

### Chloride Ingress

GGBS blended concrete is significantly more resistant to the ingress of chloride ions in concrete apart from reduced permeability. OPC used with GGBS blend chemically binds the chlorides with slag hydrates effectively reducing the mobility of chlorides thereby reducing the reinforcement corrosion risk.

### Alkalinity

Despite the reduction in  $\text{Ca}(\text{OH})_2$  caused by secondary slag hydration reactions the pH of paste remains at a level which is well in excess of that which would affect the passivity of the reinforcing steel.

### GGBS –A sustainable material for Green building construction

Replacing the Portland cement by GGBS helps in reducing  $\text{CO}_2$  emissions and in conserving non-renewable resources of lime stone.

Use of GGBS in concrete is recognized by LEED (Leadership in Energy and Environmental Design) and add points towards its certification.



### Conclusion

GGBS blended concrete have been used successfully in concrete for many years in many countries throughout the world. From all the available technical literature it is suggested that there are potentially many technical benefits to be gained from using the GGBS. Where structures have to be designed for durability requirements in very aggressive environment GGBS blend mixes are recommended in standards of most developed and developing countries. Many countries have accepted the benefits and have recommended its use in their national standards. Once the user is made aware of the properties of the material and understood the benefits to be gained there is no reason why it should not continue to be used successfully and more often in existing and future project.

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**JSW  
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# GGBS

Ground Granulated Blast Furnace Slag

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Banao Pyaar Se



# USE OF GGBS IN CONCRETE AS SUSTAINABLE GREEN BUILDING MATERIAL:

## Introduction

Sustainability, or sustainable development, is aimed at improving the quality of life for everyone, now and for generations to come. It encompasses environmental, economic and social dimensions, as well as the concept of stewardship, the responsible management of resource use.

As society makes determined moves towards sustainability, construction has a very important role to play within this new agenda, not only because of its economic and social contribution, but also because of its impact on the quality of our lives, our comfort and safety. While the building industry provides 5% to 10% of worldwide employment and generates 5% to 15% of GDP (Gross Domestic Product), the built environment accounts for 40% of energy consumption, 40% of CO<sub>2</sub> emissions, 30% of the consumption of natural resources, 30% of waste generation and 20% of water consumption.

The future global challenge for the construction industry is clearly to meet the world's growing needs while at the same time limiting the impact of its burdens by drastic improvement of its activities.

Due to exponential growing in urbanization and industrialization, byproducts from industries are becoming an increasing concern for recycling and waste management. Ground granulated blast furnace slag (GGBS) is by-product from the blast-furnaces of iron and steel industries. GGBS is very useful in the design and development of high-quality cement paste/mortar and concrete.



## What is GGBS and how it is manufactured ?

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. Blast-furnaces are fed with controlled mixture of iron-ore, coke and limestone, and operated at a temperature of about 1,500°C. When iron-ore, coke and limestone melt in the blast furnace, 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 mostly silicates and alumina from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling of molten slag through high-pressure water jets. This rapidly quenches the slag and forms granular particles generally not bigger than 5 mm. The rapid cooling prevents the formation of larger crystals, and the

resulting granular material comprises around 95% non-crystalline calcium-alumino silicates.

The granulated slag is further processed by drying and then grinding in a vertical roller mill or rotating ball mill to a very fine powder, which is GGBS.

## Chemical Composition of GGBS

Ground Granulated Blast furnace Slag consist essentially silicates and alumino silicates of calcium. Portland cement is a good catalyst for activation of slag because it contains the three main chemical components that activate slag: lime, calcium sulphate and alkalis.

The material has glassy structure and is ground to less than 45 microns. The surface area is about 350 to 450 m<sup>2</sup> / kg Blaine. The ground slag in presence of water and an activator which are commonly sulphates and /or alkalis which are supplied by Ordinary Portland Cement react chemically with GGBS and hydrates and sets in a manner similar to Portland Cement.

Parameter	JSW GGBS	As per IS : 12089 – 1987 (Reaffirmed 2008)	
CaO	37.34%	---	
Al <sub>2</sub> O <sub>3</sub>	14.42%	---	
Fe <sub>2</sub> O <sub>3</sub>	1.11%	---	
SiO <sub>2</sub>	37.73%	---	
Magnesium Oxide (MgO)	8.71%	Max. 17.0%	
Manganese Oxide (MnO)	0.02%	Max. 5.5%	
Sulphide Sulphur	0.39%	Max. 2.0%	
Loss On Ignition	1.41%	---	
Insoluble Residue	1.59%	Max. 5%	
Glass Content (%)	92%	Min. 85%	
Chemical Moduli:			
1. $\frac{CaO+MgO+1/3Al_2O_3}{SiO_2+2/3Al_2O_3}$	1.07	≥ 1.0	The presence of major oxides with granulated slag shall satisfy at least one of the equation
2. $\frac{CaO+MgO+Al_2O_3}{SiO_2}$	1.60	≥ 1.0	

# Properties of Concrete made with GGBS blend with Ordinary Portland Cement

## Plastic Concrete

### Water Demand

For concrete made with equal slump lower water content is required compared to Ordinary Portland Cement. This will help in reduced capillary pores and hence concrete will be of better durability.

### Stiffening time

Because GGBS is slower to react with water than OPC its use in concrete increases the stiffening time of concrete. This will help in more time available for placing the concrete.

### Heat of hydration and early age thermal cracking

The rate of heat evolution associated with GGBS is reduced as the proportion of slag is increased. This helps in greater heat dissipation and reduced temperature rise which will reduce the likelihood of thermal cracks. Lower thermal cracks helps in long term durability.



## Hardened Concrete

### Compressive strength and strength development:

The rate of hydration reaction of GGBS concrete is temperature dependent. GGBS has higher activation energy than OPC and therefore their reaction rate is more sensitive to temperature change. As the temperature increases the rate of gain of strength in GGBS blend concrete is greater than OPC concrete. The influence of temperature on strength development is of significance when considering the behaviour of concrete in-situ. In such situation the rate of strength development and ultimate strength may be appreciably different from that indicated by standard cured cubes.

### Tensile Strength & Elastic Modulus

Compared to concrete produced with only OPC, the GGBS blend produced concrete tend to have a slightly higher tensile strength and elastic modulus for a given compressive strength.



### Surface Finish

Generally, GGBS makes it easier to achieve a good surface finish. In addition the colour of concrete will be lighter than concrete produced with only OPC.

### Durability

Durability of concrete is related to its permeability or diffusion to liquids and gases and its resistance to penetration by ions such as Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup>. Generally speaking, provided the concrete is well cured GGBS blended concrete is likely to be more durable than similar concrete produced with only OPC.

### Alkali-Silica Reaction

Use of GGBS blend with OPC is one of the ways to reduce the Alkali-Aggregate Reaction, when aggregate used in concrete is alkali reactive. Use of GGBS with OPC reduces the total alkali content in cementitious material. Thereby, deterioration of concrete due to alkali aggregate reaction could be avoided.

### Sulphate Resistance

Concrete containing GGBS are acknowledged to have higher resistance to attack from sulphates than those made with only OPC. This is due to overall reduction in C<sub>3</sub>A level of concrete and to the inherent reduction in permeability.