Ground Granulated Blast- Furnace slag as a cement replacing material in concrete- A Review

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***Abstract*: - As we know concrete is a mixed composition of cement, fine aggregates, coarse aggregates and water. It plays a white cell roll in development of vast infrastructure i.e., construction of buildings, highways, bridges etc. Ordinary Portland cement is the main ingredient used for the production of concrete. Due to usage of lime in the manufacturing process of cement, a large volume of carbon dioxide emission causes greenhouse effect and global warming. Hence to reduce such emissions, and alternate you material must be used in each production. One of the beneficiary material was ground granulated blast furnace slag, which is obtained from the blast furnace of iron and can be used in concrete production. This paper reviews the utilization and efficiency of GGBS which affects the properties of concrete. Number of studies was done with the help of previous journals in partial replacement of GGBS concrete. Which include properties like flexible strength, compressive strength, split tensile strength, workability, electrical conductivity, and sulphate attack and chloride resistance. This study reviews the usage of GGBS as partial replacement of cement in concrete. GGBS as an eco-friendly product was found to enhance the properties of concrete and to be utilized in the production of concrete without dumping onto the ground.**

***Keywords:* - GGBS, Workability, flexible strength, comparison, connectivity, sulphate and chloride resistance.**

1. INTRODUCTION

The most extensively used construction material around the world is probably concrete. In terms of per capita consumption it is next to water. However, environmental sustainability is also important in terms of damage caused by the extraction of raw material and emission of carbon dioxide during cement manufacturing. This brought research implementations on the reduction of cement consumption by replacement of cement with other supplementary materials. These materials are naturally available industrial waste or by-products that are less energy intensive. The materials called pozzalonas when combined with carbon hydroxide exhibit cementations properties. Most commonly used pozzalonas are fly ash, silica fume, metakaolin, ground granulated blast furnace slag. The different admixtures when blended with concrete Tested for performance so as to ensure a reduced life cycle cost. There are different By-products and processed which possess pozzalonic properties. Lately the use of natural pozzalonas like GGBS as a partial replacement for cement was found. Different various methods are implemented to improve the durability of concrete, and to achieve high performance concrete, with the use of GGBS which is relatively a new approach. The problem with GGBS is its requirement for excessive water when mixed with ordinary Portland cement. This present paper focus on characteristics of concrete with partial replacement of cement with GGBS. As we know the blast furnace slag is one of the By-product of Iron manufacturing industries. Iron ore, Coke and limestone are fed into the furnace and the resulting molten slag floats above molten iron at a temperature of about 1500^0C two 1600^0C. Molten slag has a chemical composition of about 30% to 40% of SIO2 about 40% of CAO, which is nearly similar to the chemical composition of Portland cement. After iron is removed off, remaining molten slag, which consists of mainly siliceous and aluminous residue is then water quenched and subjected to rapid cooling, resulting in the formation of Glassy crystalline granulates. This glassy granular material are dried and pulverized which is known as ground granulated blast furnace slag (GGBS). The production of GGBS requires less amount of energy for the production of Portland cement. This replacement of GGBS with Portland cement leads to the significant reduction in emission of carbon dioxide. The GGBS therefore it's an eco-friendly product which can be used as a replacement up to 80% in Portland cement used in concrete.

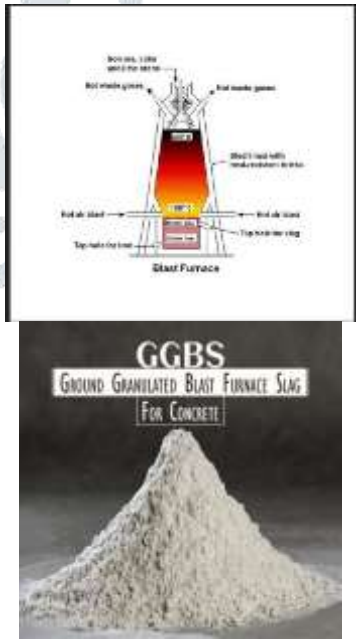

Fig 1: Sources of Ground Granulated Blast Slag

CHEMICAL COMPOSITION OF GGBS

The chemical composition of slag depends on composition of the raw material used in the iron production process. Silica and aluminium impurities from the iron ore and Coke are combined in the blast furnace which is of lower viscosity levels in form of slag. The pig iron mainly consists of mixture of limestone and forsterite or in some cases dolomite. The top layer material which floats on iron is decanted for separation which is the blast furnace slag.

TYPICAL CHEMICAL COMPOSITION

calcium oxide	=40%
Silica	= 35%
Aluminum	=13%
Magnesium	=8%

The glass type of slag which is used for blending with Portland cement typically where is between 90-100% and depend on the cooling method which is initiated. The quenched glass depend on the proportion of network forming elements such silica and aluminium or network modifier such as calcium magnesium and to a lesser extend of aluminium. This leads to higher degrees of network De-plomatization and reactivity. This forms granular product with very limited in crystal formation which is highly cementations in nature can be grounded too cement fineness and hydrates like Portland cement.

TYPICAL PHYSICAL PROPERTIES

Color:	white
Specific gravity	2.9
Fineness	350m2/kg
Bulk Density	1200kg/M3

APPLICATIONS OF GGBS

- Blast furnace slag and steel furnace slag are major materials used as industrial byproducts, in the United States about 100 years and about 150 years in Europe.
- Ground granulated blast furnace slag (GGBS) is used in composite cements as a cementations component of concrete for many years.
- In the second half of the 19th century, its cementations properties were discovered, and by the end of 19th century, the first cements containing GGBS were produced.
- The use of GGBS as a separately ground material added at the concrete mixer together with OPC has gained its acceptance in the late 1950s. In some countries, the term “slag cement” is used for pure GGBS.
- Currently, GGBS were used as a direct replacement for OPC in proportions of 1:1 basis by its weight. It is used to make durable concrete structures in combination with OPC and with other pozzolanic materials.
- At present, benefits are of its costs reduction for the adoption of GGBS. GGBS used 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.

- GGBS which is used as a durable material for concrete structures in combination with OPC or other pozzolanic materials.
- GGBS has been widely used for its ease in concrete durability, extending the lifespan of buildings from 50-100 years.
- Concrete made with GGBS cement is observed to have higher setting time than concrete made with ordinary Portland cement (OPC), depending on the percentage amount of GGBS added as the cementations material, but also continues to gain strength after a longer period in production conditions.
- This result in lower heat of hydration and lower temperature rises, but may also affect construction schedules where quick setting times are required.
- It provides higher resistance to chloride ingress reducing the risk of reinforcement corrosion and provides higher resistance to attacks by sulfate and other chemicals

USES OF GGBS

the major use of GGBS is its utilization in all ready-mix deliveries. The technical benefits, which GGBS imparts to concrete are including,

- Better workability, making placement and compaction of concrete easier.
- Lower early age temperature rise, which help in reducing the risk of thermal cracking when used for mass concrete pours.
- GGBS reduces the risk of damages caused by alkali-silica reaction (ASR)
- Elimination of the risk of damaging internal reactions.
- High resistance to attack by sulphate and other chemicals.
- Considerable sustainable benefits.

2. LITERATURE REVIEW

Venu Malagavelli et al. [1] studied on high performance concrete with GGBS and robo sand and concluded that the percentage increase of compressive strength of concrete is 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

Qian Jueshi and Shi Caijun [2] studied on high performance cementing materials from industrial slag and reviewed the recent progresses in the activation of latent cementitious properties of different slag. They opined that Alkali-activated slag, such as blast furnace slag, steel slag, copper slag and phosphorus slag should be a prime topic for construction materials researchers.

Md. Moinul Islam et. al.[3] discussed the results of partial replacement of cement using slag in various percentages (10% –70%). He tested various properties of concrete and found that the compressive strength and tensile strength of mortar mixes with slag when determined at the ages of 3, 7, 14, 28, 60, 90 and 180 days decreases at early ages of curing (3 and 7 days). However, the rate of decrease diminishes with the increasing age of curing. 40% of cement replacement is the optimum use of slag in the mortar because it has19% compressive strength and 25% tensile strength when compared to OPC mortar. He concluded that the use of slag reduces the amount of cement content in a mortar mix as well as heat of hydration which results in lower risk of thermal

cracking. Thus the use of slag concrete in construction becomes economical and also environmentally safe.

Peter et al. (2010)[4] studied the BS 15167-1 which requires that the minimum specific surface area of GGBS shall be 2750 cm2/g (BS 15167-1:2006). GGBS is classified into three grades in China; S75, S95 and S105. Minimum 3000 cm2/g surface area is required for the GB/T18046 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). Slag with a specific surface area between

4000 cm2/g and 6000 cm2/g would significantly improve the performance of GGBS concretes.

Santosh Kumar Karri et. al. [5] researched by using 30%, 40% and 50% as cement replacement levels and cured the specimens of M20 and M40 grade of concrete for 28 and 90 days. He tested various properties of concrete and found that the compressive strength and tensile strength of mortar mixes with slag when determined at the ages of 7, 14, 28 and days decreases at early ages of curing (3 and 7 days).The specimens showed increase in compressive strength when tested at 7 and 28 days, for 20% replacement of cement. Concrete cubes were also exposed to H2SO4 and HCl.

A. Oner and S. Akyuz et. al [6] conducted a study in which he replaced cement by weight partially with GGBS in various percentages from 15% -110%. Compressive strength test was conducted on test specimens which cured at 7, 14, 28, 63, 119, 180 and 365 days and it was found that early age strength values of GGBS concrete mix are lower than the strength after more passing days. This is because of the strength gain which takes longer time for the GGBS concrete because the pozzolanic reaction is slow and depends on the calcium hydroxide availability. It was also observed that as the percentage of GGBS is increased, the strength gain increases. The optimum level of GGBS content is 55% –59%for maximizing strength. He also found out that the GGBS has positive effects on the workability as the GGBS content increases, the water/binder ratio decreases for the same workability.

Sabeer Alavi.C et. al. [7] studied the effects of partial replacement of cement with10 -50% of GGBFS and found that 30% GGBFS replacement is good as beyond that the compressive strength starts decreasing. He also concluded that the split tensile strength and flexural strength conducted at 7 and 28 days increases with increase in GGBFS content. It was also found that the workability increases with the increase in percentage of GGBFS.

Chao-Lung Hwang and Chao-Yin Lin [8] replaced cement with BFS in various percentages (0 –80%) with three different w/c ratios (0.35, 0.47 and 0.59) in his research and found that the use of slag reduces the strength of mortar at early age (3 days) but it enhance after 7 days. It was also found out that when the specimens demoulded at the age of one day had significantly less strength as compared with those demoulded at one and half days. Three different temperatures were used during curing and specimens cured under 500C have the best results. He also concluded that the bleeding of the mortar will also reduce when the mortar is mixed with slag. The pores tend to become smaller when slag is used in the mix. This may increases the durability of the cement mortar when it is exposed to adverse environment.

3. CONCLUSIONS

Following constructions can be drawn from the experimental investigation conducted on the behaviour of concrete with GGBS as partial replacement for cement.

1. Use of GGBS as a replacement of cement helps to reduce the energy consumption in the manufacturing of cement.
2. Use of GGBS in the concrete also helps to reduce the heat of hydration, resulting less shrinkage and temperature.
3. GGBS mixed cement concrete produce more resistance to sulphate attacks.
4. The partial replacement of cement with GGBS in concrete mix has shown enhanced performance in terms of strength and durability.
5. All kind of pozzolanic materials are reducing the permeability of concrete for below the control one.
6. Workability of concrete increase with the increase in GGBS replacement level.
7. GGBS as positive effect on the workability.
8. In the most cases compressive strength decrease with the increase the percentage of GGBS.
9. Split tensile strength and flexural strength also decreases with the increase the percentage of GGBS.
10. Using GGBS in concrete helps to reducing the cost of construction because the price of GGBS is about 25%-50% less than that of OPC.
11. Reuse of slag helps to protect the environment from pollution(Reduce CO2 emission)

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