

# EXPERIMENTAL INVESTIGATION ON COMPARITIVE STUDY OF GGBS CONCRETE

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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. The ground granulated blast furnace slag is a waste product from the iron manufacturing industry, which may be used as partial replacement of cement in concrete due to its inherent cementing properties. This paper presents an experimental study of compressive and flexural strength of concrete prepared with Ordinary Portland cement, partially replaced by ground granulated blast furnace slag in different proportions varying from 0% to 40%. The use of steel often helps the designer to select proportions that are aesthetically pleasing. Structural steels have high strength, ductility and strength to weight ratio. Thus it has become the obvious choice for long span bridges as steel is more efficient and economic. Among the various types of bridges plate girder bridges, truss bridges and box girder bridges are more commonly used. As the cost of steel is rising we have to reduce the amount of steel used without affecting the strength of section. In this thesis a plate girder bridge is designed as per the Limit state method using the IS 800:2007, IRC: 24-2000 and analysed by SAP-2000. Basically the Indian standards are derived from the British Standards. The basic concept is the same. Only the values of various parameters vary according to the design and fabrication/ erection practices existing in India. Design calculations are carried out for simply supported single span. Seismic and wind effect is not taken in to account at design stage. To clarify the design procedure and the current state of practice, a comprehensive literature search and survey were conducted. Recommendations pertaining to best practices for planning, design, and construction activities, as well as applications and limitations are also provided.

**Keywords:** Compressive strength, Flexural Strength, Ground Granulated Blast Furnace Slag (GGBS)

## 1. INTRODUCTION

Concrete is basically a mixture of cement, fine and coarse aggregates. High-performance concrete (HPC) conforms to a set of standards above those of the most common applications, but not limited to strength. Some of the standards are ease of placement, compaction without segregation, early age strength, permeability etc. The researchers have done considerable work on replacing the cement with fly ash and blast furnace slag without affecting the strength.

River sand (Fine aggregate), which is one of the constituents used in the production of concrete, has become expensive and scarce. So there is large demand for alternative materials.

## 2. PROPERTIES OF GGBS

### GGBS And concrete Properties

On its own, ground granulated blast furnace slag (GGBS) hardens very slowly and, for use in concrete, it needs to be activated by combining it with Portland cement. Atypical combination is 50 per cent GGBS with 50 per cent

Portland cement, but percentages of GGBS anywhere between 20 and 80 per cent are commonly used. Thereafter the percentage of GGBS, the greater will be the

Effect on concrete properties

### Setting times

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.

### Water demand

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

### Consistence

While concretes containing GGBS have a similar or slightly improved consistence to equivalent Portland and cement concretes, 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.

### Early age temperature rise

The reactions involved in the setting and hardening of concrete generate 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. There are a number of factors which determine the rate of heat development and the maximum temperature rise. These include the percentage of GGBS, the total cement it us content, the dimensions of the structure, the type of formwork and ambient weather conditions. The greater the percentage of GGBS, the lower will be the rate at which heat is developed and the smaller the maximum temperature rise.

As well as depressing the peak temperature, the time taken to reach the peak will be extended. For mass concrete structures, it is common to use 70 per cent GGBS to control the temperature rise. With thinner sections, significant savings in crack control reinforcement can be achieved even with lower levels of GGBS of 50 per cent or less.

### Strength gain in GGBS concrete

With the same content of cement it us 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 per cent GGBS. At higher GGBS percentages the cement it 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 the strength development will be as shown in the following table: Strength achieved as percentage of 28-day strength

Under normal circumstances, concretes with up to 70 percent GGBS will achieve sufficient strength within one day of casting to allow removal of vertical formwork without mechanical damage. At high GGBS percentages, extra care should be taken with thin sections poured during winter conditions when the concrete hardening may have been affected by the cold ambient air.

### 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 per cent 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.

### Ground Granulated Blast Furnace Slag (GGBS):

GGBS is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS is used to make durable concrete structures in combination with ordinary portland cement and/or other pozzolonic 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. Use of GGBS significant reduces the risk of damages caused by alkali-silica reaction, higher resistance to chloride, and provides higher resistance to attacks by sulfate and other chemicals. GGBS is procured from vizag steel plant (VSP). The fineness modulus of GGBS using blain's fineness is 320 m<sup>2</sup>/kg and other properties of GGBS given in Table No.3.

**Table:1 Strength achieved as percentage of 7,28 & 90-day strength**

Age	0% GGBS	50% GGBS	70% GGBS
7-days	75%	45 to 55%	40 to 50%
28-days	100%	100%	100%
90-days	105% To 110%	110 to 120%	115 to 130%

**Table:2 Physical Properties Of GGBS**

Chemical Properties	GGBS (%)
SiO <sub>2</sub>	34.06
Al <sub>2</sub> O <sub>3</sub>	18.8
Fe <sub>2</sub> O <sub>3</sub>	0.7
CaO	32.4
MgO	10.75
SO <sub>3</sub>	0.85
S	0.65
MnO	0.49
Na <sub>2</sub> O	0.31
K <sub>2</sub> O	0.98
Cl	0.008

**Table:3 Physical Properties Of GGBS**

Characteristics	Requirement as per BS: 6699
Fineness(M <sup>2</sup> /Kg)	275(min)
Soundness Le-Chatelier Expansion (mm)	10.0 (max)
Initial Setting Time (min)not less than OPC	Min. 30 Minutes
Insoluble Residue (%)	1.5 (Max)
Magnesia Content (%)	14.0 (Max)
Sulphide Sulphar (%)	2.00 (Max)
Sulphite Content (%)	2.50 (Max)
Loss on Ignition (%)	3.00 (Max)
Manganese Content (%)	2.00 (Max)
Chloride Content (%)	0.10 (Max)
Moisture Content (%)	1.00 (Max)
Glass Content (%)	67 (Min)
Compressive Strength (N/mm <sup>2</sup> ) After 7 Days After 28 Days	12.0(min) mpa 32.5 (min) mpa

### 3. REVIEW OF LITERATURE

#### Shariq et al. (2008)

Studied the effect of curing procedure on the compressive strength development of cement mortar and concrete incorporating ground granulated blast furnace slag. The compressive strength development of cement mortar incorporating 20, 40 and 60 percent replacement of GGBS for different types of sand and strength development of concrete with 20, 40 and 60 percent replacement of GGBS 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.

#### Peter et al. (2010)

Studied the BS 15167-1 which requires that the minimum specific surface area of GGBS shall be 2750 cm<sup>2</sup>/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 cm<sup>2</sup>/g for grade S75 GGBS, 4000 cm<sup>2</sup>/g for grade S95 and 5000 cm<sup>2</sup>/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 cm<sup>2</sup>/g and 6000 cm<sup>2</sup>/g would significantly improve the performance of GGBS concretes.

#### MojtabaValinejadShoubi 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 ECO<sub>2</sub> by reducing the amount of PC showing how they affect economical, environmental and social aspects positively.

**Aveline Darquennes et al. (2011)**

Determine the slag effect on cracking. Their study focuses on the autogenously deformation evolution of concretes characterized by different percentages of slag (0 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.

**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.

**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.

**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.

**Need for the study**

Normal concrete lacks required strength, workability and durability which are more often required for large concrete structures such as high rise buildings, bridges, and structures under severe exposure conditions. By increasing concrete strength, the required thickness of concrete members and the cost of concrete structures can both be reduced. Therefore, it is felt necessary to improve the strength and performance of concrete with suitable admixtures to cater present need. In this study, it is planned to replace some percentage of cement with GGBS to develop the high performance concrete.

**4. METHODOLOGY**

The methodology for this study is given in the form of flow chart. Flow chart is given in Figure 1. For any successful investigation, numerous tests have to be performed and the trend of results should be carefully before arriving at the final conclusion. To realize the results from the tests experimental set up and testing procedures are required. Material characteristics are the following:

- a. Portland Pozzolona cement with specific gravity of 3.15
- b. Locally available river sand (Manjra sand).
- c. Locally available coarse aggregate.
- d. Ground granulated blast furnace slag with specific gravity of 2.94
- e. Water conforming to the requirements of water of concreting and curing.

**Table:4 Physical Tests on cement:**

Sr Nos.	Test Conducted	Results Obtained	Requirement As per IS
1	Specific Gravity	3.15	-
2	Normal Consistency	31%	-
3	Setting times, (minutes)	Initial 150	Min 30
		Final 210	Max 600

4	Fineness(m <sup>2</sup> /kg)	342	300
5	Soundness(mm) Le-chatelier test	1.00	10.0 mm max

### 5. RESULT & DISCUSSION

The main aim of the study is comparison of test result of compression & flexural test of M-30 & M-25 grade of concrete in 7 & 28 days. It also obtain suitability of GGBS as replacement of OPC in concrete.

#### i) Slump Test-

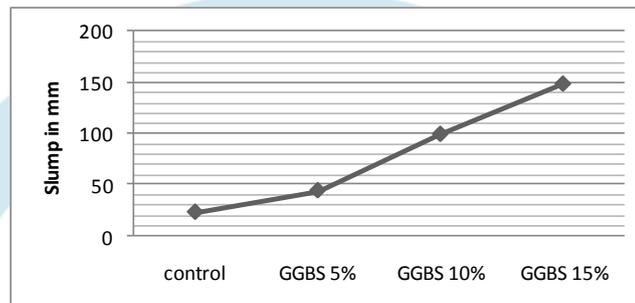


Fig.1 Slump values of control & GGBS concrete

Slump tests were performed on both control and GGBS concretes and the results are presented in Fig.1. It is obvious in this figure that, the addition of GGBS increases slump value of concrete.

#### ii) Compressive Strength-

##### a) For M-30

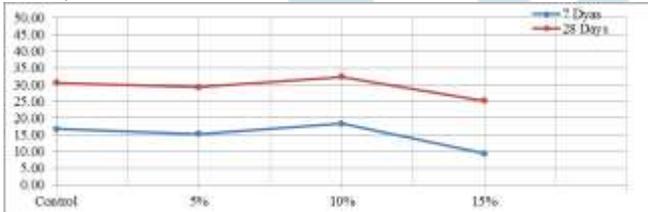


Fig.2 Compressive strength control & GGBS concrete for M-30

##### b) For M-25

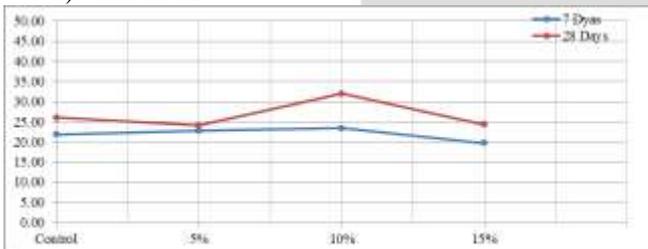


Fig.3 Compressive strength control & GGBS concrete for M-25

##### c) For M-20

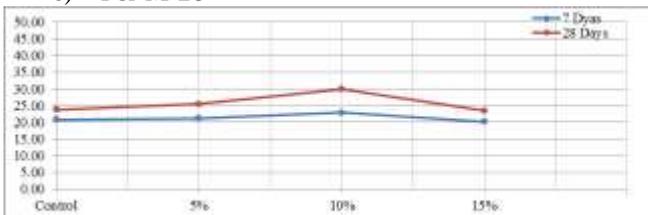


Fig.4 Compressive strength control & GGBS concrete for M-20

It is observed that GGBS based concrete has achieved increasing compressive strength for 10 % replacement of cement at the age

of 7 & 28 days.

### iii) Flexural Strength-

a) For M-30

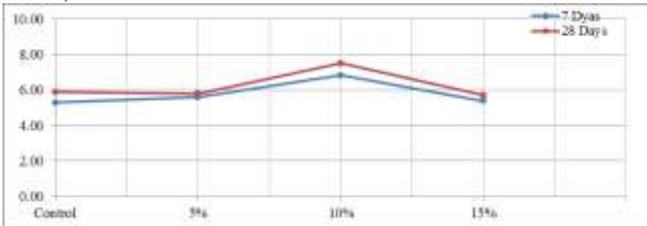


Fig.5 Flexural strength of control & GGBS concrete for M-30

b) For M-25

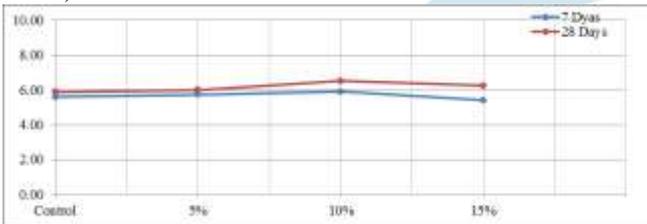


Fig.6 Flexural strength of control & GGBS concrete for M-25

c) For M-20

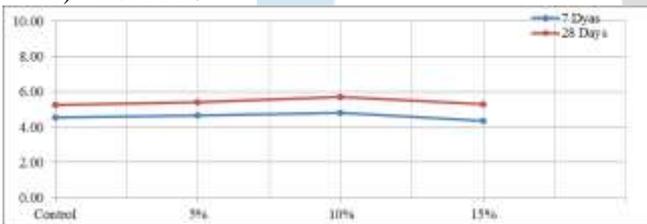


Fig.7 Flexural strength of control & GGBS concrete for M-20

Similarly, It is observed that GGBS based concrete has achieved increasing compressive strength for 10 % replacement of cement at the age of 7 & 28 days.

### CONCLUSION

Based on the results and observations made in this experimental research study, the following conclusions made;

The increase in % of GGBS results in decrease in strength of concrete.

The reduction in cost of concrete of construction at the current market rate is 8% in the case of GGBS as replacement of OPC by 10%.

The partial replacement of OPC in concrete by GGBS not only provides the economy in the construction but it also facilitate eco-friendly disposal of the waste slag which available more quantities in steel industries.

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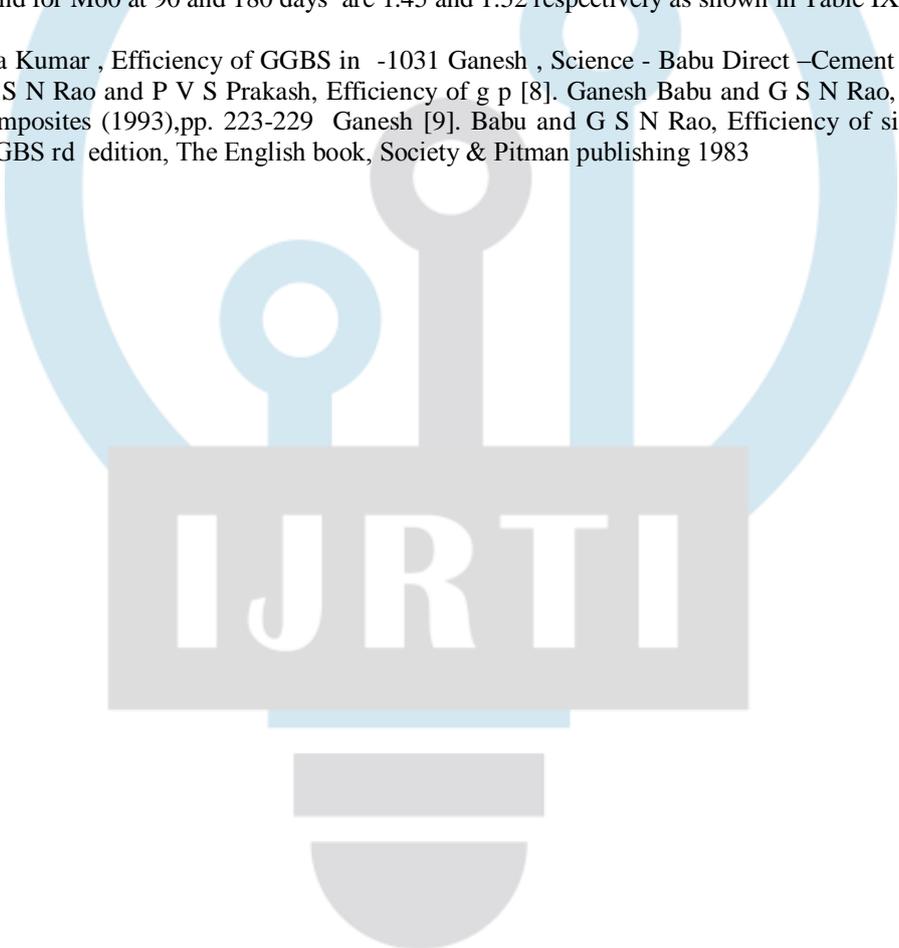
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