USE OF GGBS IN CONCRETE AS SUSTAINABLE GREEN BUILDING MATERIAL:

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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_2 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.

In construction, steel has developed as a material of choice and offers a wide range of solutions that can make buildings more energy efficient, less costly to operate and more comfortable.

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 mil 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 alumina silicates of calcium. It is by-product of manufacture of pig iron in blast furnace. 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 400 to 600 m^2 / kg Blaine. The rough and angular shaped 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.

Properties of Concrete made with GGBS blend with Ordinary Portland Cement

Plastic Concrete

Water Demand

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

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.

Drying Shrinkage

Use of GGBS has very little if any influence on the drying shrinkage of concrete.

Creep

For high replacement levels (>70%) reduction in creep of as high as 50% is possible due to later age strength gain of GGBS blended concrete.

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.

Formwork Pressure:

Higher formwork pressure is relevant with the use of GGBS blended concrete when concrete is cast at ambient temperatures as low as <5°C, else it is not relevant.

Formwork Striking Time:

Use of high levels of GGBS blend (>70%) in concrete may require the extension of formwork striking time. In practice, however, the actual construction process often requires concrete to be cast one day and vertical formwork next day. In such cases it is quite likely that minimum striking time will in any case be extended and that therefore the use of GGBS may not affect the actual construction process.

Curing:

For long term durability it is beneficial if GGBS blended concrete is cured for longer 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^- and SO_3^+. Generally speaking, provided the concrete is well cured GGBS blended concrete is likely to be more durable than similar concrete produced with only OPC.

Permeability:

In well cured concrete containing blend of GGBS, the long term permeability is reduced due to continued hydration beyond 28days and overall finer pore structure

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 blend 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_3A level of concrete and to the inherent reduction in permeability. Provided Al_2O_3 of GGBS is less than 15%, then concrete containing about 70% of GGBS is considered as comparable to concrete produced with Sulphate Resistant Cement (SRC).

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.

Carbonation:

The influence of addition of GGBS on carbonation has been the subject of much research and there still appears to be some disagreement as to its effects. The reasons for much of this debate appear to be related to the test procedures and conditions used in the studies and to the basis on which comparisons are made.

Alkalinity:

Despite the reduction in $Ca(OH)_2$ 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.

Abrasion Resistance:

In adequately cured concrete when comparison is made with equal grade of 100% OPC concrete there is slight advantage in terms of abrasion resistance due to use of GGBS blend in concrete.

GGBS –A sustainable material for Green building construction:

Replacing the Portland cement by GGBS helps in reducing CO2 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.

References

1. MALHOTRA, V.M. and MEHTA, P.K., Pozzolanic and cementitious materials, Gordon and Breach Publishers, Philadelphia, (1996), pp.191.

2. MEHTA, P.K., Bringing the concrete industry into a new era of sustainable development, Cement Manufacturers Association, New Delhi, (1998), pp.49 – 67. 5. PRAVEEN KUMAR and S.K.KAUSHIK, ‘Some trends in the use of concrete: Indian scenario’. The Indian Concrete Journal, (2003), pp.1503 – 2003.