Review on Ground Granulated Blast-Furnace Slag as a Supplementary Cementitious Material

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ABSTRACT
The use of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete mix, for overall economy. The present work is a support to use the waste product from steel industry is helpful in cement which also helps to reduce the carbon footprint. In recent years Blast Furnace Slag when replaced with cement has emerged as a major alternative to conventional concrete and has rapidly gain the concrete industry's attention due to its cement savings, energy savings, cost savings, socio-economic and environmental benefits. The present study reports the results of an experimental study, conducted to evaluate the strengths and strength efficiency factors of hardened concrete, by partially replacing the cement by various percentages of ground granulated blast furnace slag. The optimum GGBS replacement as cementitious material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effective.

In this work we are going to study the effects of GGBS on the compressive strength of the cements concrete by replacing cement with GGBS by 10%, 15%, 20%, and 40%. This project work also includes the benefits of using GGBS and its effects on the cement and concrete properties and its durability, and its sustainability.

General Terms
Ordinary Portland Cement, Cement Properties, GGBS Properties, Setting Time, Soundness, compressive Strength.

Keywords
Ground granulated blast furnace slag, Cement Concrete, Compressive Strength.

1. INTRODUCTION
The Blast-Furnace slag is a by-product of the 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 ^{0}C to 1600 ^{0}C. The molten slag has a composition of about 30% to 40% SiO_2 and about 40% CaO, which is nearly similar to the chemical composition of

Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched and cooled rapidly, resulting in the formation of a glassy crystalline granulates. This glassy granulatesare dried and pulverizedwhich is known as ground granulated blast-furnace slag (GGBS).The production of GGBS requires less additional energy as compared with the energy needed for the production of Portland cement. The replacement of Portland cement with GGBS will lead to significant reduction of carbon dioxide gas emission. GGBS is therefore an environmental friendly construction material. It can be used to replace as much as 80% of the Portland cement used in concrete.

Blast Furnace Concretehas better water impermeability characteristics as well as improved resistance to corrosion and sulphate attack. As a result, the service life of a structure is increases and the maintenance cost reduced.

Concrete is porous in nature, regular cement produces large amount of heat resulting in shrinkage & temperature cracks. The combined effect of surface cracks with porosity in concrete adversely affects the life of steel. Therefore there is a big need of alternative product to strengthen concrete which combats deterioration of steel.Use of GGBS in the concrete generates less heat while mixing with the water against cement. It also helps to reduce the heat of hydration resulting less shrinkage and temperature cracks in the concrete.

Fig.1 Blast furnace slag and ground granulated blast furnace slag.

2. HISTORY OF USING GGBS IN CONCRETE
There are many examples of using the GGBS concrete in the construction, following are some examples where the GGBS concrete were used.

1. World Trade Centre, New York (about 40% replacement).
2. Airfield Pavement of Minneapolis Airport (35 % replacement).

3. Atlanta‘s Georgia Aquarium (worlds one of the largest aquarium),(20% to 70% replacements).
4. Detroit Metro Terminal Expansion (30% Replacement).
5. The Air Train linking New York‘s John Kennedy International Airport with Long Island Rail Road Trains (20%-30% replacements).
6. Tsing Ma Bridge, Hong Kong (59%-65% replacement).

From the above examples it is cleared that the world is aware of the advantages of GGBS uses in concrete. The main aim of the use of GGBS is to improve the durability, reduce the maintenance cost, to increase the service life, increase the economy of the construction with using the cheaper material as a replacement of the cement, and to reduce the cement consumption. Today it is necessary to reduce the carbon footprints as it affects the environment and ultimately affects the life on the planet and around 5% CO_2 equivalent is produced from the single industry i.e. from cement industry. In production of one tonn of cement it consumes about 5000MJ of energy, 1.5 tonnes of mineral extraction, and produces 0.95 tonnes of CO_2 equivalent, this consumption of natural resources and formation of large amount of CO2 equivalent it is necessary to find some alternative material instead of the cement which has cementitious.

3. ANNUAL CEMENT PRODUCTION

CEMBEURO (The European Cement Association) has given some statistics on the Cement production per year in the world is shown in the following figure.

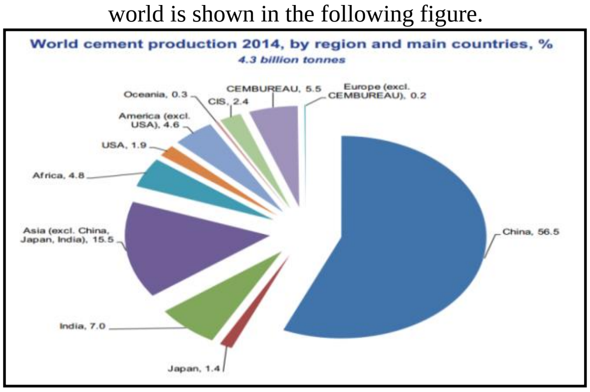

Fig.2 World’s cement Production per year.

According to the CEMBEURO:-

1. Concrete is second most consumed material in the world after Water.
2. On average, each year, 3 tons of concrete are consumed by every person on the planet
3. Cement Industry is a single industry which produces 5% of total global CO2 Emission.
4. Cement production is growing by 2.5% annually, and is expected to rise from 2.55 billion tons in 2006 to 3.7 - 4.4 billion tons by 2050.
5. It means that to produce 4.3 Billion tonns of cement World produces 0.95 X (4.3 X 109) = 4.085 billion tonnes of CO2 Equivalent produce every year (Apprx.). Which is very high. 6. Hence we required some alternative material which reduces this Emission considerably and use of cement.

In production of one tonne of Portland cement would require about 1.5 tonnes of mineral extractions together with 5000 MJ of energy, and would generate about 0.95 tonne of CO2 equivalent. So this replacement of the cement up-to the some extent helps to reduce environmental impact due to production of cement.

4. CHEMICAL COMPOSITION OF BLAST FURNACE SLAG

Blast furnace slag is composed of the following oxides,

Table 1.oxides composition of the Blast furnace Slag.

Oxides	Content
SiO2	19.71
Al2O3	5.20
Fe2O3	3.73
CaO	62.91
MgO	2.54
LOI	0.96
SO3	2.72
K2O	0.90
Na2O3	0.25

This composition is quite closer to the composition of Portland cement.

5. EFFECT OF GROUND GRANULATED BLAST FURNACE SLAG ON CEMENT CONCRETE

The behavior of cement concrete after replacing the cement with ground granulated blast furnace slag in several percentages is shown below.The following figures shows the strength at different ages of concrete mix which is used as the control mix for the work. This mix is taken as the reference to the project work and the cement contents were replaced by suitable percentages of Blast Furnace Slag.

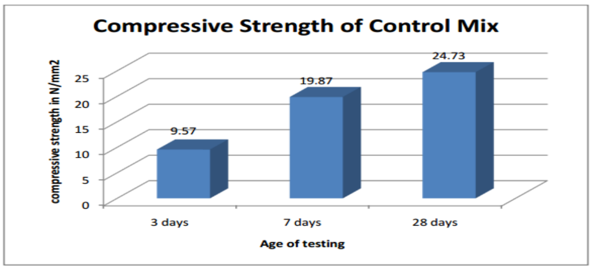

Fig.3 Compressive strengths of design mix at different ages of curing

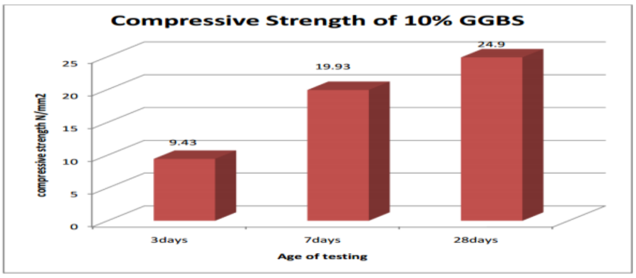

Fig.4 Compressive strengths of mix with 10% replacement of cement with GGBS at different ages of curing .

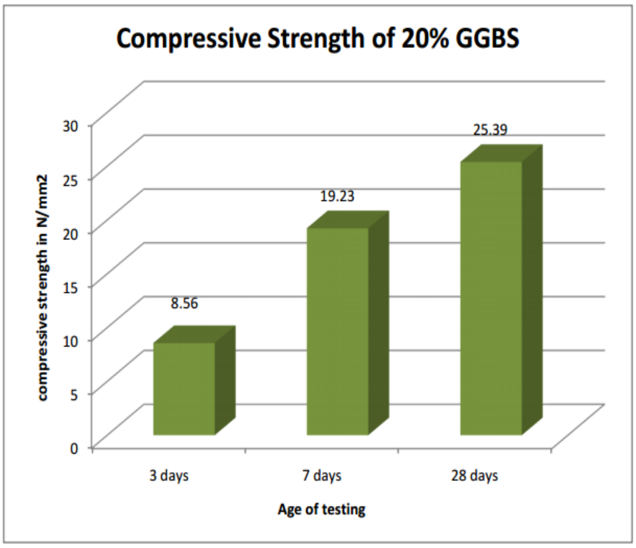

Fig.5 Compressive strengths of mix with 20% replacement of cement with GGBS at different ages of curing .

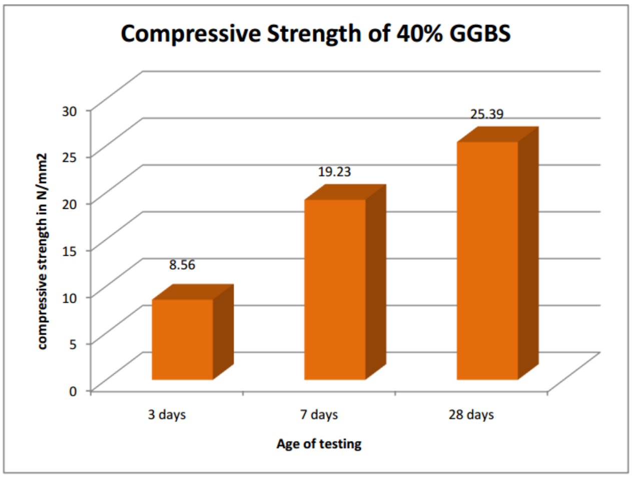

Fig.6 Compressive strengths of mix with 40% replacement of cement with GGBS at different ages of curing .

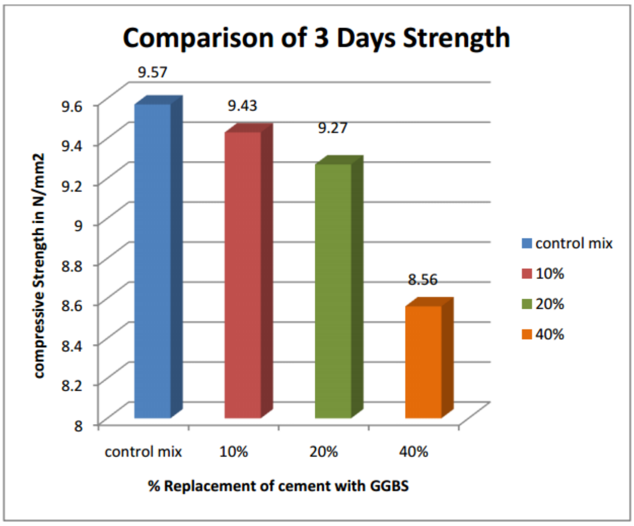

Fig.7 comparison of 3 days compressive strengths of mixes with 0%(control mix), 10% 20% and 40%.

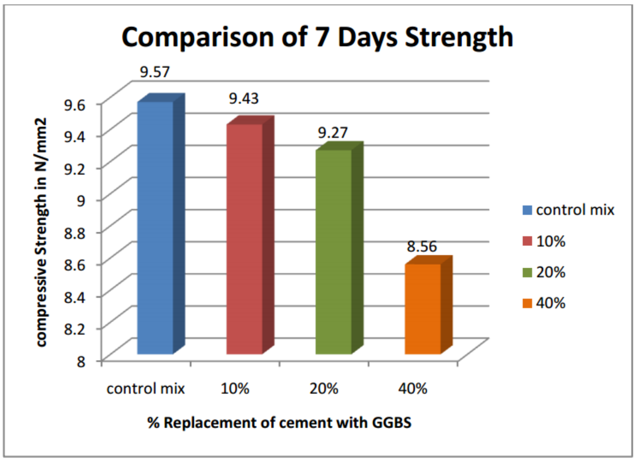

Fig.8 comparison of 7 days compressive strengths of mixes with 0%(control mix), 10% 20% and 40%.

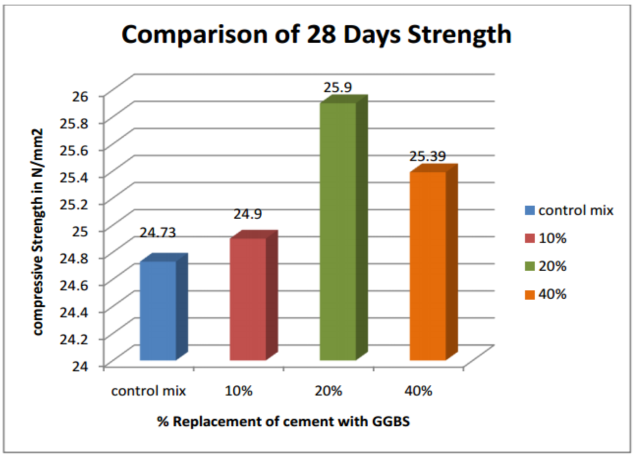

Fig. 9 comparison of 28 days compressive strengths of mixes with 0%(control mix), 10% 20% and 40%.

From the above results and the graphs, it can be conclude that the maximum strength result of the concrete after 7days and 28 days curing is with the 20% replacement of the cement by GGBS.From the works review it has been found that the GGBS takes more time to react with the water, hence the early strength gained by the Concrete with GGBS is less than the concrete with no replacement. From the above result the 3 Days strength of the concrete decreases with the increase of the percentage of the GGBS. The above test results shows the strength gain properties of the GGBS, as the GGBS starts gaining the strength the considerable rise in strength is taken place and the compressive strength increases with time. From interpreting the above results we can conclude that the strength of the concrete is increases with increase in the percentage of the GGBS in concrete. But researchers also states that the GGBS need cement to ignite to react with water hence we can replace the cement up-to certain percentage.From all the results and the discussions it is been found that the Ground Granulated Blast furnace Slag becomes a good alternative to the cement and can be used effectively with the cement in the cement concrete.

4. CONCLUSIONS

The following conclusions can be drawn from the experimental investigations conducted on the behavior of concretes with GGBS as partial replacements for cement-

1. The partial replacement of cement with GGBS in concrete mixes has shown enhanced performance in terms of strength and durability. This is due to the presence of reactive silica in GGBS which offers good compatibility.
2. It is observed that there is an increase in the compressive strength for different concrete mixes made with partial replacement of cement by GGBS. The increase in strength is due to high reactivity of GGBS with Cement.
3. The use of GGBS as a replacement of cement helps to reduce the Energy consumption in the manufacturing of cement.
4. It has been reported that the manufacture of one tonn of Portland cement would require about 1.5 tonns of mineral extractions together with 5000 MJ of energy, and would generate about 0.95 tonn of CO2 equivalent, with replacement of GGBS we can reduce the quantity of carbon equivalent produced with a material which is a by-product of Steel industry and readily available.
5. Concrete with reduced permeability increases the durability of the structure.
6. Use of GGBS in the concrete generates less heat while mixing with the water as against cement. It also helps to reduce the heat of hydration resulting less shrinkage and temperature cracks in the concrete.
7. As we know that concrete is vulnerable to sulphate attack on account of the Presence of Tri calcium Aluminates (C3A) in clinker. Reaction is formed with sulphate particles present in the atmospheric moisture and natural soil water, leading to internal stress & cracks in the Concrete. GGBS mixed cement concrete produces more resistance to sulphate attacks.

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