Behavior of Cement Concrete by Partially Replacing Cement with Ground-granulated Blast Furnace Slag.

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Abstract - *According to the construction section, the necessary supplies are currently unavailable. Therefore, we must come up with a different plan of action by substituting other components for cement, fine aggregate, and coarse aggregate in the concrete. The most expanding component of concrete is cement. Cement manufacturing is responsible for more than 5% of the world's carbon dioxide emissions. This technique uses GGBS, an alternative source of cement a compressive analysis of the characteristics of concrete with GGBS partially substituting cement. Made in the blast furnace that produces iron, GGBS is a by-product. Blast furnaces are supplied with a precisely regulated mixture of iron ore, coke, and limestone and run at temperatures between 1500 and 1600 °C. It has an off-white hue. In this studies M35-grade concrete mixtures have GGBS replacement percentages of 20%, 30%, and 40% of the original cement. Strength measurements at 7 and 28 days include compressive strength. It is determined what percentage of GGBS substitution is ideal by comparing the strength to regular concrete.*

Key Words: **Ordinary Portland cement, GGBFS, Compressive strength, Design mix, conventional concrete.**

1.INTRODUCTION:

In the globe, concrete is undoubtedly the most frequently used building material, with almost six billion tons manufactured annually. in terms of individual consumption. There is only water in the area. The most significant material element in the constructed environment is concrete. Concrete with less embodied energy might benefit the economy and the environment greatly without sacrificing functionality or driving up costs. Portland cement, aggregates, and water are the three primary components of concrete. Although Portland cement typically makes up about 12% of the mass of the concrete, it accounts for around 93% of the total embodied energy of the material and 6–7% of global $CO2$ emissions. To minimize the unfavorable features, you can use some remedial steps.

1.1 Formation of GGBS and its compositions:

An iron manufacturing industry byproduct is ground-granulated blast furnace slag. Melted slag rises to the top of the molten iron at a temperature of approximately 15000 - 16000 °C as a result of feeding the furnace with iron ore, coke, and limestone. About 30% to 40% $SiO2$ and 40% CaO make up molten slag, which is nearly identical to Portland cement's chemical makeup. GGBFS will reduce carbon dioxide gas emissions in place of Portland cement. It is therefore a building material that is friendly to the environment. GGBFS is regarded as an environmentally beneficial material since it usually doesn't need to be processed before being used in concrete in modern thermal power plants. With GGBS, we can replace roughly 80% of the Portland cement in concrete. Improved resistance to sulfate attack, corrosion, and water impermeability are among the qualities of GGS. because of decreased heat hydration. It lessens the possibility of thermal fracture. It is more resilient and workable, but less permeable to other organizations.

1.2 Using Concrete with GGBFS:

an improved and more robust basis. decreasing and managing heat cracking. lower heat-induced hydration. sustained development of strength. strengthened defenses against peaty, acidic substances. heightened resilience to salt and sulfates in the maritime milieu. These days, high-rise structures, bridges, and highways are the main uses for GGBS concrete.

2. AIM AND OBJECTIVE:

- Determine whether using GGBS instead of cement while building concrete is feasible.
- Examine how concrete cubes' compressive strengths behave. When substituting 20%, 30%, or 40% of the cement with GGBS, compare the outcome to conventional normal concrete and the number of cubes cast. Then, compare the qualities with standard mix M35.
- The goal is to determine the most cost-effective replacement percentage without compromising strength and to offer affordable building costs.

3. LITRATURE REVIEW:

- **T. Vijayagowri, P. Sravana, P. Srinivasa Rao (2014)** Studies on strength behaviour of high volumes of slag in concrete 'Investigated the effects on compressive strength, split tensile strength and flexural strength of concrete at 28, 90, 180 and 360 days by partial replacement of cement with GGBFS on. He used 50% GGBFS as replacement material of cement an also used various water/binder ratios are 0.55, 0.50, 0.45, 0.40, 0.36, 0.32, 0.30 and 0.27. He observed that the strength gain by replacement of slag is inversely proportional to the water/ binder ratio and slag concrete gains appreciable amount of strength at later ages (90 days onwards). He found out that the strength of high volume of slag concrete is more at later ages because rate of hydration of slag with Ca(OH)2 and water is slow. He concluded that on replacement of cement by 50% GGBFS helps to reduce the cement content of concrete, thereby reducing the cost of concrete and also protecting the environment from pollution.

- **Reshma Rughooputh and Jaylina Rana (2014)** Partial replacement of cement by ground granulated blast furnace slag in con Crete 'Studied the effects on various properties of concrete including compressive strength, tensile strength, splitting strength, flexure strength, modulus of elasticity, drying shrinkage and initial surface absorption by partial replacement of OPC by GGBFS on. The tests were conducted with replacement ranging from 30 % to 50% at 7and 28 days. It was found that compressive strength is lower at the early age but increase after the later age time. Flexural strength of test specimens increased by 22% and 24%, tensile strength increased by 12% and 17% for 30% and 50% replacement respectively. Drying shrinkage increased by 3% and 4%. Static modulus of elasticity increases by 5% and 13%. Based on the results the optimum mix was the one with 50% GGBFS.

- **Mohammed Shariq, Janaka prasad, A.K. Ahuja (2008)** Strength development of cement mortar and concrete incorporating GGBFS' Studied the effect of curing procedure on the cement mortar and concrete incorporating ground granulated blast furnace slag compressive strength development. The compressive strength development of cement mortar is calculated by the 20, 40 and 60 percent replacement of GGBFS for different types of sand. Similarly, the strength development of concrete is investigated with 20, 40 and 60 percent replacement of GGBFS on two grades of concrete. Tests results show that the incorporating 20% and 40% GGBFS is highly significant to increase the compressive strength of mortar after 28 days and 150 days, respectively.

- **Santosh Kumar karri, G.V. Rama Rao, P. Markandeya Raju (2015)** Partial replacement of cement with GGBS in concrete '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 com pressive 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 of 1% and 5% concentration and were tested for compressive strength at 90 days and 28 days respectively.

- **C. Sabeer Alavi, I. Bhaskar, R. Venkata Subramani (2013)** Strength and durability characteristics of GGBFS based SSC 'Studied the effects of partial replacement of cement with 10- 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 4 in percentage of GGBFS.

4. MATERIAL FOR EXPERIMENTS:

4.1 Cement Content: Ordinary Portland cement (OPC) is the best type of Portland cement to use in concrete structures used for general construction. There are three variations offered. Cement in grades 33, 43, and 53 in this investigation had an OPC53 grade, meaning that its specific gravity was 3.04 and its fineness was 4%.

4.2 Coarse Aggregate: I utilized aggregate with a maximum size of 20 mm, a constant grade, and uniform grading. Its specific gravity is 2.70, and its rate of water absorption is 0.75%.

4.3 Fine Aggregate: This piece uses river sand from Zone II. The maximum size of the fine aggregate is 4.75 mm, the specific gravity is 2.60, and the water absorption is 1.16%.

4.3 Water: Concrete is mixed and cured using portable water.

4.4 Ground-granulated blast furnace slag, or GGBFS: is a by-product of the iron-making process. The chemical composition of Portland cement is comparable to that of molten slag. When the molten iron is tapped out, the residual slag, which is primarily composed of silicious and aluminous residue, is rapidly quenched with water, forming glassy granulate.

5. MIX DESIGN STEPS FOR M-30 GRADE CONCRETE:

As IS recommended concrete based on {IS10262-2019}.

(a) Steps for mixed design for concrete:
1. Grade of Concrete = M-30
2. Cement = OPC-53
3. Size of Coarse aggregate = 20 mm
4. Exposure condition = Severe
5. Workability = 75 mm
6. Method of concrete placing = manual mixing
7. Minimum cement content = 320 kg/m^3

(b) Test result for material:
1. Specific gravity of cement = 3.04
2. Specific gravity of coarse-aggregate = 2.70
3. Specific gravity of fine-aggregate = 2.60
4. Water absorption of coarse-aggregate = 0.75%
5. Water absorption for fine-aggregate = 1.16%
6. Sand specification= Zine-II

(c) Target mean strength for M-30 grade concrete = 38.25 N/mm^2

(d) Selection of water-cement ratio = 0.45

(e) Selection of water content = 207.236 kg/m^3

(f) Cement content =425.73 kg/m^3

(g) Coarse aggregate (per m^3) = 1119.93 kg

(h) Fine aggregate (per m^3) = 630.69 kg

6. TEST ON CONCRETE:

Workability test of Concrete: Concrete's workability may improve the material's consistency and flowability. The workability of concrete slump cone examination: This test determines how consistent concrete is. Concrete has a mix ratio of C:S:A::1:66:3.04, whereas normal concrete has a mix ratio of C:S:A::1:48:2.63. Standard concrete has slump values of 82.50 mm, whereas GGBFS concrete has 86 mm.

7. RESULT AND DISCUSSION:

The sample of concrete were cast in accordance with IS 10086-1982. The cube, cylinder, and beam samples were cured in a water pond for a period of 28 days. At seven and twenty-eight days, the strength metrics of self-compacted concrete were compared to those of conventionally cured concrete.

Fig-1: Casting of Cube.

Fig-2: Casting of Cylinder

Fig-3: Casting of Beam

6.1 TEST OF SAMPLE:

Compressive Strength test: Compressive Strength is equal to P/A, where A is the cross-sectional area (150 × 150 x 150 mm) and P is the applied load.

Fig-4: Compressive strength test in UTM

TABLE-1: Compressive Strength results of Concrete.

S.NO.	M30 Concrete with GGBFS %	07 days Compressive strength N/mm²	28 days Compressive strength N/mm²
Conventional concrete	0.0%	21.00	30.00
MIX-1	10%	24.50	38.10
MIX-2	20%	24.20	36.50
MIX-3	30%	25.15	39.65
MIX-4	40%	23.95	34.35

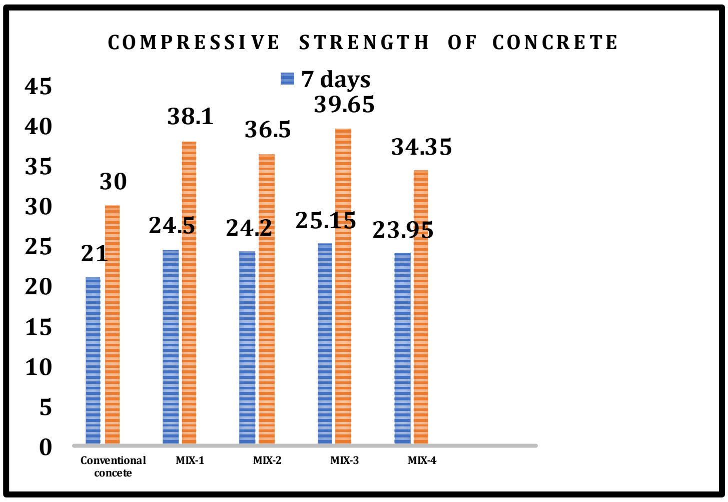

Chart-1: Compressive strength of concrete after 7, and 28-days Conventional concrete vs GGBFS concrete.

Split tensile strength test: utilizing 300-mm-high and 150-mm-diameter cylinders. Where P is the load, D is the cylinder diameter, and L is the cylinder length, the formula for split tensile strength is 2P/πDL.

Fig- 5: Split tensile strength test in UTM

TABLE-2: Tensile Strength results of Concrete:

S.NO.	M30 Concrete with GGBFS %	07 days tensile strength N/mm²	28 days tensile strength N/mm²
Conventional concrete	0.0%	3.17	3.18
MIX-1	10%	3.52	4.52
MIX-2	20%	3.40	4.49
MIX-3	30%	3.57	4.61
MIX-4	40%	3.35	4.42

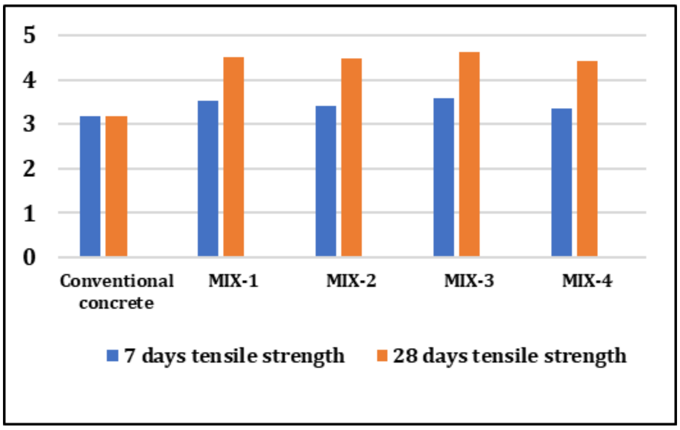

Chart-2: Tensile strength of conventional concrete after 7 and 28-days vs GGBFS concrete.

Flexural Strength test: a 150 x 150 x 700 mm beam specimen with a 2000 KN force to produce bending. WL/bd is equivalent to f strength. A hydraulic apparatus was utilized to test each of these specimens.

Fig-6: flexural strength test of concrete in UTM

TABLE-3: Tensile Strength results of Concrete:

S.NO.	M30 Concrete with GGBFS %	07 days flexural strength N/mm²	28 days flexural strength N/mm²
Conventional concrete	0.0%	3.34	4.70
MIX-1	10%	4.47	4.95
MIX-2	20%	4.55	6.75
MIX-3	30%	3.75	4.55
MIX-4	40%	4.85	5.65

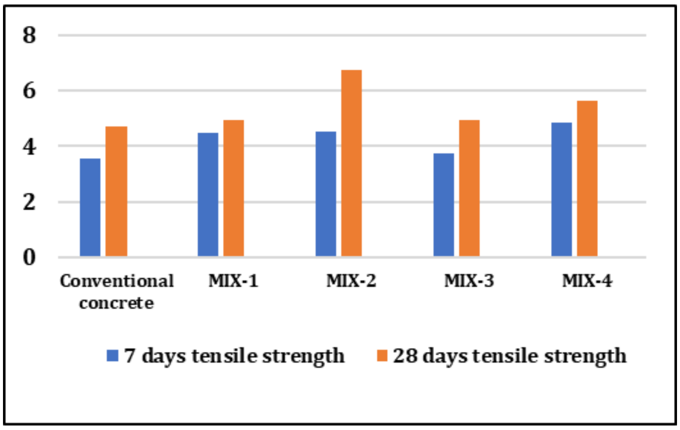

Chart-3: flexural strength OF Conventional concrete after 7 and 28-days vs Self compacting concrete.

7. CONCLUSION:

1. The current analysis shows that the best amount of GGBS to replace cement in a concrete mix is 30%.

2. GGBS compressive strength may replace conventional concrete cubes by up to 40%.

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