

The Effect of Addition of Limestone powder and Granulated Blast Slag in Concrete

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Abstract:- The comprehensive programme is taken up to study this ground granulated blast furnace aggregate used as a coarse aggregate in pavement concrete. In this, replacing the coarse aggregate to ground granulated blast furnace aggregate partially varying 0 to 50% and calculating maximum compressive strength and taking their corresponding Poisson's ratio and modulus of elasticity. Flexural strength of concrete mix decrease with increase in percentage (%) of GGBFS at the age of 7 and 28 days as compared to mix but it was nearly equal with increase in the percentage of GGBFS at the age of 56 days. The Split tensile strength of mix with different cement replacement 10%, 20%, 30%, 40%, showed in decrease for all replacement at 7 days and 28 days as compared to control mix due to slower rate of reaction. The Split tensile strength of the mix with 20%, 30% cement replacement better performed than control mix at 56 days. The results obtained from the study shows that the percentage (%) of GGBFS (10-40%) in concrete increased the Sulfate and Chloride resistance.

Keywords – Concrete, Replacement, Blast furnace slag, Limestone Powder, Workability, Compressive strength, Flexure strength, Tensile strength, Durability.

1. INTRODUCTION

Concrete is an important material in the construction industry. Concrete demands massive amount to be produce to satisfy the current need. This quantity of concrete requires a quality raw material which produces concrete. The raw materials of concrete mainly natural products like aggregates, sand and cement. The natural raw material which produced concrete is day by day become scare. There is acute need of work out some other source and type of material which can be utilized for production of concrete with same outputs. Concrete is very complex material. In the advances in technology, one of the Concept is to use waste materials in the production of concrete. Blast furnace slag is one of them. In Rajkot city small industry is there. The most of the manufacturing works related to the steel, alloys and metals products and hence its produce large amount of by product. So this by product is creating bad manner in atmosphere and also problem in dump of this material. So this

product is use in concrete by replace of coarse aggregate by some percentage and decrease the cost of concrete. Ground Granulated Blast furnace Slag (GGBS) [1] is a byproduct from the blast furnaces used to make iron. These operate at a temperature of about 1500 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 from 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.

Although normally designated as “GGBS” in the UK, it can also be referred to as “GGBS” or “Slag cement” Concrete is basically a mix of fine aggregate, coarse aggregate and cement. The main problem is the

original conventional materials are depleting and we are in hunt for alternate building materials which lands us here on the purpose of GGBS. Being a byproduct and waste using it effectively up to some extent serves as a step for a greener environment and at the same time keeping in mind that the strength of the concrete does not degrade by the usage GGBS. The properties of GGBFS aid the concrete in resisting chloride induced corrosion and the blended concrete will have a reduced pore connection which helps in preventing chloride penetration.

In this work, the effect of GGBFS replacement on the properties of GGBFS concrete is studied. Five mixes with water/cementitious (w/c) ratio and different amount of cementitious materials were studied. The amount of GGBFS replacement was set at 10-40%. Slump test, Compressive strength, flexural strength, Split tensile strength and Sulphate and Chloride resistance[2] test were performed to study the effect of GGBFS on the properties of the concrete.

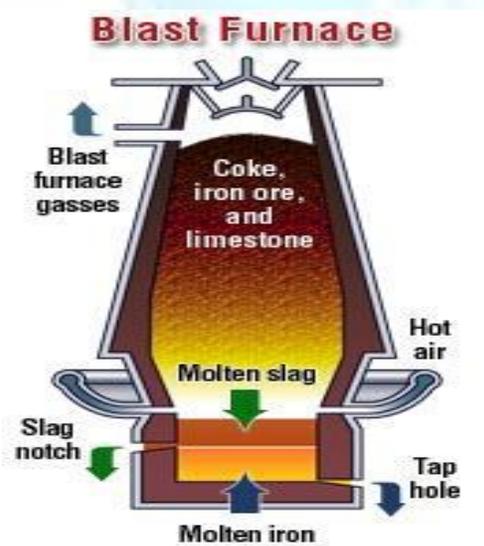


Fig 1: Sources of Ground Granulated Blast Slag

The GGBFS replacement resulted in higher early strength, lower permeability, and better durability against chloride penetration compared to OPC concrete. Concept of using Blast furnace slag and Limestone powder is not new all over the world. But using both at same time in concrete as a cement replacement is not become popular. Hence this investigation is made to check the simultaneous effect of BFS and LP on the properties concrete.

2. LITERATURE REVIEW

K.G. Hiraskar and Chetan Patil [3] In the present investigation Blast Furnace Slag from local industries has been utilized to find its suitability as a coarse aggregate in concrete making. Replacing all or some portion of natural aggregates with slag would lead to considerable environmental benefits. The results indicate that the unit weight of Blast Furnace Slag aggregate concrete is lower than that of the conventional concrete with stone chips. The experimental result show that replacing some percentage of natural aggregates by slag aggregates causes negligible degradation in strength. The compressive strength of Blast Furnace Slag aggregate concrete is found to be higher than that of conventional concrete at the age of 90 days. It has also reduced water absorption and porosity beyond 28 days in comparison to that of conventional concrete with stone chips used as coarse aggregate.

Dhanasri K, Kishore Kumar M [4] The present Investigation has been undertaken to study the effect of blast furnace slag and crusher dust on the mechanical properties of concrete, when coarse aggregates is replaced by blast furnace slag and crusher dust is replaced with fine aggregate in different percentages i.e. 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. The main parameters investigated were cube compressive strength, split tensile strength and flexural strength. The tests were conducted on concrete with Ratio 1:1.86:3.77.

Sanjay Kumar [5] The result of laboratory experiment carried out on concrete, with respect to designed M25 grade of concrete, produced from 15%, 30%, 45%, replacement of normal aggregate with blast furnace slag have been reported. The laboratory program included workability, compressive strength, split-tensile strength, flexural strength and elastic modulus of concrete. The result showed that concrete incorporating 30% fly ash and 30% blast furnace slag can be used for concrete pavement.

Mohammed Nadeem, Arun D. Pofale [6] These paper present results of experimental investigations carried out to evaluate effects of replacing aggregate (coarse

and fine) with that of slag on various concrete properties.

The basic objective of this study was to identify alternative source of good quality aggregates which is depleting very fast due to the fast pace of construction activities in India. In this study, concrete of M20, M30 and M40 grades were considered for a W/C ratio of 0.55, 0.45 and 0.40 respectively for the replacements of 0, 30, 50, 70 and 100% of aggregates (Coarse and Fine) by slag. Whole study was done in two phases, i.e. replacement of normal crushed coarse aggregate with crystallized slag and replacement of natural fine aggregate with granular slag. The investigation revealed improvement in compressive strength, split tensile and flexure strength over control mixes by 4 to 8 %. The replacement of 100 % slag aggregate (coarse) increased concrete density by about 5 to 7 % compared to control mix. Based on the overall observations, it could be recommended that slag could be effectively utilized as coarse and fine aggregates in all the concrete applications.

3. Applications and Uses Of GGBS

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 [2] are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC)[7], with GGBS content ranging typically from 30 to 70% and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction

schedules where quick setting is required. Uses Of GGBS

The major use of GGBS is in ready mixed concrete, and it is utilised in a third of all UK [2] „ready-mix“ deliveries. Specifiers are well aware of the technical benefits, which GGBS imparts to concrete, including:

- ✓ Better workability, making placing and compaction easier.
- ✓ Lower early age temperature rise, reducing the risk of thermal cracking in large pours.
- ✓ Elimination of the risk of damaging internal reactions such as ASR
- ✓ High resistance to chloride ingress, reducing the risk of reinforcement corrosion
- ✓ High resistance to attack by sulphate and other chemicals
- ✓ Considerable sustainability benefits.

In the production of ready mixed concrete, GGBS replaces a substantial portion of the normal Portland cement concrete, generally about 50 %, but sometimes up to 70%. The higher the portion, the better is the durability. The disadvantage of the higher replacement level is that early age strength development is somewhat slower.

GGBS is also used in other forms of concrete, including site-batched and precast. Unfortunately, it is not available for smaller-scale concrete production because it can only be economically supplied in bulk. GGBS is not only used in concrete and other applications include the in-situ stabilization of soil.

GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40 to 50% is used in most instances. For on the ground concrete structures with higher early-age strength requirement, the replacement ratio would usually be 20 to 30%. For underground concrete structures with average strength requirement, the replacement ratio would usually be 30 to 50%. For mass concrete or concrete structures with strict temperature rise requirement, the replacement ratio would usually be 50 to 65%. For the special concrete structures with higher requirement on durability i.e., corrosion resistance for marine structures[8], sewerage

treatment plants etc., the replacement ratio would usually be 50 to 70%.

4. MATERIALS AND METHODS

4.1 Ground Granulated Blast furnace Slag (GGBFS)

Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500°C to 1600°C.

The molten slag has a composition of 30% to 40% silicon dioxide (SiO₂)[9] and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly waterquenched, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBFS).

4.2 Material Used

The work in this paper presents the investigation on the behaviour of concrete produced from blending of cement with the combination of Ground Granulated Blast Furnace Slag[10]. The physical and chemical properties of GGBFS were first investigated.

The M-25 Mix proportioning is designed as per guidelines, according to the Indian Standard Recommended Method IS 10262- 2009. Cubes and beams mould were used for casting. Proportions of concrete as determine were 1:1.56:2.9 with a water cement ratio of 0.45 by weight.

The other concrete mixtures were made by replacing cement with 10%, 20%, 30% and 40% GGBF slag. The effect of GGBFS on concrete properties was studied by means of the fresh properties of concrete and the mechanical properties i.e. Slump test, Compressive strength, split tensile strength, flexural strength, and Sulphate and chloride resistance test. The materials used in experimental investigation include:-

4.3 Cement:

Ordinary Portland cement (OPC)[11] satisfying the requirements of IS: 4031 is used. The specific gravity of cement was found to be 3.21 & Normal consistency is 36%.

4.4 Fine Aggregates:

The sand used for the experimental programme was locally procured. The sand was first sieved through 4.75 mm sieve and remaining particles removed from sieve and then washed to remove the dust. The fine aggregate were tested as per Indian Standard Specification IS: 383-1970.

4.5 Coarse Aggregate:

A good quality of coarse aggregate having the maximum size of 10 mm and 20 mm were used in the present work whose specific gravity was to be 2.70 and 2.82. The shape of the aggregate was not flaky. The 10 mm aggregates were first sieved through 10 mm sieve and then through 4.75 mm sieve and 20 mm aggregate were first sieved through 20 mm sieve. The aggregates were tested per Indian standard Specifications IS: 383-1970.

4.6 Water:

The water to be used for casting should be free from organic matter. Tap water in the laboratory was used for mixing the ingredients of concrete and curing of the specimens.

4.7 Ground Granulated Blast Furnace Slag:

Blast furnace slag used in this work is ground granulated blast furnace slag (GGBFS). Ground granulated blast furnace slag (GGBFS) was obtained from JSW Ispat Steel Ltd. Granulated slag is an admixture that can be used as a cement replacement material according IS 456: 2000.

5. GGBS Concrete

5.1 GGBS Proportions

On its own, ground granulated blast furnace slag (GGBS) hardens[12] very slowly and, for use in concrete, it needs to be activated by combining it with Portland cement. A typical combination is 50% GGBS with 50% Portland cement, but percentages of GGBS

[4] anywhere between 20 and 80 % are commonly used. The greater the percentage of GGBS, the greater will be the effect on concrete properties. Setting Time The setting time of concrete is influenced by many factors, in particular temperature and water/cement ratio. With GGBS, the setting time will be extended slightly, perhaps by about 30 minutes. The effect will be more pronounced at high levels of GGBS and/or low temperatures. An extended setting time is advantageous in that the concrete will remain workable longer and there will be less risk of cold joints. This is particularly useful in warm weather.

5.2 Water Demand

The differences in rheological behaviour between GGBS and Portland cement may enable a small reduction in water content to achieve equivalent consistence class.

5.3 Consistency (SLUMP)

While concretes containing GGBS have a similar, or slightly improved consistence to equivalent Portland cement concrete, fresh concrete containing GGBS tends to require less energy for movement. This makes it easier to place and compact, especially when pumping or using mechanical vibration. In addition, it will retain its workability for longer.

5.4 Early Age Temperature Rise

The reduction involved in the setting and hardening of concrete generates significant heat and can produce large temperature rises, particularly in thick section pours. This can result in thermal cracking. Replacing Portland cement with GGBS reduces the temperature rise and helps to avoid early age thermal cracking.

The greater the percentage of GGBS, the lower will be the rate at which heat is developed and the smaller the maximum temperature rise.

5.5 Strength Gain In GGBS Concrete

With the same content of cementitious material (the total weight of Portland cement plus GGBS), similar 28 day strengths to Portland cement will normally be achieved when using up to 50% GGBS. At higher GGBS percentages the cementitious content may need

to be increased to achieve equivalent 28 day strength. GGBS concrete gains strength more steadily than equivalent concrete made with Portland cement. For the same 28 day strength, a GGBS concrete will have lower strength at early ages but its long term strength will be greater, the reduction in early strength will be most noticeable at high GGBS levels and low temperatures. Typically a Portland cement concrete will achieve about 75 percent of its 28 day strength at seven days, with a small increase of five to ten percent between 28 and 90 days. By comparison, a 50 % GGBS concrete will typically achieve about 45 to 55 % of its 28 day strength at seven days, with a gain of between 10 and 20 % from 28 to 90 days. At 70 % GGBS[13], the seven day strength would be typically around 40 to 50 % of the 28 day strength, with a continued strength gain of 15 to 30 % from 28 to 90 days. Under normal circumstances, the striking times for concretes containing up to 50 % GGBS, do not increase sufficiently to significantly affect the construction programme. However, concretes with higher levels of GGBS will not always achieve sufficient strength after one day to allow removal of vertical formwork, particularly at lower temperatures, lower cementitious contents and in thinner sections.

5.6 Colour

Ground granulated blast furnace slag is off-white in colour and substantially lighter than Portland cement. This whiter colour is also seen in concrete made with GGBS, especially at addition rates of 50% and above. The more aesthetically pleasing appearance of GGBS concrete can help soften the visual impact of large structures such as bridges and retaining walls. For coloured concrete, the pigment requirements are often reduced with GGBS and the colours are brighter.

5.7 Sustainability

Ground granulated blast furnace slag „GGBS“ is one of the „greenest“ of construction materials. Its only raw material is a very specific slag that is a byproduct from the blast furnaces manufacturing iron. Manufacturing of „GGBS“ utilises all of the slag and produces no significant waste. As well as the environmental benefit of utilising a byproduct, „GGBS“ replaces something that is produce by a highly energy intensive process. By comparison with Portland cement, manufacture of GGBS requires less

than a fifth the energy and produces less than a fifteenth of the carbon dioxide emissions. Further „green“ benefits are that manufacture of GGBS does not require the quarrying of virgin materials, and if the slag was not used as cement it might have to be disposed of to tip.

6. Durability

6.1 Permeability And Chemical Stability

The reaction between GGBS, Portland cement and water are complex. When Portland cement reacts with water, the insoluble hydration[14] products (mainly calcium silica hydrates) form close to the cement particle. The more soluble product of hydration (Calcium hydroxide) migrates through the pore solution and precipitates as discrete crystals, surrounded by large pores. When GGBS particles are also present, both the GGBS and Portland cement hydrate to form calcium silicate hydrates. Additionally, the GGBS react with the excess of calcium hydroxide to form a finely dispersed gel, which fills the larger pores. The result is a hardened cement paste, which contains far fewer calcium hydroxide crystals and therefore has fewer large capillary pores. The reduction in free calcium hydroxide makes concrete chemically more stable, and the finer pore structure limits the ability of aggressive chemicals to diffuse through the concrete.

6.2 Corrosion Of Reinforcement By Chloride

Steel embedded in concrete is normally protected against corrosion by the alkalinity created inside concrete by hydrated cement. In such conditions, a passive layer forms on the surface of the steel and rusting is inhibited. However, if significant amounts of chloride are able to penetrate the concrete this protection can be destroyed and the embedded steel will rust and corrode. Because of its finer pore structure, GGBS concrete is substantially more resistant to chloride diffusion than Portland cement concrete. For reinforced concrete structures exposed to chlorides, the use of GGBS will give enhanced durability and a longer useful life. This applies in many situations, including highway structures (particularly bridge parapets), car parks subjected to de-icing salts and coastal environments. Generally the higher the proportion of GGBS, the greater will be the

resistance to chloride penetration[15]. Typically, use of 50% GGBS will give high resistance to chloride and use of 70% GGBS will give very high resistance.

7. Conclusion:

The movement of moisture of GGBS mixes, probably due to the dense and strong microstructure of the interfacial aggregate/binder transition zone are probably responsible for the high resistance of GGBS mixes to attack in aggressive environments such as silage pits. The mineral composition of GGBS cement paste (with less aluminates and portlandite than Portland cement) probably contributes to this resistance. As we have seen GGBS is a good replacement to cement in some cases and serves effectively but it cannot replace cement completely. But even though it replaces partially it gives very good results and a greener approach in construction and sustainable development which we are engineers are keen about today.

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