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# STUDY OF GGBS WITH HIGH PERFORMANCE CONCRETE

Vivek Paliwal[1], Sanjay Saraswat[2]

P.G. Student, Department of Mechanical Engineering, S.A.T.I., Vidisha, M.P., India[1]
Associate Professor, Department of Mechanical Engineering, S.A.T.I., Vidisha, M.P., India[2]



**ABSTRACT:** Indian steel and copper industries are seeing an enormous growth. The byproduct produced by these industries like ground granulated blast furnace slag (GGBS) are hazardous to the atmosphere thus they are needed to be disposed off properly. Considering the long term performance and stability of structures, this study suggests replacing some percentage of cement with GGBS to develop high performance concrete. In this study an experimental investigation was done to know the use of GGBS in concrete as a replacing agent of cement. To accomplish this C-40, C-50 and C-60 high performance cement were used to prepare a concrete mix with a w/c ratio of 0.35 with suitable superplasticizers. Tests were conducted to confirm the use of GGBS as a replacing agent. Cement was replaced with 40-60% with GGBS respectively. Concrete control specimens without replacement were also cast for comparison. After casting the cube moulds specimens were tested for various tests like tensile strength test, compressive strength test, flexure strength test. From the study, based on the findings the replacement of cement with GGBS is found to have least strengths with that of control mix.

***Keywords: GGBS, High Performance Concrete, super plasticizer***

## 1. INTRODUCTION

Indian steel and copper industries are seeing an enormous growth. The byproduct produced by these industries like ground granulated blast furnace slag (GGBS) are hazardous to the atmosphere thus they are needed to be disposed off properly. . The necessity of high performance concrete is increasing because of demands in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that Mineral & chemical admixtures when used with cement replacement materials can improve the strength and durability characteristics of concrete. Pozzolanic materials like Alccofine (GGBS) and Fly ash can be used for production highly durable concrete composites. This study investigates the performance of concrete mixture in terms of Chloride Attack tests, Compressive strength, Accelerated corrosion and Sea water test test at age of 28 and 56 days

## 2. HIGH PERFORMANCE CONCRETE

High performance concrete is a concrete mixture, which possess high durability and high strength in comparison to conventional concrete. This concrete contains one or more of cementious materials such as fly ash, Silica fume or ground granulated blast furnace slag and a super plasticizer usually. The term ‘high performance’ is somewhat rhetorical because the essential feature of this concrete is that it’s ingredients and proportions are specifically chosen so as to have specific properties for the expected use of the structure such as high strength and low permeability. Hence High performance concrete is not a special type of concrete. It consists of the same materials as that of the conventional cement concrete. The use of some mineral and chemical admixtures like Silica fume and Super plasticizer enhance the strength, durability and workability qualities to a very high extent.

## 3. GROUND GRANULATED BLASTFURNACE SLAG

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of manufacturing of iron in a blast furnace where iron ore, is heated with lime stone and coke up to 1500˚C. In blast furnace when these materials melt, two products are produced – molten iron and molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises of mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The granulating process of the slag involves cooling the molten slag by using high pressure water jets. This rapidly quenches the slag and form granular particles generally not larger than 5mm in diameter. The rapid cooling prevents larger crystals formation and the resulting granular material comprises some 95% non-crystalline calcium-alumina silicates. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS (Ground Granulated Blast Furnace Slag) cement. Grinding of granulated slag is carried out in a rotating ball mill. Different forms of slag products are produced depending upon the method used for cooling of the molten slag. These products contain air-cooled blast furnace slag (ACBFS), expanded or formed slag, palletized slag and granulated blast furnace slag.

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## 4. LITERATURE REVIEW

Mahesh Patel, Prof. P. S. Rao, T. N. Patel (2013) focused on investigating characteristics of M35 concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS) and sand with the Crusher sand . The cubes and cylinders are tested for both compressive and tensile strengths. It is found that by the partial replacement of cement with GGBS and sand with Crusher sand helped in improving the strength of the concrete substantially compared to normal mix concrete. They found from the experimental results 50% of cement can be replaced with GGBS. The percentage increase of compressive strength of concrete is 10.04 and 16.54% at the age of 7 and 28 days by replacing 40% of cement with GGBS and 20% of sand

Jianyong and Yan (2001) reported the 28-day compressive strength of three high performance concrete (HPC) mixtures. Mix proportions and compressive strength results are given in Table 1 As shown in this table, Concrete B and C acquired much higher compressive strength than Concrete A at each testing age. At the age of 3 days, the compressive strengths of concrete A, B and C were 63.8, 69.3 and 69.3MPa, respectively. At 28 days of age, the compressive strengths of Concrete B and C increased greatly to 100.4 and 104.0 MPa, respectively, compared with 81.1 MPa of Concrete A. The development of compressive strength reflected the strengthening effect of ultra-fine GGBS and SF on mechanical properties of concrete.

| Mix | Mix proportions | | | | | | | Compressive strength (MPa) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OPC | GGBS | SF | SP (%) | Fine Agg. | Coarse Agg. | Water | 3 days | 7 days | 28 days |
| A | 600 | – | – | 1.6 | 610 | 1134 | 156 | 63.8 | 71.2 | 81.1 |
| B | 420 | 180 | – | 1.6 | 610 | 1134 | 156 | 69.3 | 83.2 | 100.4 |
| C | 360 | 180 | 60 | 1.6 | 610 | 1134 | 156 | 69.3 | 97.0 | 104.0 |

TABLE 1 Mix proportions (kg/m3) and compressive strength of HPC (Jianyong and Yan, 2001)

Li and Zhao (2003) studied the influence of combination of ground granulated blast furnace slag (GGBS) and fly ash (FA) on the compressive strength of high strength concrete . Three types of concretes; GGFAC (concrete incorporating GGBS and FA), HFAC (high-volume fly

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ash concrete), and PCC (control Portland cement concrete) were made and their strength was determined up to the age of 360 days. PCC had 500 kg/m3 of cement content, HFAC had 300 kg/m3 of cement & 200 kg/m3 FA, GGFAC had 300 kg/m3 of cement & 125 kg/m3 FA and 75 kg/m3 of GGBS. Table 2 gives the strength development of PCC, HFAC (containing 40% of FA) and the concrete (GGFAC) incorporating a combination of 25% FA and 15% GGBS. It can be seen that there is a general trend of increasing strength with age up to 1 year for all concretes. As expected, the behavior of HFAC at early ages is different from that of PCC and GGFAC. Though it had the highest strength at the end test age, its strength was the lowest before 56 days. The strength development of GGFAC is similar to that of PCC, only with slightly lower values before 28 days. This indicates that GGFAC can achieve adequate early compressive strength, while maintaining a high long-term strength.

| Binder combination | Cube compressive strength (MPa) | | | | | | | Strength gain from 28 day to 1-year (%) |
|---|---|---|---|---|---|---|---|---|
| | 1 day | 3 day | 7 day | 28 day | 56 day | 112 day | 360 day | |
| PCC | 40.5 | 51.2 | 66.8 | 81.1 | 87.9 | 91.2 | 96.3 | 18.7 |
| HFAC | 21.7 | 32.6 | 43 | 65.2 | 86.7 | 97.5 | 107.1 | 64.3 |
| GGFAC | 35.1 | 49.3 | 65.4 | 80.6 | 89.8 | 93.7 | 99.4 | 23.3 |

TABLE 2 Compressive strength gain of concretes (Li and Zhao, 2003)

Hooton and Titherington (2004) investigated the strength and chloride penetration resistance of high-performance concretes after curing either at 23◦C or accelerated by heating to 65◦C. Six air-entrained concrete mixtures with different cement replacement levels of slag (25–27%) and silica fume (4–8%) (by mass) were made. The water to cementitious materials ratio (w/cm) was kept constant, at 0.30. The total cementing materials content was 460 kg/m3 for all mixtures. They measured chloride penetration resistance of a series of high-performance concretes after curing either at 23◦C or accelerated by heating to 65◦C.

A Elahi, P.A.M. Basheer, S.V. Nanukuttan, Q.U.Z. Khan (2009) carried out An experimental investigation to evaluate the mechanical and durability properties of high performance concretes containing supplementary cementitious materials in both binary and ternary systems. The mechanical properties were assessed from the compressive strength, whilst the durability characteristics were investigated in terms of chloride diffusion, electrical resistivity, air permeability and water absorption. The test variables included the type and the amount of supplementary cementitious materials (silica fume, fly ash and ground granulated blast-furnace slag). Portland cement was replaced with fly ash up to 40%, silica fume up to 15% and GGBS up to a level of 70%. The results confirmed that silica fume performs better than other supplementary cementitious materials for the strength development and bulk resistivity. The ternary mixes containing ground granulated blast-furnace slag/fly ash and silica fume performed the best amongst all the mixes to resist the chloride diffusion. The mix containing fly ash showed favorable permeation results. All the ternary combinations can be considered to have resulted in high performance concretes with excellent durability properties.

Yatin H Patel, P.J.Patel, Prof. Jignesh M Patel, Dr. H S Patel studied the performance of concrete (HPC) containing supplementary cementitious materials such as Fly ash & Alccofine. The necessity of high performance concrete is increasing because of demands in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with Mineral & chemical admixtures can improve the strength and durability characteristics of concrete. Alccofine (GGBS) and Fly ash are pozzolanic materials that can be utilized to produce highly durable concrete composites. This study investigates the performance of concrete mixture in terms of Compressive strength, Chloride Attack tests, Sea water test and Accelerated corrosion test at age of 28 and 56 days. In addition find out the optimum dosage of Alccofine and fly ash from given mix proportion. Result show that concrete incorporating Alccofine and fly ash have higher compressive strength and Alccofine enhanced the durability of concretes and reduced the chloride diffusion. An exponential relationship between chloride permeability and compressive strength of concrete is exhibited.

M. Adams Joe, A. Maria Rajesh focused on investigating characteristics of M40 concrete with Various proportional of replacement of cement with Ground Granulated Blast furnace Slag (GGBS) and adding 1% of steel fiber. High Performance Concrete (HPC) is a concrete meeting special combinations of performance and uniformity requirements that cannot be always achieved routinely by using conventional constituent sand normal mixing. This leads to examine the admixtures to improve the performance of the concrete. Considering cost of construction also drawn the attention of investigators to explore new replacements of ingredients of concrete. Ten mixes were studied with GGBS & Steel Fiber using a water binder ratio of 0.35 and super plasticizer CONPLAST SP-430. The cubes, cylinders and prisms were tested for both Compressive, Split tensile, Flexural and Pull out strengths GGBS can enhance the durability aspects of HPC compared to control mix. Among the mixes the mix with replacement level as 0%,10%,20%,30%,40% & 50% of GGBS and 1% steel fiber is better with respect to strength and durability. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. It is found that by the 40% replacement of cement with GGBS and steel fiber helped in improving the strength of the concrete substantially compared to Control concrete

## 5. METHODOLOGY

### Concrete Mix Design

The concrete mix for the present study comprised of different grade of cement mixed with GGBS and Microsillica. For the study we took C-40, C-50, and C-60 grade of Portland cement and mixed them with 45% GGBS in C-40 and C-50 while C-60 cement was mixed with 30% GGBS. In addition to this 5%microsillica was added to C-40 and C-50 and 10% in C-60.

The concrete was supplied by AL WATANIYA concrete. For each truckload of concrete, slump test was carried out in accordance with CS1:1990. In addition, the bleeding of concrete was measured in accordance with ASTM C232-99

### Testing Procedure

Blocks were prepared from the above concrete mix and left for 28-days so that they gain their strength. After 28 days specimen were tested to check their compressive strength.

Fig 1: Compressive Strength testing Machine

## 6. RESULTS AND DISCUSSION

As there was an substantial increase in the workability of concrete with increase in percent replacement of cement with GGBS, therefore WLC ratio can be reduced keeping the slump constant, as a result compressive strength increases. Even if WLC ratio is reduced by using water reducers, compressive strength can be increased up to strength of normal cement concrete. Partial replacement's effect was lower tensile strength and modulus of rupture i.e., between strength of control mix & the blended cements concrete. GGBS is a waste product and only grinding makes it fit for use. Thus making it a economical cement replacement material. Consequently it also reduces the cost of concrete. Using GGBS as cement replacement material is a suitable way for its disposal, so this technique is environment friendly

The addition of GGBS to the Portland cement considerably increase its strength. Compressive strength development depends upon the GGBS replacement percentage and concrete age. The reaction of glassy compounds in GGBS is slow with water and time is taken to obtain hydroxyl ions from the hydration product of Portland cement to breakdown the glassy slag parcels at early age. However, compressive strength of GGBS concrete is higher than ordinary Portland cement concrete (OPC) after GGBS hydration and pozzolanic reaction is almost accomplished. Higher GGBS replacement percentage has higher ultimate strength. As reported by previous study good strength development of concretes containing 50–75% of GGBS by mass of cementitious materials (300–420 kg $m^{-3}$) was observed

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Effect On Environment

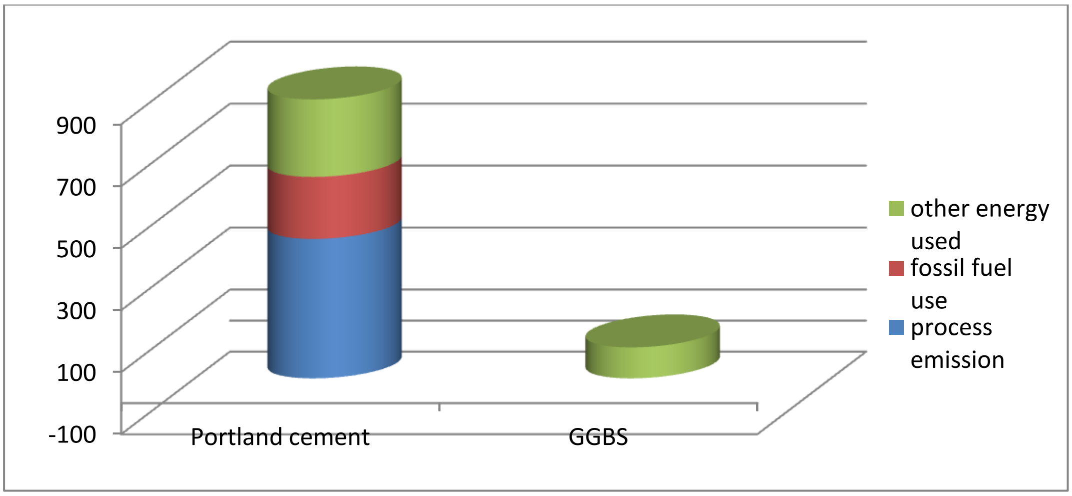


Fig 2: typical CO2 Emission for Portland cement and GBS production

(Figures in kg per ton of output)

| | | Equivalent |
|---|---|---|
| $CO_2$ | 79.4 tonnes | 25 cars or 10 acres of nature forestry/year |
| $SO_2$ | 245 Kg | |
| $NO_x$ | 343 Kg | |
| CO | 245 Kg | |
| $PM_{10}$ | 42.7 Kg | |
| Energy | 94,000 Kwh | Power 18 homes for 1 year |
| Limestone/Shale | 160 tonnes | |

Table 3: Environmental saving per typical base

Heat of Hydration

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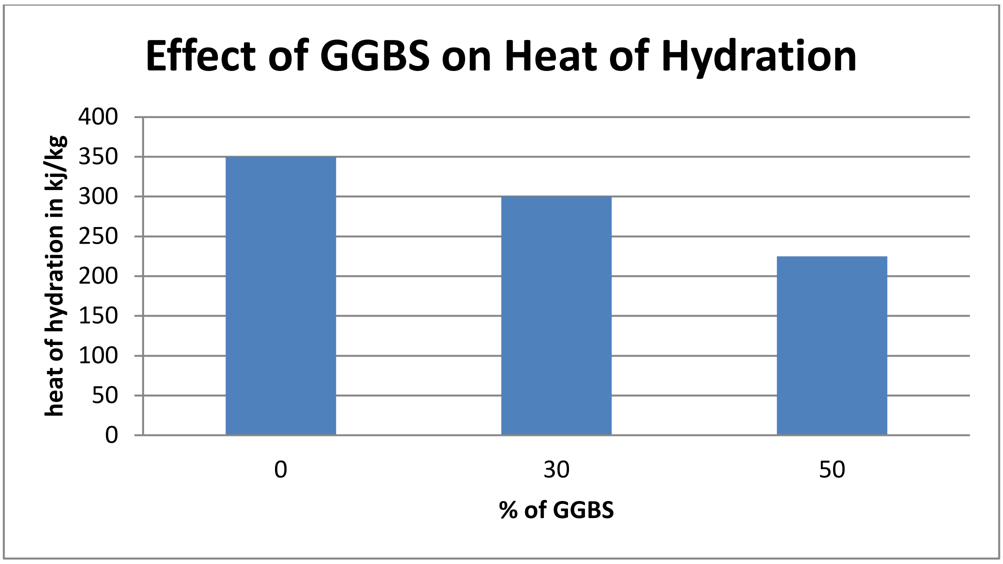


Fig 3 Effect of GGBS on heat of hydration

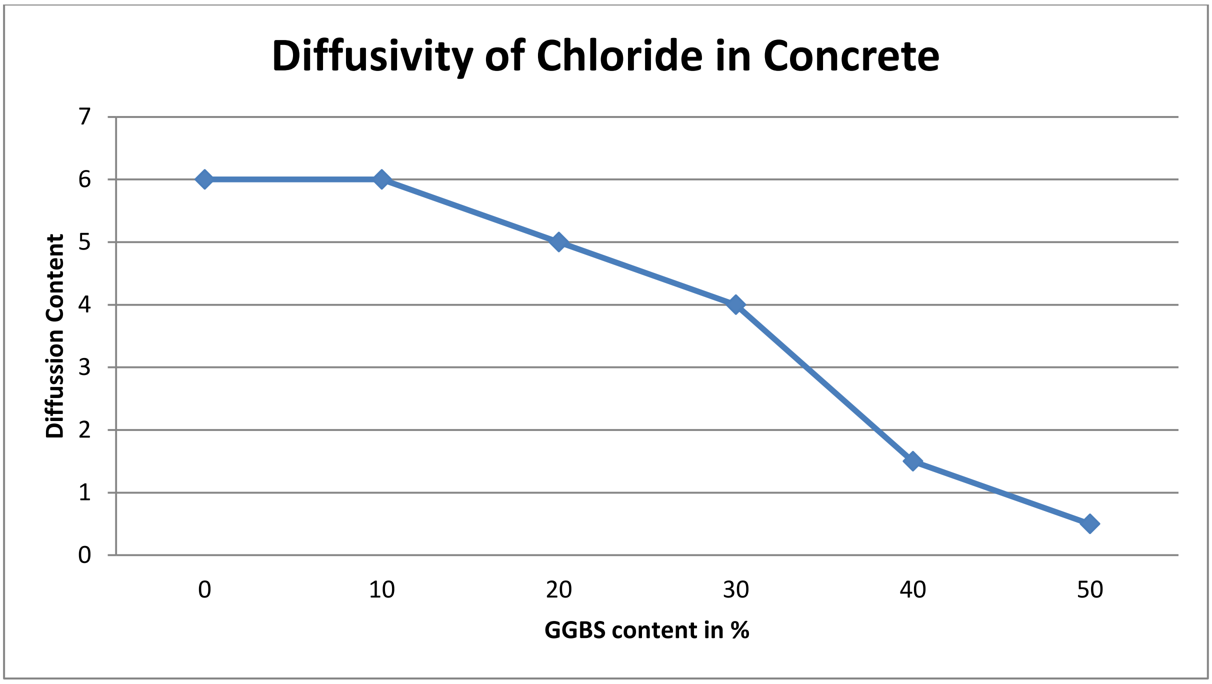


Fig 4 Diffusivity of chloride in concrete

## 7. CONCLUSION

The following conclusions are drawn from the results and discussion of this investigation:

1. By using Portland Cement with GGBS $CO_2$ emission can be reduced by 79.4 tons per year
2. GGBS also reduces $SO_2$, CO, $NO_x$, $PM_{10}$ emission considerably.

3. By using GGBS we can save up to 159.3tons of limestone/shale used for cement production
4. GGBS increases the strength of the concrete
5. GGBS reduce hydration heat thus controlling thermal cracking
6. GGBS reduces risk of cracking thus increasing the life of cement
7. GGBS also reduces the maintenance cost
8. Addition of GGBS increases long term strength of concrete
9. GGBS reduces the effect of peaty/acidic environment by increasing resistance against them
10. As it has low chloride ion diffusivity and lower porosity it is suitable to be used in marine environment

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