A Study on high performance concrete was carried out experimentally using GGBS and minerals fly ash with M-60 grade concrete

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Abstract: The steel and copper industries in India are growing quickly. This study conducts an experimental investigation to see if GGBS may take the place of cement in concrete. The study suggests using GGBS to partially replace some cement when producing high performance concrete. The effectiveness of using GGBS as a replacement agent was tested. PC composites typically contain GGBS. It has been established that GGBS improve the overall performance of concrete by reducing chloride diffusion and chloride ion permeability reducing creep and drying shrinkage, increasing sulphate resistance enhancing final compressive strength, and reducing heat of hydration and bleeding. Concrete was made using varying proportions of fly ash and crushed, granulated blast furnace slag in place of cement. Fly ash and crushed granulated blast furnace slag were combined with M53 grade high strength concrete to create the specimens' required strength and features. We use sulphonated naphthalene polymer as a super plasticizer to make high performance concrete more workable. The dosage of the super plasticizer is the same for all mix ratios. A concrete cube was cast and given 28 days to cure. The perfect replacement for GGBS and fly ash in cement has a high compressive strength a low heat of hydration, chemical resistance, improved workability, good durability and cost effectiveness.

Keywords : ground granulated blast furnace slag's workability, compressive strength, and flexural strength in cement concrete.

1. INTRODUCTION

Concrete is the most used building material in India, where annual consumption exceeds 100 million cubic meters. Traditional Ordinary Portland Cement Concrete, which is designed based on compressive strength, cannot meet many functional criteria since it is discovered to be inadequate in hostile environments, for building for repair and retrofitting activities, etc.

High Performance Concrete which is superior to conventional concrete, must be produced as a result. In order to function extraordinarily well in the structure in which it is used or exposed to the environment, a high-performance concrete has had particular qualities designed for a given usage and environment.
The Strategic Highway Research Program (SHRP) has Identified a high performance concrete using the following criteria:

1) Compressive strength of 17.5 N/mm2 after 4 hours
2) Compressive strength of 35 N/mm2 after 24 hours
3) Compressive strength at 28 days: 70 N/mm2.
4) A 0.35 water-to-cement ratio
5) After 300 cycles of freezing and thawing, the durability factor is > 80

1.1 Characteristics High Performance Concrete

ACI defines HPC as. Concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practices. High-performance concrete has some of these characteristics

- High strength
- High early strength
- High modulus of elasticity
- High abrasion resistance
- High durability and long life in severe environments
- Low permeability and diffusion
- Resistance to chemical attack
- High resistance to frost and deicer scaling damage
- Toughness and impact resistance
- Volume stability
- Ease of placement
- Compaction without segregation
- Inhibition of bacterial and mold growth

1.2 Benefits of using GGBS in concrete

❖ **Sustainability**

It has been reported that the manufacture of one tonne of Portland cement would require approximately 1.5 tonnes of mineral extractions together with 5000 MJ of energy, and would generate 0.95 tonne of CO2 equivalent. As GGBS is a by-product of iron manufacturing industry, it is reported that the production of one tonne of GGBS would generate only about 0.07 tonne of CO2 equivalent and consume only about 1300 MJ of energy.

❖ **Colour**

Off-white describes the hue of pulverized granulated blast furnace slag. Furthermore, GGBS-built concrete displays this whiter hue, especially at replacement levels exceeding 50%. Due of the more aesthetically acceptable appearance of GGBS concrete, large structures like bridges and retaining walls can have a more subdued visual impact. The need for pigment in colored concrete is typically reduced when using GGBS, and the colors are also more vivid.

❖ **Setting Times**

The temperature and the ratio of water to cement are two of the numerous elements that affect how quickly concrete sets. The setting time will be slightly increased with GGBS, possibly by about 30 minutes. When the GGBS level is high and/or the temperature is low, the effect will be more noticeable. A longer setting time is helpful since there will be fewer joints because the concrete will be usable for longer.0In warm weather, this is particularly beneficial.

1.3 Advantages of fly ash

A cost reduction.

Increase compressive strength and decrease hydration heat.

Reduce the pore size and porosity.

1.4 Chemical Composition of GGBS and OPC

Chemical Analysis%	**Portland Cement**	**GGBS**
SiO_2	20.10	34.35-35.04
Al_2O_3	4.015	11.80-15.26
Fe_2O_3	2.50	0.29-1.40
CaO	61.30	36.80-41.40
MgO	3.13	6.13-9.10
K_2O	0.39	0.39
Na_2O	0.24	0.34
TiO_2	0.24	0.42
P_2O_5	<0.90	<0.10
MnO	-	0.43
SO_3	4.04	0.05-2.43
TiO_2	0.24	0.42
P_2O_5	<0.90	<0.10
MnO	-	0.43
SO_3	4.04	0.05-2.43

Table 1.1

2.LITERATURE REVIEW

1. Kavita Chandrakar is a Research Scholar at the Department of Civil Engineering at NIRT Bhopal, Madhya Pradesh, while V. V. Singh is a professor at the same institution. The title of the study is "An Experimental Study on High Performance Concrete Using Mineral Fly Ash and GGBS With M-60 Grade Concrete."

2. Anjali Prajapati et al. (2017) investigated the impact of mineral admixtures, such as fly ash and GGBS, on the performance of HPC utilizing M-60 grade IS cube specimens. Portland cement was partially replaced by the weight of the binder. The replacement of fly ash and GGBS varies from 10% to 30%. To improve the workability of high-performance concrete, we used Conplast SP430-Sulphonated Naphthalene Polymers as a super plasticizer. For all mix proportions, the dosage for super plasticizers is the same. We also substituted foundry sand for fine aggregate in a variety of ratios. For each of the various scenarios, we looked into the compressive strength, split tensile strength, and flexural strength. The grade M60 HPC mix concrete is created in accordance with Indian standards.

3. By replacing a portion of the cement and fine aggregate with ground granulated blast furnace slag (GGBS) and granulated blast furnace slag (GBS), Rajith M. and Amritha E. K. (2015) studied the behavior of M30 concrete. After 28 days of curing, compressive, split tensile, and flexural strength tests are performed on cubes, cylinders, and beams. To determine the ultrasonic pulse velocity, cubes are employed. Cement and fine aggregate replacement rates by GGBS and GBS are 20, 25, and 25, 50, respectively. In this work, a water cement ratio of 0.45 was used. The strength of concrete was found to be improved when GGBS and sand were used in part instead of cement and sand, respectively, in conventional mix concrete.

4. Reshma Rughooputh and Jaylina Rana (2013) investigated the effects of partially substituting GGBS for OPC on a number of concrete parameters, including compressive strength, tensile strength, splitting strength, flexure strength, modulus of elasticity, drying shrinkage, and initial surface absorption. 30% and 50% of GGBS by weight were used to replace some of the cement, and tests were done after 7 and 28 days. A lower early compressive strength gain but a higher later compressive strength gain was shown to be caused by GGBS in concrete. Tensile strength of test specimens improved by 12% and 17% to 30% and 50% replacement, respectively, while flexural strength increased by 22% and 24%. Shrinkage during drying went up by 3% and 4%.

5. In order to explore the strength and strength efficiency parameters of hardened concrete, S. Arivalagan (2012) substituted 20%, 30%, and 40% GGBS for cement at various ages. The specimens demonstrated an increase in compressive strength for a 20% replacement of cement when tested at 7 and 28 days. At 20% cement replacement, the concrete's split tensile and flexural strengths also grew. The GGBS filling effect is what causes the strength to increase. Additionally, it was discovered that the level of concrete's workability was typical and that it rose with the addition of GGBS.

6. Yogendra.O. Patil et al. (2012) conducted research on the impact of partial cement replacement with varying percentages of GGBS on the compressive strength and flexural strength of concrete. At 7, 28, and 90 days, the tests were carried out, and replacement levels ranged from 10% to 40%. It was shown that the percentage of cement replacement with GGBS has an inverse relationship with the strength of concrete. The slight drop in compressive and flexural strength of 4–6% for 90 days of curing and above that of more than 15% is shown when OPC is replaced by GGBS up to 20%. He came to the conclusion that GGBS, which replaces OPC by 20%, results in a decrease in the price of concrete at the going rate.

7. T. Vijaya Gowri et.al. (2011) investigated the effects of partial replacement of cement with GGBS on compressive strength, split tensile strength and flexural strength of concrete at 28,90,180 and 360 days. He used 50% GGBS as replacement material of cement for various water/binder ratios i.e.,0.55,0.50,0.45,0.40,0.36,0.32,0.30 and 0.27. he observed that the high volumes of slagconcrete gain an appreciable of strength at later ages (90 days onwards) and it increases with a decrease in water/binder ratios. He found out that the strength of the strength of high volume of slag concrete is more at later ages because of slower hydration of slag with Ca (OH)2 and water. He concluded that on replacement of cement by 50% GGBS helps to reduce the cement content of concrete. There by reducing the cost of concrete and also protecting the environment from pollution.

8. The effects of partial cement replacement with varied percentages of GGBS on the compressive strength and flexural strength of concrete were studied by Yogendra. Patil et al. (2012). The experiments were run at 7, 28, and 90 days, and replacement amounts ranged from 10% to 40%. It has been demonstrated that the proportion of cement replacement with GGBS and concrete strength are inversely related. When OPC is replaced by GGBS up to 20%, there is a modest reduction in compressive and flexural strength of 4-6% for 90 days of curing and above that of more than 15%. He came to the conclusion that GGBS results in a reduction in the price of concrete at the market rate, replacing OPC by 20%.

3.Experimental Investigation

3.1 MATERIAL USED

1. Cement
2. Fine gravel
3. Coarse gravel
4. Water
5. Powder GGBS
6. Fly Ash
7. Superplasticizer

3.2 Material details

3.2.1 Cement:

BIRLA SUPER 53 grade regular Portland cement was utilized in this experiment. All OPC properties were assessed using IS: 12269:1987. The cement used for casting needs to be new and up to code.

3.2.2 Fine Aggregate:

Both standard IS-specified sand and locally accessible river sand were employed as forms of fine aggregate or sand. The river sand was retained almost entirely on the IS:15 sieve (150-micron size) after passing through the IS:480 sieve (aperture 4.75 mm square).

3.2.3 Coarse Aggregate: A locally available crushed stone aggregate with a nominal maximum size of 16mm was used as the coarse material. The coarse material. The sieve analysis and physical features are shown in table 4. The coarse material was sieved through the 4.75 mm to remove the tiny particles. Washed aggregate was employed in the study.

3.2.4 Water: Concrete was blended and cured using potable water, and the pH level of the water was below 6. There were no acids, oils, salts, or sugars in the water that was used.

3.2.5 GGBS Powder: Off-white cementitious substance known as “ground granulated blast furnace slag” (GGBS)

3.2.6 Fly Ash: A byproduct of coal-fired electric generating stations is fly pulverized coal is blown into the furnace’s burning chamber for instant combustion. Fly ash is the term for the lower weight ash that flies away when coal is burned. The heavier ash falls to the ground after coal is burned.

3.2.3 Superplasticizer

Complect SP430 DIS

3.3 Materials properties

3.3.1 Cement

Table 3.1- Physical properties of ordinary Portland cement (OPC)

Characteristics	Experimental values
Blaine's fineness (m2/kg)	301
Specific gravity	3.15
Soundness (mm)	3.5
Setting time (minutes)	
1. Initial	105
2. Final	180
Compressive strength (MPa)	
1. 3-days	24
2. 7-days	34
3. 28-days	45

3.3.2 GGBS powder

Table 3.2- Physical properties of ground granulated blast slag

Characteristics	GGBS values
Fineness (m2/kg.)	340
Specific gravity	2.86
Soundness (mm)	1.5
Initial setting time (minutes)	150

3.3.3 Fine aggregate

Table 3.3- Sieve analysis and physical properties of fine aggregate

IS Sieve designation	**Weight retained (gm)**	**percent weight retained**	**percent weight passing**	**Cumulative retained percent weight**
4.75 mm	3	0.6	99.4	0.6
2.36 mm	38	76	91.8	8.2
1.18 mm	108	21.6	70.2	29.8
600 micron	83	16.6	53.6	46.4
300 micron	115	23	30.6	69.4
150 micron	105	21	9.6	90.4
Residue	48	9.6	-	-

Physical Properties
Grading = Zone II (IS: 383-1970)
Fineness modulus = 2.45
Specific gravity = 2.61
Density (loose) = 15.4 KN/m3

3.3.4 Coaese aggregate

Table 3.4. Sieve analysis and physical properties of coarse aggregate

IS Sieve designation	Weight retained (gm)	Percent weight retained	percent weight passing	Cumulative percent weight retained
80 mm	0	-	100	-
40 mm	0	-	100	-
20 mm	40	0.4	99.6	0.4
10 mm	8150	81.5	18.1	81.9
4.75 micron	1550	15.5	2.6	97.4
Reside	260	2.6	-	-

Physical properties:

1. Fineness modulus = 6.8
2. Specific gravity = 2.63
3. Density (loose) = 14.3 kN/m3

4. **METHODOLOGY**

4.1 Mix proportion

M60 grade of concrete –

1:1.35:2.19 for block 150x150x150mm (0.003375 m3)

Mix	GGBS %	Fly Ash %	Quantity (Kg/m3)						
			Cement	GGBS	ly ash	Fine aggregate	Coarse aggregate	Water	Superpla-sticizer
M1	-	-	1.7	-	-	2.29	3.76	0.65	1.36
M2	-	-	1.7	-	-	2.29	3.76	0.65	1.36
M3	-	-	1.7	-	-	2.29	3.76	0.65	1.36
M1	15	-	1.445	0.255	-	2.29	3.76	0.65	1.36
M2	25	-	1.275	0.425	-	2.29	3.76	0.65	1.36
M3	35	-	1.105	0.595	-	2.29	3.76	0.65	1.36
M1	-	15	1.445	-	0.255	2.29	3.76	0.65	1.36
M2	-	25	1.275	-	0.425	2.29	3.76	0.65	1.36
M3	-	35	1.105	-	0.595	2.29	3.76	0.65	1.36

Table – 4.1: Quantity of material.

4.2 Casting and curing of test specimen

The liquid was poured into 150 * 150 * 150 mm cube molds after being fully mixed. In this world, we principally prepared 9 different M60 Grade concrete mixes, including concrete mixes produced by replacing GGBS and fly ash as well as traditional aggregate concrete (CAC). After one day of casting, the cubes are demolded, placed in water to cure at room temperature with a relative humidity of 85% and taken out for testing after seven, twenty-one, and thirty-eight days.

4.3 Testing

4.3.1 Workability test

The workability of fresh concrete was measured by means of the conventional slump test. Before the fresh concrete was cast into molds, the slump value of the fresh concrete was measured using slump cone. **Procedure for Concrete Slump Cone Test**

1. Clean the internal surface of the mold and apply oil.
2. Place the mold on a smooth horizontal non- porous base plate.
3. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.

6. Clean away the mortar or water leaked out between the mould and the base plate.

7. Raise the mold from the concrete immediately and slowly in vertical direction. Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested

NOTE:

The above operation should be carried out at a place free from Vibrations or shock and within a period of 2 minutes after sampling.

Slump Value Observation:

The slump (Vertical settlement) measured shall be recorded in terms of millimeters of subsidence of the specimen during the test.

Results of Slump Test on Concrete Slump for the given sample=______mm

When the slump test is carried out, following are the shape of the concrete slump that can be observed:

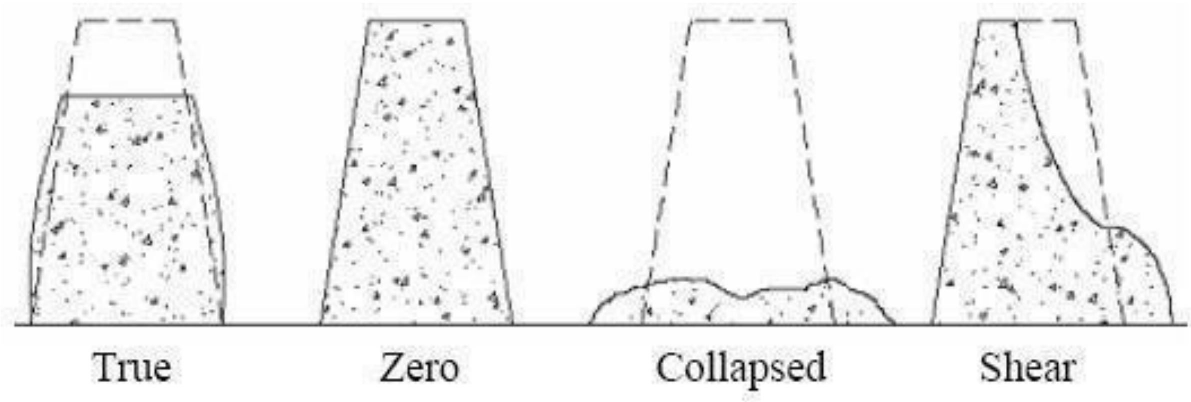

Figure- 4.1 : Types of Concrete Slump Test Results

- **True Slump** –
  True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in figure-1.

- **Zero Slump** –
  Zero slump is the indication of very low water-cement ratio, which results in dry mixes. This type of concrete is generally used for road construction.

- **Collapsed Slump** –
  This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.

- **Shear Slump** –
  The shear slump indicates that theresult is incomplete, and concrete to be retested.

4.3.2 Water absorption test

The water absorption was calculated in order to assess whether there was an increase in the mortar's pore space as a result of weathering by exposure to silage effluent. This test was carried out in accordance with the Spanish Standards UNE 67-027-84. The mortars were immersed in water, at atmospheric pressure until saturation. Water absorption was measured as a percentage of the saturated mass of the specimen using equation:

$$Wa = (Ws - Wd / Ws) * 100$$

Where: Wa = Water absorption

Ws = Final weight after absorption

Wd = Initial dry weight

4.3.3 Compressive Strength

Definition

Compressive strength is the ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression strength to reduce the size, while in tension, size elongate

Procedure for Concrete Cube Test

1. After the designated curing period, remove the specimen from the water and wipe away any excess moisture.
2. Round the specimen's size to the nearest 0.2m.
3. Scrub the testing device's bearing surface. Place the specimen in the device so that the load is distributed across the cube's opposing sides.
4. Center the specimen on the machine's base plate.
5. Gently turn the movable part by hand until it meets the specimen's top surface.
6. Continue applying the load continuously at a rate of 140kg/cm2/minute until the specimen fails.
7. Note any peculiar characteristics of the failure type and the maximum load.

Figure-4.2

5.CONCLUSION

1. Chemical attack on concrete used in construction is construction is severe over time research is required to find a more durable concrete for this climate because fixing this damage always costs a lot of money.

2. In harsh situations where acids and salts are present GGBS are more durable than PC-only products Durability also increased as GGBS concentrations rose.

3. PC concrete will have less maintenance required and a longer lifespan with the inclusion of GGBS.

4. The inclusion of GGBS will extend PC concrete's lifespan and require less maintenance.

5. GGBS can be utilized as a cement substitute, lowering cement usage and construction coasts. Utilizing industrial waste products protects the environment and protects the environment and preserves natural resources.

6. At the age of 28 days GGBS based concretes have demonstrated an increase in strength for a 20% replacement of cement. The filling action of GGBS contributes to increased strength.

7. With the addition of GGBS up to 40% replacement level for M35 grade concrete the degree of concrete workability was standard.

6. REFERENCES

1. "An Experimental Study on High Performance Concrete Using Mineral Fly Ash and GGBS with M-60 Grade of Concrete," by Kavita Chandrakar and V.V. Singh.

2. "Sustainable studies on concrete with GGBS as a replacement material in cement, "by S. Arivalagan.

3. Strength development of cement mortar and concrete using GGBS by M. Shariq, J. Prasad, and A.K. Ahuja.

4. Er. Kimmi Garg and Kshipra Kapoor –"Analysis of strength characteristics of GGBS concrete".

5. Bureau of Indian Standards, New Delhi, "IS 456:2000, Indian Standard Code of Practice for Plainand Reinforced Concrete." 6. Ishwar Chandra Thakur, N. Kisku, J.P. Singh, Sheo Kumar (2016), "Properties of Concrete Incorporated with GGBS," International journal of Research in Engineering and Technology, Volume: 05 Issue: 08, PP:275-281.Jayie Shah, (2014), Studying the effects of

6. Bureau of Indian Standard, New Delhi, "recommended Guidelines for Concrete Mix Design", IS 10262:2009

7. Bureau of Indian Standards, New Delhi, IS 516:1959, "Flexural Strength of Concrete."

8. Bureau of Indian Standard, New Delhi, IS 9399:1959, "Specification for Apparatus for Flexural Testing of Concrete."

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