Enhancement of Corrosion Resistance Using GGBFS in Concrete with M Sand as Fine Aggregate

M.Devi

Department of Civil Engineering, Paavai College of Engineering, Namakkal, Tamilnadu, India.

Abstract

Manufactured sand (M sand) is an alternative material for natural river sand since the demand for river sand has increased tremendously, causing deficiency and increase in price. Mineral admixtures are added in concrete to improve the durability properties. The objective of this work is to study the strength and corrosion resisting properties of concrete with M-sand as fine aggregate and Ground Granulated Blast Furnace Slag (GGBFS) as supplementary cementitious material. Along with the strength properties, resistance to corrosion is evaluated by means various electrochemical techniques such as Rapid Chloride Penetration Test (RCPT), Accelerated corrosion test, Impedance measurement and Gravimetric weight loss measurement.

KEYWORDS – Concrete, M sand, Corrosion, Mineral admixture, GGBFS, Strength, Durability

I. Introduction

Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Since manufactured sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed. Ground Granulated Blast Furnace Slag (GGBFS), which is obtained by rapidly quenching the molten ash from the furnace, when used as partial replacement of cement in concrete, results in reduction of cement consumption and CO2 production besides enhancing strength and durability properties. Corrosion of reinforcing bar embedded in concrete causes most of the failures in concrete structures. The time to initiate corrosion is determined largely by the amount and the quality of concrete cover as well as the permeability of concrete. The expansive forces caused by corrosion of steel can cause cracking, spalling and staining of the concrete, and hence loss of structural bond between the reinforcement and concrete. In such situations, GGBFS, having finer particle size and higher specific surface area is suitable for preparing high density and low permeability concrete which offers higher resistance to corrosion. In this paper, an experimental study dealing with the strength and corrosion resistance behavior of concrete with M sand as fine aggregate and GGBFS as mineral admixture at the dosage of 10%, 20%, 30%, 40% and 50% by weight of cement was carried out.

II. MATERIALS AND METHODOLOGY

Ordinary Portland Cement (OPC 43 Grade) was used throughout the investigation. M-sand, conforming to Zone-II having specific gravity 2.68 and fineness modulus 2.70 was used as fine aggregate. Natural granite aggregate having density of 2700kg/m3, specific gravity 2.7and fineness modulus 4.33 was used as coarse aggregate. High yield strength deformed bars of diameter 16mm was used for corrosion tests. To attain strength of 20 N/mm^2 a mix proportion was designed based on IS 10262-1982 and SP23:1982(21). The mixture was 1:1.517:3.38 with water cement ratio 0.45.

Concrete cubes of size 150 x 150 x150mm, beams of size 500 x 100 x 100 mm, cylinders of size 150mm diameter and 300 mm long were cast for compressive, flexural and split tensile strength tests. Concrete cylinders of size 75 mm diameter and 150 mm length with centrally embedded high yield strength rebar were cast for impedance measurement and accelerated corrosion test in the saline media under a constant voltage of 6 volts from the D.C power pack. For weight loss measurement the cylinders were immersed in 3% NaCl solution under alternate wetting (3days) and drying (3days) conditions over a period of 90 days. At the end of 90days, from the weight loss obtained corrosion rate is calculated. The Rapid Chloride Penetration Test was performed by monitoring the amount of electrical current that passes through concrete discs of 50mm thickness and 100mm diameter for a period of six hours. The total charge passed through the cell in coulombs has been found in order to determine the resistance of the specimen to chloride ion penetration.

III. RESULTS AND DISCUSSION

3.1. Strength tests

The compressive, flexural, split tensile and bond strength development of M sand concrete containing 10% to 50% replacement of ground granulated blast furnace slag is shown in Figures 1 to 4.

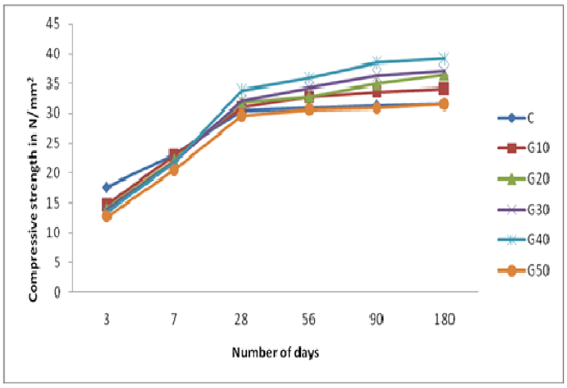

Fig 1 Compressive strength

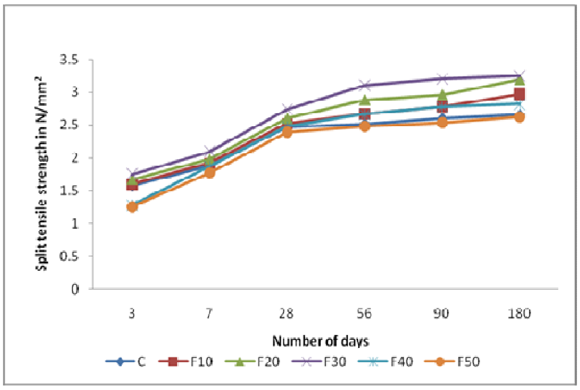

Fig.2 Split tensile strength

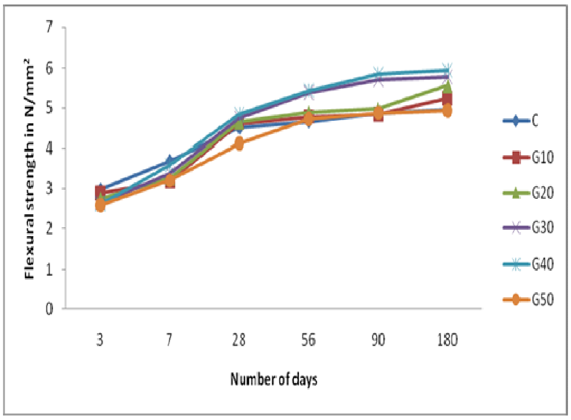

Fig 3. Flexural strength

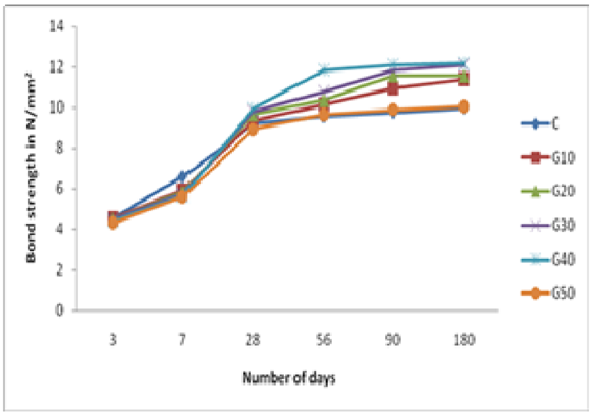

Fig 4. Bond strength

Compressive, split tensile, flexural and bond strength results obtained after3, 7, 28, 56, 90,180 days have been shown in Figures 1 to 4. It can be seen that at the age of 3 and 7days, the strength values of GGBFS blended M sand concrete specimens are lower than the control specimen. From figure1 it is evident that, the early strength of GGBFS blended concrete is lower than the control specimen for all percentage replacement up to 28 days. Considering Figure 2 it can be understood that the split tensile strength of the GGBFS concrete is initially lower than the control specimen for the first 7 days and is then found to be almost equal at 28 days. In accordance with Figures 3 and 4 it is evident that the flexural strength as well as the bond strength of the GGBFS concrete are found to be lower than the control specimen up to 7 days. This is because the rate of hydration is slow at early ages hence delay in setting time leading to increased loss of moisture which decreases the strength development for the concrete incorporating GGBFS.

When comparing the strength test results it is observed that the addition of GGBFS as partial replacement of cement up to 40% in M sand concrete produces increase in strength properties. However, the strength of the 50% blended GGBFS is comparatively lower than the control specimen at all ages due to extension in initial and final set and quick loss of workability. Among all the percentages of GGBFS, the specimens with 40% of GGBFS have shown maximum improvement in compressive, split tensile, flexural and bond strength tests which was considered to be the optimum percentage addition.

3.2 Corrosion tests:

The corrosion resistance performance of the GGBFS at various percentages in M sand concrete is shown in Figures 6 to 8. The corrosion initiation time for control concrete was found to be 168 hours. Figure 6 shows the corrosion initiation time for 10%, 20%, 30%, 40% and 50% of GGBFS blended M sand concrete.

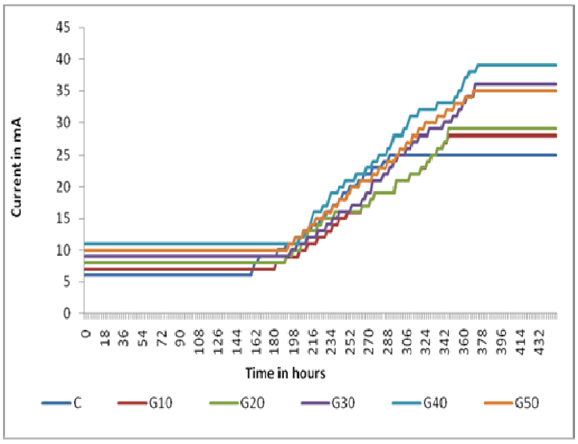

Fig 6 corrosion initiation time

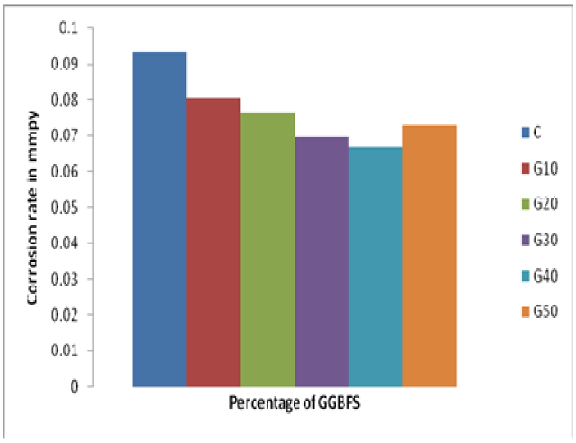

Fig 7 Corrosion rate

Figure 7 clearly indicates that the rate of corrosion decreases with the increase of percentage of GGBFS. Considering the weight loss measurements, the results revealed that the corrosion rate has decreased to the maximum extent in 40% GGBFS blended concrete.

Chloride diffusion results of the different percentages of GGBFS after 28, 56, 90 and 180 days curing are are displayed in Table 1.

Table 1 Rapid chloride penetration test results

Percentage of GGBFS	Charge passed in Coulombs			
	28 days curing	56 days curing	90days curing	180days curing
10%	3350	3065	2812	2710
20%	3100	2412	2378	2262
30%	2872	2313	2172	2063
40%	2743	2112	2015	1985
50%	2798	2279	2115	2088

The chloride ion penetration capacity of the specimens with various percentages of GGBFS is discussed here.From the performance of the M sand concrete with 10%, 20%, 30%, 40% and 50% replacement of cement by GGBFS it was observed that the corrosion resistance performance of concrete with 40% GGBFS is greater than all the specimen. Thus GGBFS blended cement concrete is found to be more effective in limiting chloride diffusion than normal concrete.

The impedance parameters,charge transfer resistance Rct and double layer capacitance Cdl derived are tabulated in Table 2

Table 2 AC Impedance parameters for GGBFS blended M sand concrete

Specimen identification	Charge transfer resistance (R_{ct})Ohm cm^2	Double layer capacitance(C_{dl}) $\mu F/cm^2$	Improvement in corrosion resistance %
M sand concrete (Control specimen) - C	946	1049	-
(40%) GGBFS blended M sand concrete-F30	1189	855	25.68

From the AC. impedance values taken for the optimal percentage addition of GGBFS (40%) in M sand concrete it can be observed that, when compared with the M sand concrete specimens without GGBFS, the percentage of increase in corrosion resistance was found to the highest. The results obtained from AC impedance have good agreement with weight loss and impressed voltage methods..

IV CONCLUSION

It could be concluded from the above results that, among all the percentages of GGBFS added over the range of 10 to 50%, the strength properties and the corrosion resistance behavior of the M sand concrete are gradually increasing up to 40% of replacement. While considering 50% replacement of GGBFS, there is a reduction in strength and corrosion resistance performance. Similarly the specimens with 40% GGBFS show highest corrosion resistance. Hence, the replacement level of 40% of GGBFS is considered to be the optimum level of cement replacement in M sand concrete for getting maximum strength and corrosion resistance.

REFERENCES

[1] S.C.Pal, Abhijit Mukherjee and S.R.PathakCorrosion Behavior of Reinforcement in Slag Concrete, ACI Materials Journal/ November-December, pages521-527,(2002)

[2] S.N. Raman, M.F.M. Zain and H.B. Mahmud, "Influence of quarry dust and mineral admixtures on the 28th day initial surface absorption of concrete", in Sustainable Development in Concrete Technology: Proceedings of the Seventh International Conference on Concrete Technology in Developing Countries, Kuala Lumpur, Malaysia, pp. 33-42,(2004).

[3] S.Pavia and E.Condren, Study of the durability of OPC versus GGBS Concrete on Exposure to Silage Effluent, Journal of Materials in Civil Engineering, , pages313-320,April 2008

[4] Rose, J “The Effect of Cementitious Blast Furnace Slag on Chloride Permeability of Concrete,” Corrosion, Concrete, and Chlorides, SP-102, American Concrete Institute, Farmington Hills, Mich., 19 p. (1987)

[5] Regourd, M, “Structure and Behavior of Slag Portland Cement Hydrates,” Seventh International Congress on the Chemistry of Cement, V. I, Sept. 1980, pp. 63-67(1980).

[6] Sahu A.K., Sunil Kumar and Sachan A.K.. Quarry stone waste as fine aggregate for concrete. The Indian concrete journal. pp. 845-848. (2003)

[7] Roy, D. M., and Idorn, G. M., "Hydration, Structure, and Properties of Blast Furnace Slag Cements, Mortars, and Concrete," ACI Journal, Proceedings, V. 79, No. 6, , pp. 445-457 (1982)

[8] Roy, D.M. and Parker, K.M., "Microstructures and Properties of Granulated Slag Portland Cement Blends at Normal and Elevated Temperatures," Fly Ash, Silica Fume, Slag, and Other Mineral By-Products in Concrete , SP-79, American Concrete Institute, Farmington Hills, Mich, pp. 397-414, 1983

[9] Saika, K., Watanabe, H., Suzuki, M. and Hamazaki, K. "Properties of Granulated Blast Furnace Slag Cement Concrete," Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, V. II, , pp.1367- 1400. 77 (1992),

[10] Saraswathy V., and H.-W. SongCorrosion Performance of Fly Ash Blended Cement Concrete: A State-of-Art Review, Corrosion Review; 24(1-2): pp.87-122(2006).

[11] Sanjayan, J. G., and Sioulas, B., "Strength of Slag Cement Concrete Cured in Place and in Other Conditions," ACI Materials Journal, V. 97, No. 5, pp. 603-611 (2000)

[12] Safiuddin M., M.F.M. Zain, M.F. Mahmud and R.S. Naidu, "Effect of quarry dust and mineral admixtures on the strength and elasticity of concrete", Proceedings of the Conference on Construction Technology, Kota Kinabalu, Sabah, Malaysia, pp. 68-80. (2001)

[13] Santhakumar.A.R. "Concrete Technology", Oxford University Press

[14] Rafat siddique, ,Special Structural concretes, Galgotia publications(2000).

[15] Ramakrishnan, V. and Akman, M. S., Proceedings of the US-Turkey Workshop, Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, Istanbul, Turkey, May 9 1992, pp. 97-98(1992)