STUDY OF BLAST FURNACE SLAG TO IMPROVE PROPERTIES OF CONCRETE - A REVIEW

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Abstract--The utilization of supplementary cementation materials is well accepted, since it leads to several possible improvements in the concrete composites, as well as the overall economy. Cement with BFS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, and cost savings, environmental and socio-economic benefits. The aim of this research to know the properties of concrete by partially replacing cement by various percentages of ground granulated blast furnace slag for M25 grade of concrete at 7, 28, 56 days. From this study, it can be concluded that, since the grain size of GGBFS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. The aim of this research to know the result of the Slump test, compressive strength, Split tensile strength, flexure strength by Blast furnace slag by replacing cement at different levels.

Keywords: GGBS, Slump Test, Compressive Strength, Split Tensile Strength, Flexural Strength.

INTRODUCTION

Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is the second most highly used item in the world after water. Production of cement used in concrete involves emission of large amount of CO₂ which is major contributor for green house effect and global warming. So, this leads to the ecological imbalance and cause pollution. Environmental restrictions of cement use in concrete have resulted in search for alternative which can be used in place of cement in concrete. Now a day, ground granulated blast furnace slag, limestone powder and fly ash is successfully used in concrete as a cement replacement which are cement saving , energy saving and cost saving and moreover cause environmental and socio-economic benefits. (Reference: - Chander Garg, Ankush Khadwal (Volume-3 Issue-6, August 2014)

Blast Furnace Slag

Blast furnace slag is a nonmetallic by-product produced in the process of iron making (pig iron) in a blast furnace and 300kg of Blast furnace slag is generated when 1 ton of pig iron produced. In India, annual productions of pig iron is 70-80 million tons and corresponding blast furnace slag are about 21-24 million tons. Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10 and does not present a corrosion risk to steel in pilings or to steel embedded in concrete made with blast furnace slag cement or aggregates. The blast furnace slag could be used for the cement raw material, the roadbed material, the mineral admixture for concrete and aggregate for concrete, etc. Now in India, resources of natural sand are very lacking, it is necessary that the new fine aggregate was sought. The property of blast furnace slag is similar to natural sand, the price is cheap and the output is large too, could be regarded as the substitute of the natural sand. But there is no experience about application of blast furnace slag fine aggregate in concrete and the reports about the research are also few. (Reference: - Sujata D. Nandagawali et al. Volume 3, Issue 4, July 2014)

Applications of Blast Furnace Slag

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years. Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete. (Reference: - N. R. Dhamge et al. Volume 3, Issue 4, July 2014)

Use of Blast Furnace Slag

GGBS has been used in composite cements and as a cementitious component of concrete for many years. The first industrial commercial use (about 1859) was the production of bricks using Un-grounded GBS. In the second half of the 19th century the cementitious properties were discovered and by the end of 19th century the first cements containing GBS were produced. Since the late 1950's the use of GGBS as a separately ground material added
at the concrete mixer together with Portland cement has gained acceptance. It should be noted that in some countries the term "slag cement" is used for pure GGBS. Practically, there are no concrete, mortar or grout applications which preclude the use of an appropriate amount of GGBS. World-wide, it can be expected that the expansion of GGBS use will continue for the foreseeable future. (Reference:- Euroslag Association)

**Slag Cement:** Factory produced can be made in one of two ways. Either the individual components (the GBS and the Portland cement clinker) can be ground separately and subsequently blended or they can be interground which mixes and grinds in a single operation. In the European cement standard EN 197-1, nine cements containing slag are listed which may have slag contents between 6 wt.-% and 95 wt.-%. Slag cements are available through most of Europe and, indeed, most of the world. (Reference:- Euroslag Association)

**Concrete:** Besides as a constituent of slag cement in some parts of Europe GGBS is available as a separately ground material which can be used by the concrete producer as a cementitious component. Properties: Using slag cements or GGBS as a concrete addition result in several advantageous concrete properties. Slag cements have a low heat of hydration. Concrete made with blast furnace slag cement or with GGBS as an addition has a high durability as a result of the low capillary porosity. It is resistant to chloride penetration, sulphate and Thaumasite sulphate attack. Protection against alkali silica reaction, a low risk of thermal cracking, a high electrolytic resistance and a consistent light colour are further advantages. A better workability and easier finish ability are documented. These properties favour the use of slag cements or mixtures of Portland cement with GGBS in all situations especially where high levels of durability are called for. Using GGBS may locally cause a blue-green coloration of the fresh demoulded surface of hardened concrete. With air the typical colour vanishes within a short time. (Reference :- Euroslag Association)

**Mortar:** Slag used as a cementitious component in mortars enhances their workability and can allow further working time for the bricklayer. (Reference :- Euroslag Association)

**Grout:** Grouts containing slag have been used on many occasions to control temperature rise during hydration and in areas of aggressive conditions. (Reference :- Euroslag Association)

**Aggregate:** Ungrounded BFS is suitable as a normal weight aggregate in concrete. (Reference :- Euroslag Association)

**Road Making:** Ungrounded BFS can be used as a base layer material in road construction. (Reference:- Euroslag Association)

**Manufacture of Blast Furnace Slag**

Ground granulated blast furnace slag (GGBFS) is a by-product from the blast-furnaces used to make iron. These operate at a temperature of about 1,500 degrees centigrade and are fed with a carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This 'granulated' slag is then dried and ground to a fine powder. (Reference :- Wikipedia)

**Properties of Blast Furnace Slag**

**Water Demand**

GGBS allows for water reduction of 3 to 5% in concrete without any loss in workability. Water should not be added to GGBS concrete after dispatch from the concrete plant as it reduces strength and durability of the concrete. (Reference:- Ecocem.ie -The Green Cement)

**Placing, Compacting and Pumping**

GGBS makes concrete more fluid, making it easier to place into formwork and easier to compact by vibration. GGBS concrete remains workable for longer periods allowing more time for placing and vibrating. Pumping is also easier due to the better flow characteristics. (Reference:- Ecocem.ie -The Green Cement)

**Strength Development**

GGBS concrete has slightly slower strength development at early ages, but will have equal if not greater strength at 28 days compared to non GGBS concrete. At 7 days GGBS concretes will have 50 to 60% of its characteristic strength compared to 70 to 80% for Portland cement only concrete at the same time. At 28 days GGBS concrete will have fully developed its characteristic strength and will continue to develop strength past 90 days. It is good practice to make 56 day cubes when using GGBS concrete at 50% and above should there be any concern over later strength development. (Reference:- Ecocem.ie -The Green Cement)

**Setting Times**
The initial setting time of concrete is dependent on the concrete’s constituents, curing conditions and its application use. Concrete with up to 30% GGBS will exhibit similar initial setting as concrete with Portland cement only. At replacement levels of 40 to 50% the initial set is likely to be extended by one to two hours and for concrete containing more than 50% GGBS setting time maybe extended past three hours. (Reference:- Ecocem.ie -The Green Cement)

**Bleeding**

Concrete with up to 40% GGBS replacement does not exhibit different bleeding characteristics from that of concrete made with Portland cement. For higher percentages of GGBS there is a period of bleeding due to the increase in setting times of these mixes. Concrete should be allowed to bleed fully before finishing. Early finishing can lead to the remixing of the surface layer of the concrete which can reduce the surface integrity and lead to dusting and delamination. (Reference:- Ecocem.ie -The Green Cement)

**Colour**

GGBS is white in colour and it will noticeably lighten the colour of concrete at replacement levels of 50% plus. (Reference:- Ecocem.ie -The Green Cement)

**Literature Review**

Sonali K. Gadpalliwar et al. (2014) has observed that ground granulated blast furnace slag (GGBS) Rice husk ash (RHA) and Quarry sand (QS) are among the solid wastes generated by industry. To overcome from this crisis, partial replacement of natural sand (NS) with Quarry sand and partial replacement of cement with GGBS and RHA can be an economic alternative. This research is carried out in three phase, in first phase mix of M40 grade concrete with replacement of 0%, 15%, 30%, 45%, 60%, 75%, 90% and 100% of quarry sand with natural sand is carried out to determine the optimum percentage of replacement at which maximum compressive strength is achieved. It is observed that when natural sand is partially replaced with 60% quarry sand maximum strength is achieved. In second phase, cement is partially replaced with GGBS by 10%, 20% and 30%. In phase three, combination of GGBS and RHA is partially replaced with cement. The composition of 22.5% GGBS + 7.5% RHA with 60% of quarry sand gives good strength results.

Mojtaba Valinejad et al. (2013) reviewed in their research the specifications, production method and degree of effectiveness of some industrial byproducts such as GGBS, Silica Fume and PFA as cement replacement to achieve high performance and sustainable concrete which can lead not only to improving the performance of the concrete but also to the reduction of ECO2 by reducing the amount of PC showing how they affect economical, environmental and social aspects positively.

Martin et al. (2012) studied the influence of pH and acid type in the concrete. The conclusions were that concrete tested cannot adequately address the durability threat to all parts of wastewater infrastructure over a significant life span due to the extraordinarily harsh nature of this form of attack.

Aveline Darqueannes et al. (2011) determined the slag effect on cracking. Their study focuses on the autogenous deformation evolution of concretes characterized by different percentages of slag (and 42% of the binder mass) under free and restraint conditions by means of the TSTM device (Temperature Stress Testing Machine).

Elsayed (2011) investigated experimentally in his study the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF) and fly ash (FA). The results were compared to the control concrete, ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA and SF in this experiment was 10%. The strength and permeability of concrete containing silica fume, fly ash and high slag cement could be beneficial in the utilization of these waste materials in concrete work, especially in terms of durability.

Dongsheng Shi et al. (2011) In their experimental study the potential use of blast furnace slag fine aggregate was that produced by 3 different steel factory in high strength concrete and mechanical properties of high strength concrete were studied. The concrete using the blast furnace slag fine aggregate is admitted the increase of compressive strength as well as the case of the river sand when the water cement ratio is reduced, and the compressive strength can attain 100N/mm2. The strength of concrete using blast furnace slag fine aggregate is lower than the strength of concrete using natural river sand as fine aggregate, and the strength of concrete using mixture fine aggregate is middle of strength used river sand and strength used blast furnace slag fine aggregate. The crushing values of blast furnace slag fine aggregate is bigger than the natural river sand, and it could influence the strength concrete using blast furnace slag fine aggregate.

Reginald Kogbara et al. (2011) investigated the potential of GGBS activated by cement and lime for stabilization/solidification (S/S) treatment of a mixed contaminated soil. The results showed that GGBS activated by cement and lime would be effective in...
Reducing the leach ability of contaminants in contaminated soils. 

Naoual Handel et al. (2011) in this study we sought to use the Crushed Crystallized slag of blast furnace. It is used as an aggregate in preparing slag concrete filling of steel columns. It is produce by totally or partially replacing the calcareous gravel by Crushed Crystallized slag of blast furnace. The study is comparison between slag concrete and ordinary concrete. The characterization of these concretes was made based on their mechanical properties: i.e., compressive strength, tensile strength and elastic modulus, and their durability. The experimental results showed a beneficial effect is bound-up by the percentage of slag used in concrete.

Venu Malagavelli et al. (2010) In this paper focuses on investigating characteristics of M30 concrete with partial replacement of cement with Ground Granulated Blastfurnace Slag (GGBS) and sand with the ROBO sand (crusher dust). 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 ROBO sand helped in improving the strength of the concrete substantially compared to normal mix concrete.

Peter et al. (2010) studied the BS 15167-1 which requires that the minimum specific surface area of GGBS shall be 2750 cm²/g (BS 15167-1:2006). In China, GGBS is classified into three grades; namely S75, S95 and S105. The GB/T18046 requires a minimum surface area of 3000 cm²/g for grade S75 GGBS, 4000 cm²/g for grade S95 and 5000 cm²/g for grade S105, which are higher than the BS EN’s requirements (GB/T18046-2008). It was reported that slag with a specific surface area between 4000 cm²/g and 6000 cm²/g would significantly improve the performance of GGBS concretes.

Shariq et al. (2008) studied the effect of curing procedure on the compressive strength mortar incorporating 20, 40 and 60 percent replacement of GGBFS for different types of sand development of cement mortar and concrete incorporating ground granulated blast furnace slag. The compressive strength development of cement and strength development of concrete with 20, 40 and 60 percent replacement of GGBFS on two grades of concrete are investigated. Tests results show that the incorporating 20% and 40% GGBS is highly significant to increase the compressive strength of mortar after 28 days and 150 days respectively.

Wang Ling et al. (2004) analyzed the performance of GGBS and the effect of GGBS on fresh concrete and hardened concrete. GGBS concrete is characterized by high strength, lower heat of hydration and resistance to chemical corrosion.

The objectives and scope of present study are –

1. To find the optimum percentage of replacement of GGBFS at which maximum strength is obtained.
2. To use pozzolanic material such as GGBFS in concrete by partial replacement of cement.
3. The present Investigation has been undertaken to study of blast furnace slag to improve properties of concrete when cement is replaced by Ground granulated blast furnace slag in different percentages. In this work, the effect of GGBFS replacement on the properties of GGBFS concrete is studied. Slump test, Compressive strength, flexural strength, Split tensile strength and Sulphate and Chloride resistance test were performed to study the effect of GGBFS on the properties of the concrete.
4. To provide economical construction material.
5. Provide safeguard to the environment by utilizing waste properly.

REFERENCES


