Significance of GGBFS in enhancing strength properties of concrete with M Sand

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ABSTRACT

In this paper an experimental investigation has been carried out to determine the significance of Ground Granulated Blast Furnace Slag (GGBFS) on the strength and microstructural properties of concrete containing manufactured sand (M sand) as fine aggregate. GGBFS was utilized as supplementary cementitious material at 10%, 20%, 30%, 40% and 50% by weight of cement. The effect of GGBFS on the strength properties was analyzed by conducting compressive, split tensile, flexural strength and bond strength tests in addition to water absorption, permeability and bulk density analysis. The optimum percentage of GGBFS to be added to get maximum strength and durability was also determined.

KEYWORDS

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

INTRODUCTION

Manufactured sand can be used as an economical alternative to river sand since natural sand has become a meager construction material and also highly pricey. The utilization of manufactured sand as building material has been accepted in the construction industry in recent years because of the scarcity of natural sand everywhere[1-2]. In addition to that, manufactured sand provides an opportunity to control the mineral content in the particles since natural sand often contains undesirable minerals and clays, and the effect of these materials on both the fresh and the hardened states of concrete can be extremely harmful[3-4]. The use of mineral admixtures such as fly ash, silica fume, slag and metakaolin in concrete improves workability, reduces the heat of hydration, minimizes cement consumption and enhances strength and durability properties by reducing the porosity due to the pozzolonic reaction[5-8]. Ground Granulated Blast Furnace Slag which is a by-product of steel manufacturing industry enhances the strength and durability characteristics when used in concrete due to its cementitious nature[9-12]. In this paper, an experimental study dealing with the strength and permeability 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[13-15]. The effect of GGBFS on the strength properties was analyzed by conducting compressive, split tensile, flexural strength and bond strength tests in addition to water absorption and bulk density analysis. The durability test to determine the permeability characteristics was Rapid Chloride Penetration Test (RCPT). The optimum percentage of replacement of cement by GGBFS to give maximum strength and durability was determined.

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. The Rapid Chloride Penetration Test (RCPT) is used to determine the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The RCPT 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. A voltage of 60 V DC is maintained across the ends of the specimen throughout the test. The total charge passed through the cell in coulomb has been found in order to determine the resistance of the specimen to chloride ion penetration.

RESULTS AND DISCUSSION

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 after 3, 7, 28, 56, 90, 180 days curing is shown in Figures 1 to 4.

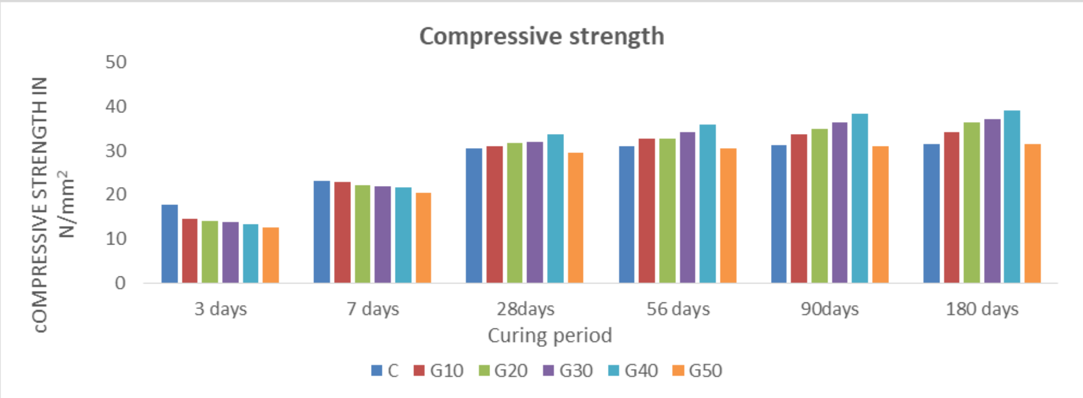


Fig 1 Compressive strength

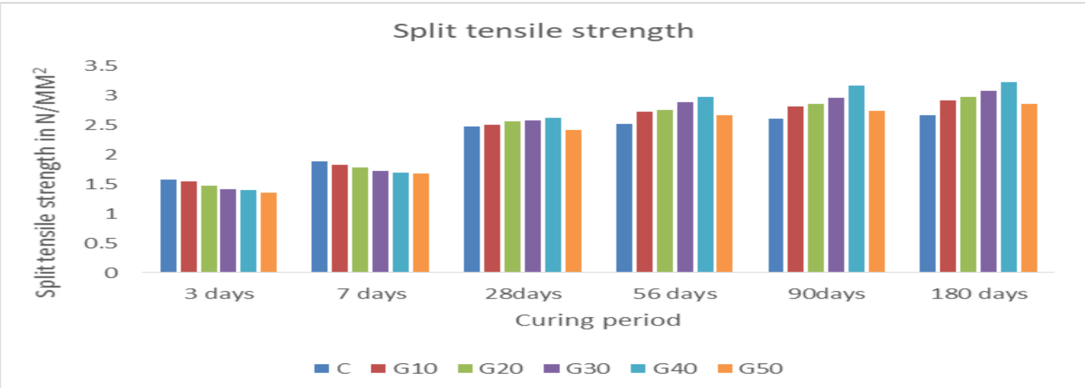


Fig.2 Split tensile strength

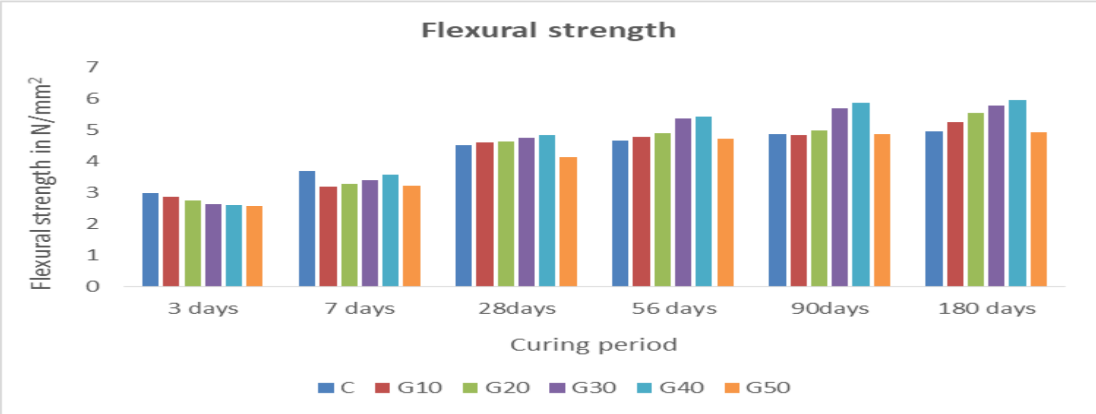


Fig 3. Flexural strength

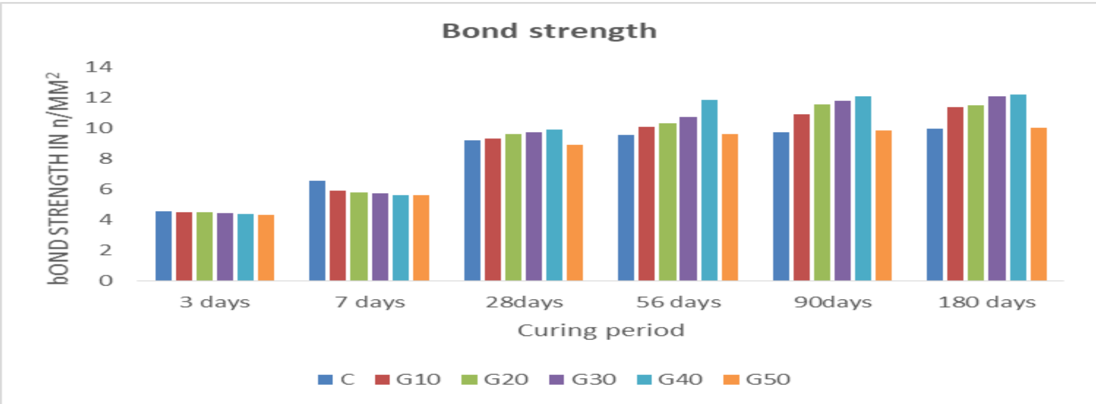


Fig 4. Bond strength

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. When early strength is considered, the rate of strength gain is generally inversely proportional to the amount of GGBFS used in the blend. But from 28 days onwards, the strength values were found to be increase consistently with time and the magnitude of the strength was more than the control specimen for all percentages of GGBFS. Hence, the drop in early strength should not be considered as sign of poor quality as this is often accompanied by enhancement of other properties.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.

Micro structural properties:

Water absorption of hardened concrete specimens was calculated based on ASTM C642-81. Cubes of size150X 150 X 150mm were cast and after 28 days curing the cubes were taken out and dried in an oven at 105°C for 24 hours. The dried specimens were cooled to room temperature (25°C), weighed accurately and noted as dry weight (Wd). Dry specimens were immersed in water and the weight of the specimens at predetermined intervals was taken after wiping the surface with dry cloth. The values obtained from the water absorption, permeability and bulk density tests performed on the quarry dust concrete and GGBFS blended quarry dust concrete specimens are tabulated in Table 1.

Table 1 . Microstrutural properties

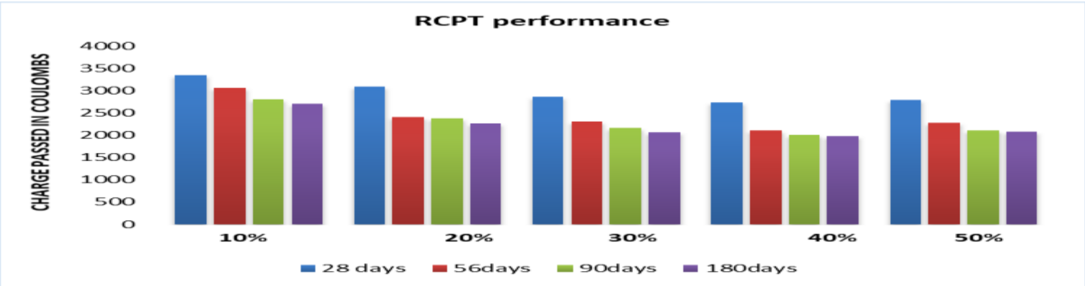
S. No.	Identification	Water absorption (%)	Permeable voids (%)	Bulk density kg/m^3
1	C- Control	4.15	2.812	2410
2	G10 (GGBFS 10%)	3.9	1.568	2414
3	G20 (GGBFS 20%)	2.55	1.291	2428
4	G30 (GGBFS %)	2.19	0.985	2530
5	G40 (GGBFS 40%)	1.78	0.648	2538
6	G50 (GGBFS 50%)	1.65	0.626	2542

The test values obtained on the micro structural properties of GGBFS and quarry dust concrete specimens reveal that, the increase in GGBFS percentages, resulting in decrease in water absorption, percentage of voids and increase in bulk density. The incorporation of GGBFS in cement paste helps in the transformation of large pores in the paste into smaller pores, resulting in decreased permeability of the matrix. Because of the reduction in permeability, concrete containing GGBFS require less depth of cover than conventional concrete requires protecting the reinforcing steel.

Permeability test (RCPT)

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



Use of GGBFS as a partial replacement of portland cement has been found to reduce permeability and has shown to result in good resistance to chloride penetration The pore structure of the paste is changed through the reaction of the slag with the calcium hydroxide and alkalis released during hydration. The pores are filled with calcium silicate hydrates instead of calcium hydroxide. Additionally, because workability is enhanced, the water cement ratio can be lowered, thus resulting in a denser paste structure. It has been postulated that slag replacement of portland cement will decrease the permeability by producing a finer pore size distribution even though the total porosity may increase. Thus 40% GGBFS blended cement concrete is found to be more effective in limiting chloride diffusion than normal concrete.

CONCLUSION

The test results of GGBFS incorporated specimens have shown that the addition of GGBFS replacing cement partially up to 40% in M sand concrete produces increase in strength. 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 23.84%, 21.72%, 20.95% and 22.22% improvement respectively for compressive, split tensile, flexural and bond strength tests after 180days curing which was considered to be the optimum percentage addition. Similarly GGBFS shows decrease in permeability rate when compared with control specimen which is concrete without GGBFS. From the above results, it is revealed that the 40% replacement of cement with GGBFS shows maximum improvement and strength and permeability properties and hence it is considered to be the optimum percentage to be added in concrete containing M sand as fine aggregate.

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