature degree was measured as well. For each concrete mix, standard cylinders, 15 cm in diameter and 30 cm in height were prepared for testing in tensile Brazilian test after 28 days. To ensure full compaction of concrete, a vibrating table was used during placing of concrete. The cylinders specimens were demoulded after 24 hours and then submerged under water until tested. Eighteen cylinders were cast from each mix and cured in clean water for 28 days as shown in figure 3(b). The crushing load was recorded to determine the tensile strength of concrete sample using compression testing machine. In this study, a total of seventy two cylinders were tested in different ages (3, 7 and 28 days) to study the effect of iron filing in tensile strength of concrete. The four different percentage of iron filing performed were (0%, 10%, 20%, and 30%) from cement quantity.

(a) Concrete Cylinder before testing (b) Concrete Brazilian test

Figure 3 Cylinder specimen after curing, testing

Cylinder No.	% of iron filing	0%	10%	20%	30%
1	From cement portion in concrete mix	2.80	2.29	2.67	2.55
2		2.42	3.43	3.44	3.31
3		2.55	2.42	2.55	2.80
4		2.16	3.06	2.54	2.93
5		2.42	3.18	2.80	2.67
6		2.67	2.67	3.31	3.18
Average (MPa)		**2.50**	**2.84**	**2.88**	**2.91**

Table 2. Concrete tensile strength results

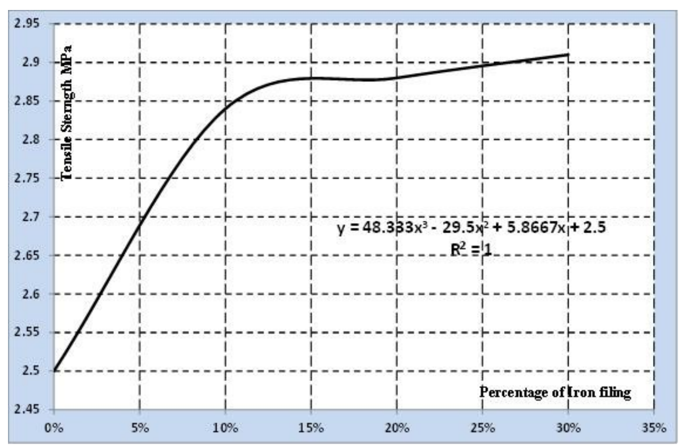

Figure 4 Relation between Tensile strength after 28 days with percentage of iron filing

The results obtained from the concrete tensile strengths conducted for 24 cubes after 28 days are listed in table2. The average strength for each case of study was indicated in this table. Figure 4 shows a curve plotted to represent the relation between average tensile strength and percentage of iron filing in concrete mix. This curve can represent the effect of iron filing in concrete after 28 days.

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From this curve an equation is formulated to anticipate the tensile strength of concrete mix which may be obtained in case of iron filing add to concrete mix as percentage from cement quantity. The proposed formula can be described as follow:

$$f_{ct} = +48.33 * K^3 - 29.50 * K^2 + 5.87 * K \quad + F_{ct} \quad (2)$$

Where

K is the percentage of iron filing.

F_{ct} is the designed concrete tensile strength with 0% of iron filing.

f_{ct} is the anticipated concrete tensile strength after using K percentage of iron filing.

IV. Summary and Conclusions

This research work is concerned with studying the effect of iron filing in concrete compressive and tensile strengths. Four different percentage of iron filing were added to concrete mix to measure the variation which may be obtained in compression and tensile concrete strengths after 28 days. From this study it is concluded that:

1- Concrete compressive strength increased gradually when iron filing added to the concrete mix. A formula represented this relation is proposed that may be used to anticipated the percentage of increase crossponding to each quantity of iron filing added.
2- Concrete compressive strength increased by 17% when 30% of iron filling added to the concrete mix.
3- Concrete tensile strength had a minor effect if the percentage of iron filing used more than 10%. A formula represented this relation is proposed that may be used to anticipated the percentage of increase cross ponding to each quantity of iron filing added.
4- Concrete tensile strength increased by 13% when 10% of iron filling added to concrete mix.

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