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THE EFFECT OF GGBS ON THE STRENGTH AND CHLORIDE PENETRATION OF CONCRETE

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ABSTRACT

This paper deals with replacement of cement in concrete by ground granulated blast furnace slag (GGBFS) with different replacement levels. The strength and chloride penetration of concrete mixes determined by replacing 40%, 50%, 60% and 70% of cement with GGBFS. Total five slag based concrete mixes of different mix proportions were used. For each mix standard sizes of cubes, cylinders and prisms were cast and tested for mechanical properties and rapid chloride penetration at different ages of curing. The obtained results were compared with control concrete and the mix contains 50% replacement with GGBS perform better strength and chloride penetration compared with all other concrete mixes.

Key words: Slag, Pozzolonaic, Mechanical, Durability.

INTRODUCTION

In developing countries, energy plays a crucial role in growth of economy. In context of low availability non-recoverable energy sources coupled with requirements of large quantities of energy to materials like cement, steel etc., CO_2 emission from cement industry is about 0.82 tons per ton of cement. CO_2 emissions from cement manufacture alone amount to 10% of the Greenhouse Gases (GHG). To reduce GHG the cement utilization can be reduced to possible extend by replacing the cement with suitable pozzalanic material. The reactive glass content and fineness of GGBS alone will influence the cementitious/pozzolanic efficiency or its reactivity in concrete composites. GGBS is a latent hydraulic material it produces C-S-H gel after reacting with water. Slag is used to make durable concrete structures in combination with OPC and other pozzolanic materials. The development and use of blended cement is growing mainly due to considerations of cost saving, energy saving, environmental protection and conservation of resources. GGBS is now recognized as a desirable cementitious ingredient of concrete, and as a valuable cement

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replacement material that imparts some specific qualities to the composite cement concrete. Concrete mixes made with GGBS continues to gain strength over time, and has been shown double its 28 days strength over periods of 10 to 12 years.

Literature review

Bilim and Atis[1] concluded that flexural and compressive strength of the slag-incorporated mortars increased with an increase in the Na content of liquid sodium silicate used for alkali activation. Abdelkader et al.[2] reported that at very early ages, the efficiency coefficient of this slag is sensitive to the replacement rate but remains close to that of an inert mineral admixture. Oner and Akyuz[3] reported that the optimum level of GGBS content for maximizing strength is at about 55-59% of the total binder content. Saraswati and Basu[4] were explained that GGBSC can be developed using commercially available Indian cement and GGBS with cement replacement level at least upto 53.3 percent. Cheng et al.[5] reported that the reduction of pH value due to the addition of GGBS seems no adverse effect on the corrosion resistance of GGBS concrete.

Wainwright and Rey[6] showed that the addition of slag at both levels of 55% and 85% resulted in an increase in workability. Osborne[7] reported that that structural concretes containing up to 50% of slag as cementitious material are considered suitable for the same uses, in ordinary and mild exposure applications, as conventional Portland cement concretes of the same design strength. Jain and Paul[8] showed that concrete containing 50 percent GGBS have better sulphate resistance properties and however 70 percent GGBS concrete had almost zero expansion.

Scope of present work

Concrete is the most costlier and energy intensive component of concrete. The unit cost of the concrete can be reduced by partial replacement with GGBS. The utilization of GGBS instead of dumping it as waste material can be partly used on economic grounds as pozzolana for partial replacement of cement because of its beneficial effects such as lower demand for similar workability and better sulphate resistance.

EXPERIMENTAL

Materials used

Cement: The ordinary portland cement of 53 grade was used, conforming to IS: 12269[12]-1987. The values of fineness and specific gravity values are 97% and 3.16, respectively.

Ground Granulated Blast Furnace Slag (GGBFS): GGBS is mineral admixture having pozzolanic property. Different percentage of replacement levels was used in the concrete mixes as per IS 456-2000[9]. GGBS was procured from Visakhapatnam (A. P.).

Fine aggregate: Natural river sand passing through 4.75 mm IS sieve was used. The specific gravity and fineness modulus of fine aggregate are 2.61 and 2.57.

Coarse aggregate: Crushed granite of 20 mm down and 12.5 mm sieve retained was used. For this work, the values of specific gravity and fineness modulus are 2.66 and 7.66 respectively.

Water: Potable water available in the university campus was utilized for making concrete.

Mix proportion

ACI method of concrete mix design was adopted for designing the mix. The mix was designed to achieve target compressive strength of 49.5 Mpa at 28 days. The mix proportion was 1:1.59:1.80 by weight of constituent material with water binder ratio 0.40.

Casting and curing

A rotary drum mixer of tilting type was used for mixing of concrete ingredients. All the specimens were cast in standard moulds and vibrated on a standard vibrating Table. Test specimens were demoulded after 24 hrs from the commencement of casting and placed into the curing tanks till the time of testing.

Details of test specimens

Each series consists of standard cubes, cylinders and prisms of size 150 mm × 150 mm, 300 mm × 150 mm, 100 mm × 200 mm, 50 × 100 mm and 500 mm × 100 mm × 100 mm, respectively.

Tests on hardened concrete

Compressive strength

Compression is the most common test conducted on hardened concrete. Three cubes of size 150 mm × 150 mm are tested using a compression testing machine of 2000 KN capacity as per IS 516:1959[11] and the compressive strength can be evaluated.

Split tensile strength

The specimens were palced under CTM and the load was applied without shock and increased continuously at a nominal rate within the range 1.2 N/(mm^2/min) to

2.4 N/(mm^2/min). The maximum load applied was recorded and the split tensile strength was calculated as per IS 516:1959[11] and shown in the Fig. 2.

Flexural strength

The prisms of size 500 mm × 100 mm × 100 mm were placed and tested under digital UTM of capacity 200 KN. The flexural strength values are given in the Table 2.

Rapid chloride permeability test (RCPT)

The specimens were removed from curing tank, blot off excess water. Specimen of size 50 × 100 mm was insert and clamped the two halves of the test cell together to seal with sealant around the boundaries of the specimen and cell. Record the current value at every 30 min up to 6 hrs. Each half of the test cell must remain filled with the appropriate solution for the entire period of the test. The procedure was adopted as per ASTM C1202[10]. The values are shown in the Fig.3.

RESULTS AND DISCUSSION

Compressive strength test

From Fig. 1, when GGBS was used, the compressive strength for 7 days of the concrete mix G1 with 40% GGBS and mix with 50 % GGBS G2 were decreased up to 19.14% and 8.67% compared with that of the reference concrete mix G0. The compressive strength of mixes like G3 and G4 was increased by 2% to 6% compared with G0 control concrete mix. It can be observed that the compressive strength of concrete mix G3 is almost equal to the control concrete mix G0.

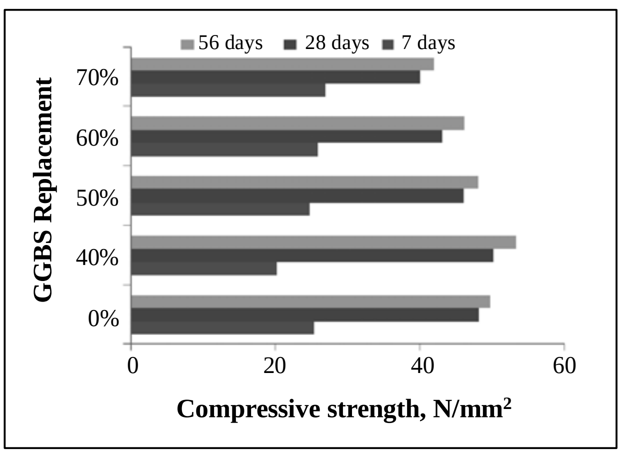

Fig. 1: Variation of compressive strength with GGBS replacement

From Fig. 1, the compressive strength for 56 days of the concrete mix G1is increased up to 6% compared with that of the reference concrete mix G0. The compressive strength of mixes like G2, G3 and G4 was reduced by 5.6%, 10.5% and 17.2% compared with G0 concrete mix. This shows that at the age of 7 and 28 days there is marginal improvement with 40% GGBS mix when compared with reference mix.

Split tensile strength test

The split tensile strength of the concrete mixes at 7, 28 and 56 days were shown in the Fig. 2, the split tensile strength of the concrete mixes G1 and G2 with 40% and 50% GGBS increased up to 10% and 24% compared with that of the reference concrete mix G0. The split tensile strength of concrete mixes G3 and G4 were increased by 16% and 3.5% compared with control concrete mix G0. All the mixes having GGBS are showing increasing results when compared with conventional concrete at the age of 7 days. The split tensile strength at 28 days of concrete mixes G1, G2, G3, and G4 increases by 13%, 24.2%, 17%, and 3.5% compared with reference concrete mix G0. This shows mixes having GGBS are showing increasing results when compared with conventional concrete at the age of 28 days. All the mixes having GGBS are showing increasing results when compared with conventional concrete at the age of 56 days.

Table 1: Concrete mixes

Mix ID	G0	G1	G2	G3	G4
OPC (%)	100	60	50	40	30
GGBS (%)	-	40	50	60	70

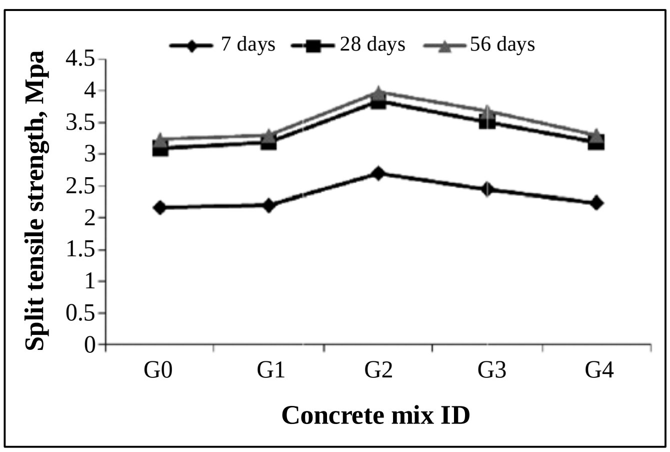

Fig. 2: Variation of split tensile strength of GGBS with curing period

Flexural strength test

The flexural strength of the concrete mixes at 28 and 56 days were shown in the Table 2, the flexural strength of the concrete mixes at 28 days G1 and G2 with 40% and 50% GGBS increased up to 5% and 14% compared with that of the reference concrete mix G0. The split tensile strength of concrete mixes G3 and G4 were increased by 17% and 10% compared with control concrete mix G0. All the mixes having GGBS are showing increasing results when compared with conventional concrete at the age of 28 days. From Table 2, the flexural strength at 56 days of concrete mixes G1, G2, G3, and G4 increases by 7%, 16%, 17.5%, and 11% compared with reference concrete mix G0. This shows mixes having GGBS are showing increasing results when compared with conventional concrete at the age of 56 days.

Table 2: Test results for flexural strength (N/mm^2)

Mix ID	G0	G1	G2	G3	G4
28 days	4.21	4.24	4.80	4.91	4.62
56 days	4.24	4.53	4.91	4.98	4.71

Rapid chloride penetration test

The rapid chloride penetration test is shown in Fig. 3. The charge passed along the cylindrical specimens of concrete mixes G1, G2, G3 and G4 is less when compared to control concrete mix G0.

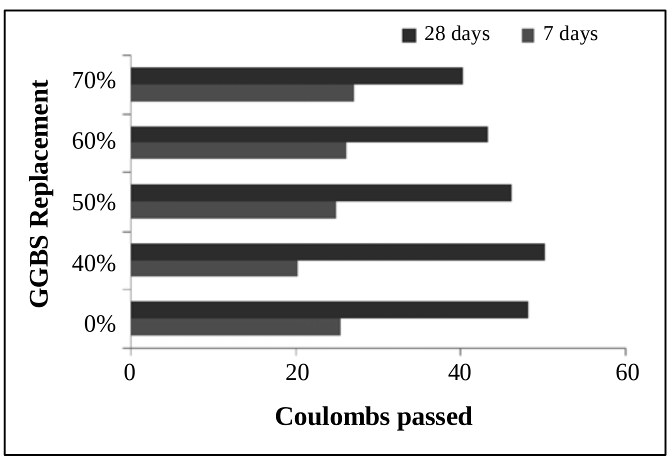

Fig. 3: Variation of cuurent passed with reference to concrete mix

The rapid chloride penetration values for the mixes G1, G2 and G3 fall under the category of low and concrete mix G4 fall under very low category compared with the control concrete mix. The percentage of GGBS increases the resistance of the chloride penetration decreases.

CONCLUSIONS

(i) At the age of 7 days, the G3 and G4 mixes shows comparable with control concrete.

(ii) The compressive strength at 28 days of GGBS based concrete mixes shows decreases with increase percentage of GGBS in concrete mix. At the ages of 28 and 56 days, the mix containing 40% GGBS replacement level shows marginal improvement in compressive strength compared with control concrete mix.

(iii) At all the ages 7, 28 and 56 days, the split tensile strength of concrete mix containing 50% GGBS replacement level shows improvement in strength compared with control concrete mix and other GGBS concrete mixes.

(iv) The flexural strength of concrete with 60% GGBS shows higher value when compared with other mixes at 28 and 56 days.

(v) The rapid chloride penetration values for the mixes G1, G2 and G3 fall under the category of low and concrete mix with 70% GGBS fall under very low category when compared with the control concrete mix. It can be observed that, as the percentage of GGBS increases the resistance of the chloride penetration decreases.

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