Properties of Mortar Incorporating Iron Slag

Tamara HUMAM[1], Rafat SIDDIQUE[2*]

[1]*Graduate Student, Department of Civil Engineering, Thapar University, Patiala (Punjab) 147004, India*
[2]*Senior Professor of Civil Engineering, Department of Civil Engineering, Thapar University, Patiala (Punjab) 147004, India*
E-mail(s): tamarahumam@yahoo.com ; siddique_66@yahoo.com;

[*] Corresponding author: Phone: (91) 9876078644; Fax: (91) 2393005

Abstract

In the present study effects of replacement of fine aggregate (sand) with high percentages of iron slag on the properties of Mortar. Cement mortars of mix proportion 1:3 with incorporating various percentage of iron slag was designed. Fine aggregate were replace with five percentage of iron slag. The percentages of replacements were 0, 10, 20, 30, and 40% by weight of fine aggregate. Tests were performed for compressive strength, split tensile strength, sulphate resistance, Rapid Chloride Permeability Test. Test for all replacement levels of iron slag at different curing periods (7, 28, 56 days). Test result indicates that inclusion of iron slag as partial replacement with fine aggregate enhances the properties of Mortar.

Keywords

Compressive Strength; Cement mortars; Fine aggregate; Iron slag; Rapid Chloride Permeability Test; Splitting tensile strength; Sulphate resistance.

Introduction

In the iron and steel industry, when pig iron from blast furnace is changed to steel in the converters, basic converter slag is produced in large quantities. This has not been useful.

In Portland cement has only found limited applications in construction or stabilization of dams, dikes, embankments, road building, and agriculture (to lower the natural acidity of

soils or other fertilisers). The main problem with using converter slag in civil engineering is the possible presence of free lime; especially large-sized components of Heated undisolved limestone, because when it hydrates, its volume increases and this swelling can lift the top layers. In this paper, use of iron slag as the raw material for Portland cement production before firing is discussed. Additional mixing of blast-furnace slag with the clinker after firing is considered. Use of slag in India is to the tune of 15 to 20 % by cement industry rest is mostly unused. The use of industrial by-products in mortar not only helps in reducing green house gases but helps in making environmentally friendly construction materials. Fine aggregates are part of all the three major applications of construction namely masonry, plastering and concreting, due to increased construction activities in India. This study was undertaken to utilize large quantities of iron slag produced in India. So, this investigation explored the possibility of replacing part of fine aggregate with iron slag in mortar.

Significant work has been reported on the use of iron slag in mortar. Reported that Mortar containing high volumes of iron slag exhibited excellent mechanical properties, Barnett et al. [1] development the mortars containing ground granulated blast-furnace slag and Portland cement was investigated. All mortars gain strength more rapidly at higher temperatures and have a lower calculated ultimate strength; the early age strength is much more sensitive to temperature for higher levels of ground granulated blast-furnace slag. The calculated ultimate strength is affected to a similar degree for all GGBS levels and water–binder ratios, with only the curing temperature having a significant effect.

Nataraja et al. [6] investigated the possibility of utilizing Granulated Blast Furnace Slag (GBFS) as and substitute in cement mortar. The compressive strength of cement mortar for 0.4 w/c ratio is less compared with the strength of water cement ratios 0.5 and 0.6. Nadeem and profale [5] reported highlights upon the feasibility study for the utilization of granular slag as replacement of natural fine aggregate in construction applications (Masonry and plastering). Mortar split tensile strength increased in 1:3 & 1:4 mix proportions at 75% granular slag replacement by 15.97 & 16.0% respectively and in 1:5 & 1: 6 mix proportions the increase was observed 11.56 & 10.29 % at 50% replacement level. The increase in strengths at 100% replacement was noted as 6.08, 7.11 and 5.39% in 1:3, 1:4 and 1:5 mix proportions respectively and in 1:6 it was below 0.59% compared to 0%. Monsh and Asgarani [4] studied the slags from blast furnace (iron making) and converters (steel making) after magnetic separation are mixed with limestone of six different compositions.

Reported that mortar containing high volumes of iron slag exhibited excellent durability characteristics, Cerulli el at. [2] performed the Blast furnace slag is a residue of steel production. It is a latent hydraulic binder and is normally used to improve the durability of concrete and mortars. Manso el at. [3] performed Ladle furnace basic slag is a by-product of the steelmaking industry. This study examines the properties of masonry mortars made with ladle furnace basic slag and the other conventional components such as sand, cement, and admixtures.

Siddique el at. [6] studied iron and steel industry by-products (GGBS) in cement paste and mortar with the increased industrialization, generation of industrial by-products which has increased significantly.

The aim of the research was carried out to evaluate the performance of iron slag as fine aggregate. Substitute in mortar with respect to compressive strength, splitting tensile strength, sulphate resistance, Rapid Chloride Permeability Test. Results of this investigation would be very useful in the use of high volume of iron slag in mortar construction.

Material and Method

In this research ordinary Portland (43 grade) cement was used. It met all the requirements of Indian Standard Specifications IS: 8112 [8]. The Iron Slag has black in colour and it was taken from the Dhiman Iron and Steel industry located at Mandi Gobindgarh, Punjab. It was fine aggregate and natural sand which is conforming to grading Zone II. Fine aggregate met the requirements of Indian Standard Specifications IS: 383 [9]. The specific gravity of fine aggregate was 2.59, respectively whereas their fineness modulus was 2.63.

Mixture Proportions

In the present study [10] the mix proportion 1:3 (one part of cement &iron slag and 3 parts of sand) fractions are prepared. In this series of mix the water is taken as per cement consistency only with different percentage of iron slag and sand. Five additional mortar mixtures (M-1, M-2, M-3, M-4 and M-5) were proportioned where fine aggregate (sand) was replaced with iron slag by 0% (Standard mix), 10%, 20%, 30% and 40%. Mixture proportions are given in Table 1.

Table 1. Mortar mixture proportions

Mix	Ratio% Iron slag	Cement (gm)	Sand (gm)	Iron Slag (gm)	Water (Liter)
M1	0	200	600	0	747
M2	10	200	540	60	747
M3	20	200	480	120	747
M4	30	200	420	180	747
M5	40	200	360	240	747

Preparation and Casting of Specimens

For compressive strength and for sulphate resistance 70.5mm cubes were cast, 100 x 200mm cylinders for splitting tensile strength and for Rapid Chloride Permeability Test. All the specimens were prepared in accordance with Indian standard specifications IS: 516-1959 [11]. All the moulds were cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage out of slurry. The specimens were allowed to remain in the steel mould for the first 24 hours at ambient conditions. After that, these were demoulded with care so that no edges were broken and were placed in the curing tank at the ambient temperature for curing. The ambient temperature for curing was 27 ± 20°C. Three specimens were cast for each of the properties for all test ages.

Testing of Specimens

For each mix 45 Cubes mould of size 70.5×70.5 mm were used to prepare the mortar specimens for the determination of the compressive strength, sulfate resistance and 45 cylinder mould of size 100 mm×200 mm were used to determination of the split tensile strength and Rapid Chloride Permeability Test. All specimens were prepared in accordance with Indian Standard Specifications IS: 516-1959 [11]. These were securely tightened to correct dimensions before casting. Care was taken that there are no gaps left from where there is any possibility of leakage out of slurry. Mortar cubes 70.5x70.5mm were tested for the determination of the compressive strength, sulfate resistance [13] and cylinder 100 mm ×200 mm for determination of split tensile strength, RCPT [12]. On an average 3 specimens were tested for each property.

Results and Discussions

Compressive Strength

Compressive strength results are shown in Fig. 1. Compressive strength values are the average of 3 specimens. It is evident that the strength increased with the increase in iron slag percentages for all ages. With 10% slag, strength increased by 18% at 7 days, 12% increase at 28 days and 15% increase after 56 days. With the addition of 30% iron slag, percentage increase in strength was 59%, 20%, 60% after 7, 28 and 56 days respectively. The improvement the compressive strength of the mix with incorporation of iron slag is primarily due to the pozzolanic reaction and slag being finer than sand, resulting in particle packing behavior.

The compressive strength increases because of the chemical compositions of iron slag.

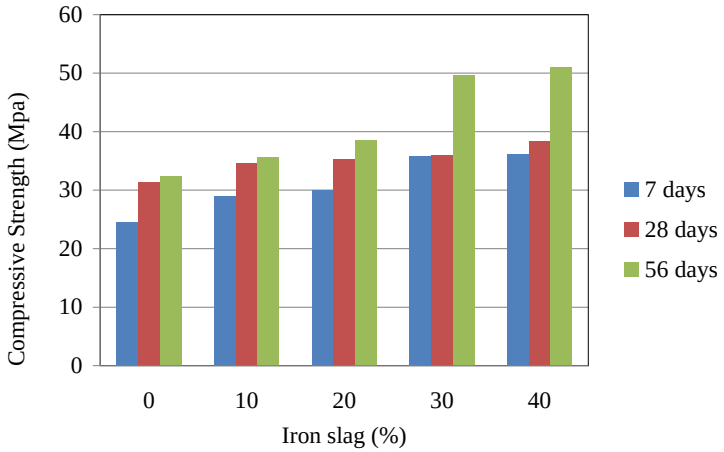

Figure 1. *Compressive Strength of Mortar*

Splitting Tensile Strength

Splitting tensile strength results are shown in Fig. 2. Splitting tensile strength of mortar mixtures increased with the increase in iron slag content at all ages. After adding 10% iron slag in the mix, there is an increase of 3% after 7 days, 9% increase after 28 days and 5% increase after 56 days. By adding 30% and 40% iron slag, there was a large amount of increase.

The results of splitting tensile strength indicates that the pattern of the increase in splitting tensile strength is similar to that of compressive strength, which is due to the action of both pozzolanic reaction and particle packing behavior

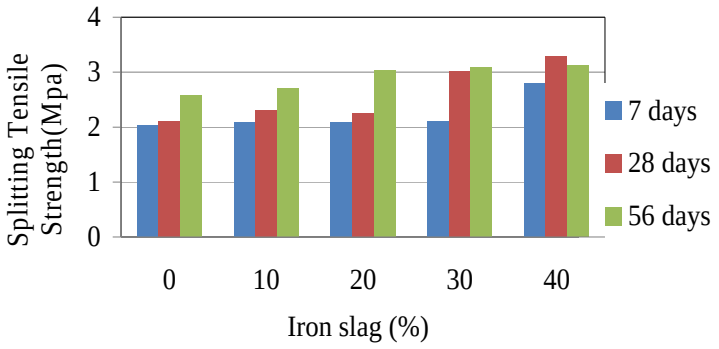

Figure 2. *Splitting Tensile Strength of Mortar*

Sulphate Resistance

The compressive strength due to sulphate attack results are shown in Fig. 3., it is observed that for the mix containing increase in 10% iron slag specimen after immersed the cubes in magnesium sulphate in solution after 7, 28 and 56 days respectively.

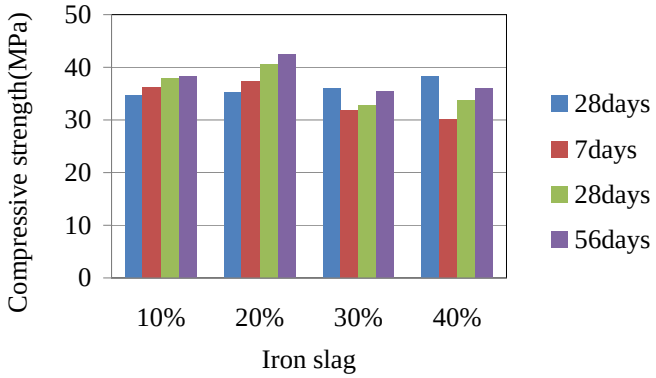

Figure 3. *Compressive Strength after immersion in Mg SO_4 solution (50g/l)*

When the replacement of iron slag increased in the mix, the strength of specimen tends to decrease as compared to the compressive strength cured in water at same ages. The increase in strength due to the replacement of fine aggregate with iron slag better sulfate resistance due to lower C3A content.

Rapid Chloride Permeability Test

Effect of iron slag as partial replacement of fine aggregates on the rapid chloride permeability of concrete at the age of 28 days, is shown in Fig. 4. Chloride ion passed were 2230, 1920, 1750, 1500, and 1280 at 0, 10, 20, 30, and 40% iron slag. Reduction in chloride ions indicate that permeability of concrete has decreased with increase in iron slag content.

Control mix with 0% slag comes under the category of “Moderate” permeability and other mixes with 10, 20, 30, and 40% iron slag come under the category of “Low permeability” as per ASTM C1202 [12]. Reduction in permeability with increase in iron slag content indicates the improvement in the microstructure of the mixes.

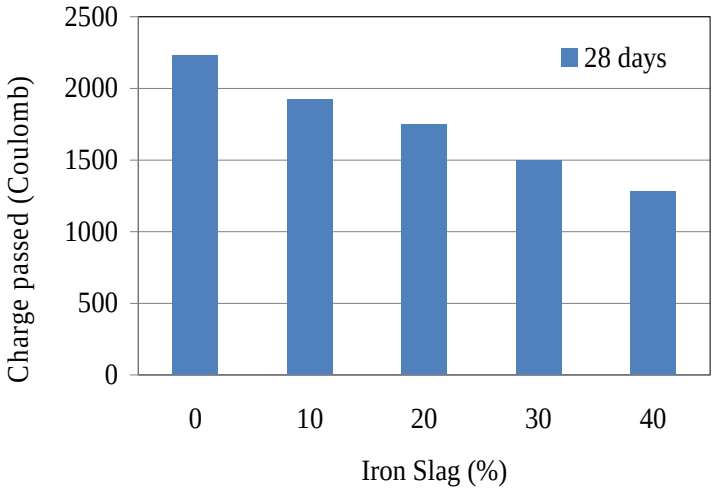

Figure 4. *Rapid Chloride Permeability Test*

Conclusions

The following conclusions can be drawn from this study: (1) The obtained experimental results show that a partial substitution in the replacement of fine aggregates with iron slag significantly enhanced the compressive strength, splitting tensile strength, Sulphate Resistance and Rapid Chloride Permeability Test. (2) compressive strength of mortar increased by a large amount of the increase in percentage 59%, 20%, 60% after 7, 28 and 56 days respectively, splitting tensile strength increased by large amount 40%, 25% , 29% after 7, 28 and 56 days respectively. In the Sulphate resistance test, the Compressive strength increases with increase the percentages of iron slag in the mix. And there was continuous improvement in all these properties at 28 and 56 days. (3) The value of RCPT Test, at 0% Chloride Ion Penetrability is moderate and at (10, 20, 30 and 40% its low).

References

1. Barnett S. J., Soutsos M. N., Millard S. G., Bungey J. H., *Strength development of mortars containing ground granulated blast-furnace slag: Effect of curing temperature and*

determination of apparent activation energies, Cement and Concrete Research, 2006, 36, p. 434-440.

2. Cerulli T., Pistolesi C., Maltese C., Salvioni D., *Durability of traditional plasters with respect to blast furnace slag-based plaster*, Cement and Concrete Research, 2003, 33, p. 1375-1383.
3. Manso J. M., Rodriguez A., Argon A., Gonzalez J. J., *The durability of masonry mortars made with ladle furnace slag*, Construction and Building Materials, 2011, 25, p. 3508-3519.
4. Monshi A. and Asgarani M. K., *Producing Portland cement from iron and steel slags and limestone*, Cement and Concrete Research, 1999, 29, p. 1373-1377.
5. Nadeem M. and Pofale A. D., *Replacement Of Natural Fine Aggregate With Granular Slag - AWaste Industrial By-Product In Cement Mortar Applications As An Alternative Construction Materials*, International Journal of Engineering Research and Applications, 2012, 2(5), p.1258 -1264.
6. Nataraja M. C., Kumar P. G. D., Manu A. S., Sanjay M. C., *Use of granulated blast furnace slag as fine aggregate in cement mortar*, Int. J. Struct. & Civil Engg, 2013, 2(2), URL: http://www.ijscer.com/ijsceradmin/upload/ijscer_51829233a2aea.pdf
7. Siddique R., Bennacer R., *Use of iron and steel industry by-product (GGBS) in cement paste and mortar*, Resources Conservation and Recycling, 2012, 69, p. 29– 34.
8. IS: 8112 , *Specifications for 43-Grade Portland cement*, Bureau of Indian Standards, New Delhi, India, 1989.
9. IS: 383, *Specifications for coarse and fine aggregates from natural sources for concrete*, Bureau of Standards, New Delhi, India, 1970.
10. IS: 10262, *Recommended Guidelines for Concrete Mix Design*, Bureau of Indian Standards (BIS), New Delhi, India, 1982.
11. IS: 516, *Indian standard code of practice- methods of test for strength of concrete*, Bureau of Indian Standards, New Delhi, India, 1959.
12. ASTM C1202 – 10, *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*.
13. IS: C1012/C1012M – 10, *Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution.*