Experimental Investigation on the behavior of basalt fiber-reinforced concrete beams with partial replacement of cement by ground granulated blast furnace slag(GGBS)

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Abstract - The construction industry has seen a growing demand for cementitious compound, which is a primary building material. Traditionally, cementitious compound has been made using heavy materials, with steel being a popular reinforcement option. However, in recent years, there has been a trend towards reducing the amount of steel used in structures, and instead, Basalt Fibre Reinforced Polymer (BFRP) rods are being utilized. This study aims to investigate the behaviour of reinforced cementitious compound by adding BFRP bars as reinforcement and partially replacing cement with Ground Granulated Blast Furnace Slag (GGBS) in M50 grade cementitious compound. Various ratios of GGBS (0%, 20%, 40%, and 60%) were used to partially replace the cement content, and the compressive resistance, split tensile resistance were tested after 7, 14, and 28 days of curing. The cementitious compound with a 40% replacement of GGBS demonstrated raised resistance in compression resistance, split tensile resistance, and flexural resistance

Keywords –Concrete, Basalt Fiber Reinforced Polymer, Ground Granulated blast Furnance Slag

I. INTRODUCTION

Cementitious compound, a cement-based substance, is widely used in constructing buildings, bridges, tunnels, and roadways due to its advantageous attributes. It can work seamlessly with steel bars, has impressive compressive resistance, and can withstand various environmental conditions, which has made it increasingly popular in the physical structures and infrastructure. Cementitious compound comprises sand (fine aggregate), crushed rock (coarse aggregate), chemical admixtures, and water. When cement and water are mixed, they undergo a process called hydration, observation in the hardening and solidification of the cementitious compound mixture with fine and coarse aggregates, ultimately forming a composite material. Cementitious compound is a manmade type of stone that can be shaped into various forms.

1.1 OBJECTIVES OF THE STUDY

- The primary goals of the project are
- To ascertain the corporeal attributes of the substances
- To ascertain the mechanistic attributes such as compressive resistance, split tensile resistance, and durability of the cementitious compound beam
- To ascertain the bending conduct of the cementitious compound beam

1.2 SCOPE OF THE STUDY

The scope of the project is

- Ascertain the characteristics like compressive resistance, split tensile resistance of basalt fibre reinforced cementicious compound.
- Observe the merits and demerits of usage GGBS in cement in basalt reinforced cementitious compound.
- Study and compare analytical and experimental observations of the modified cementitious compound.

1.3 NEED FOR PROJECT

The need for the project is

- The cementitious compound has become one of the pollutions in the environment for that to overcome this the reduction of carbon emission various material is substituted.
- The research is to ascertain the mechanical attributes of the cementitious compound beam.
- The cementitious compound beam consists of GGBS replacement which helps to minimize the emission of Co2 and to obtain the same or higher resistance as required.

- The beam consists of BFRP bars as reinforcement in case of steel reinforcement present in the conventional cementitious compound.
- Determination of compression test on cementitious compound
- To find the flexural resistance and the split tensile resistance in cementitious compound.

II. LITERATURE SURVEY

The objective of this literature review is to showcase the performance of cementitious compound beams reinforced with Basalt Fibre Reinforced Polymer (BFRP) bars and stirrups in flexural and shear tests. The dimensions of the beams were 150 × 300 × 3 and 100mm, respectively [1]. A technique is proposed for the long-term design resistance of BFRP bars by conducting stress tests on samples that are conditioned in solutions with pH values of 9 and 13 at a range of temperatures between 20°C and 60°C[2]. The investigation involved testing of The experimental program consisted of testing beams reinforced with ribbed 8 mm, 12 mm, and 16 mm BFRP bars, as well as two control beams reinforced with 10M and 15M steel bars, in accordance with Canadian standards[3].

The findings indicate that BFRP reinforced beams with lower reinforcement ratios exhibit more cracking in flexural and shear compared to their steel reinforced counterparts, but still exhibit acceptable deformation[4].The study proposed equations for computing the cracking, yielding, and the deflection of RC- BFRC beams, and these equations were validated through experiments[5].This study investigates the impact of high temperatures on the mechanistic attributes and ultrasonic attributes of Basalt Fibre- Reinforced Cementitious compound with a high content of stone powder[6]. The objective of this paper is to examine the resilience of the bond between FRP bars and cementitious compound, with a focus on the degradation of the surface of the FRP bars when used with high-resistance cementitious compound[7]. Lately, the utilization of basalt fibres to reinforce the attributes of hardened cementitious compound has gained popularity. Nonetheless, the integration of these fibres has an impact not only on the hardened state of cementitious compound but also on its fresh attributes, specifically its workability[8]. The present study conducts experiments to explore the feasibility of utilizing basalt fibre reinforced polymer fabrics for reinforcing reinforced cementitious compound (RC) structural elements subjected to flexural loads[9]. The corrosion resistance of M30 grade cementitious compound containing basalt fibres was investigated by analysing on the resistance of cementitious compound reinforced with basalt fibres and BFRP bars against corrosion, as measured by its resistivity, potentials, and chloride ion diffusion[10]. When attaching prestressed BFRP (basalt fibre reinforced polymer) rods to reinforce cementitious compound structures, the open- up of prestress may cause interfacial shear stress at the ends of the BFRP, leading to early debonding. To avoid this issue, the interfacial adhesive resistance must not exceed the BFRP-induced shear stress from prestressing[11].

III. PROPOSED METHODOLOGY

The methodology shows the step-by-step procedure and their detailed explanation about b experimental process and observations are explained.

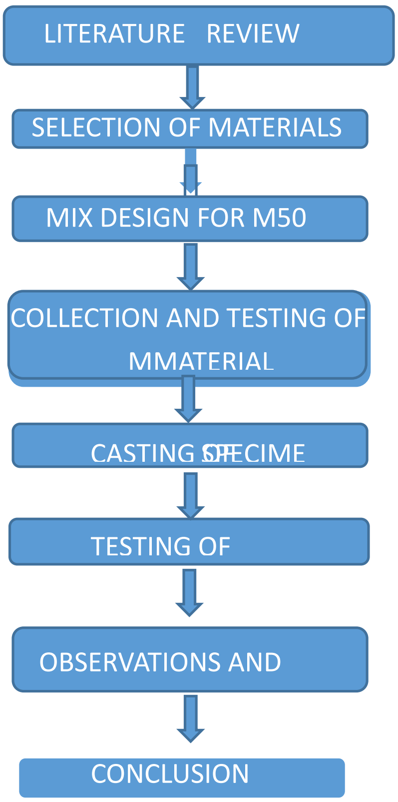

Figure 3.1: Flow chart of Methodology

- At Initial stage, the review of the literature is examined and the materials are selected as per the reference of the paper.
- After successful of the analytical part the materials which are to be used are collected and the initial test are made on it.
- The casting of cube, cylinder and beams are done as per the IS code and the specimens

are cured and the tests are made at an interval of 7, 14 and 28 days.

IV. EXPERIMENTAL INVESTIGATION:

4.1 Mix design:

The formulation used to achieve M50 grade cementitious compound adheres to the guidelines outlined in IS: 10262 - 2019. The observationing ratio for the nominal M50 grade is 1:1.54:2.33, while the water-to-cement ratio is 0.35.

4.2 Mix proportion:

The GGBS is used as portion of replacement in the cement at the range of 0%, 20%, 40% and 60% respectively. Also based on the test mixes the appropriate mix design are also made. The nominal design mix for M50 cementitious compound grade mix proportion is shown in the table.

Table 4.7 mix proportion

Materials	Quantity (kg/m^3)
Cement	450
Fine Aggregate	696
Coarse Aggregate	1051
Water	157.5
Chemical Admixture	4.31

4.3 Test on Hardened Cementitious compound

4.3.1 Compressive Strength Test:

The compressive resistance is performed following the IS 516-1999 standards on a cementitious compound sample measuring 150mm x 150mm x 150mm. The samples are immersed in clean water and removed after 7, 14, and 28 days to test their resistance. They are then placed in a dry area to ensure that all water is drained out before testing, observationing in more accurate observations. The specimen is placed in a compression testing machine and loaded gradually until it fails. The observations of the test are graphically displayed to represent the compressive resistance of the sample.

Figure 4.1 Compressive Strength test

Table 4.1 Compressive Strength of the Beam Specimen for 7,14, 28-days

S. No	Mix Details	CEMENT (%)	GGBS (%)	7 Days (N/mm2)	14 Days (N/mm2)	28 Days (N/mm2)
1.	Mix 1	100%	0%	32.5	50	57
2.	Mix 2	80%	20%	31.5	47.6	56.9
3.	Mix 3	60%	40%	32	50.5	58.5
4.	Mix 4	40%	60%	30	48	56.3

Calculation:

Size of the Cube = 150mm x 150mm

Area of the Cube = L x B = 150mm x 150mm

Characteristic compressive resistance=

$$\frac{Failure-load-of-cube}{Area-of-cube}$$

Failure load of Cube at 28 days = 1316 KN

Compressive resistance=

$$\frac{1316X1000}{150X150}=58.5N/mm2$$

4.3.2 Split tensile Strength Test:

The split tensile resistance test is conducted in compliance with the IS 516-1999 standards on cylindrical cementitious compound specimens that measure 150mm in diameter and have a length of 300mm. The cylindrical specimens are placed diagonally between the compression testing machine's loading surfaces, and a load is gradually applied until the cylinder fails, observationing in diagonal cracks.

Fig 4.2 split tensile Strength test

Table 4.2 Split-tensile values of the Beam Specimen for 7,14, 28-days

S. No	Mix Details	CEMENT (%)	GGBS (%)	7 Days (N/mm^2)	14 Days (N/mm^2)	28 Days (N/mm^2)
1.	Mix 1	100%	0%	2.70	3.5	4.35
2.	Mix 2	80%	20%	2.7	3.4	4.1
3.	Mix 3	60%	40%	2.61	3.8	4.48
4.	Mix 4	40%	60%	2.53	3.5	4.13

Calculation:

Size of Cylinder: Diameter = 150mm,

Height = 300mm

Area of cylinder = π x D x L

Characteristic split-tensile resistance=

$$\frac{2XFailure-load-of-cylinder}{Area-of-cylinder}$$

Failure Load = 317 KN

Split resistance =

$$\frac{2X317X1000}{3.14X150X300}=4.48N/mm2$$

4.3.3 Flexural Strength Test:

The flexural test is conducted in compliance with the standards outlined in IS 516- 1999. Cast concrete beams of standard size: **150 mm × 150 mm × 700 mm** (or 100 mm × 100 mm × 500 mm depending on standard used).

Table 4.3 Flexural Strength Comparison Table (Strengths at 7, 14, and 28 Days)

Mix ID	CEMENT (%)	GGBS (%)	Flexural Strength at 7 Days (MPa)	Flexural Strength at 14 Days (MPa)	Flexural Strength at 28 Days (MPa)
Mix 1	100%	0%	3.78	4.54	5.24
Mix 2	80%	20%	3.51	4.26	4.93
Mix 3	60%	40%	3.19	3.91	4.58
Mix 4	40%	60%	2.88	3.51	4.17

V. **RESULT AND DISCUSSION**

5.1 Compression Test

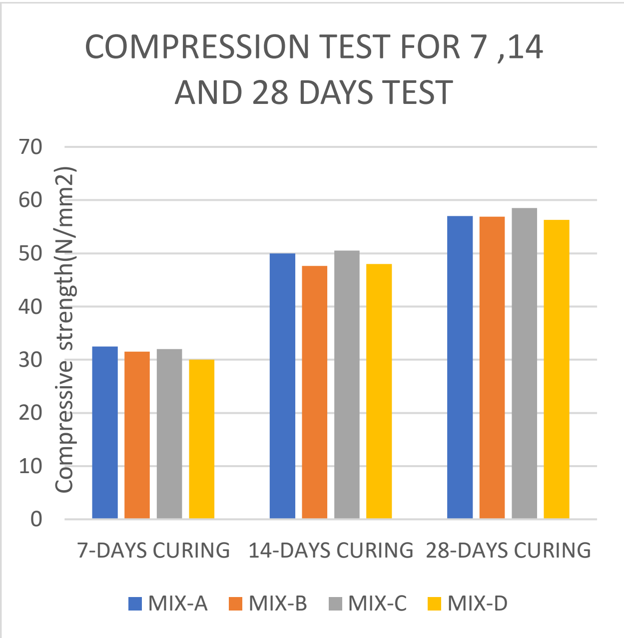

Fig.5.1 Compression test for 7,14 and 28 days test

- A graph is used to illustrate the compressive resistance of cementitious compound cube specimens for four different mixes, with values taken at 28 days. Mix 1, which is a conventional cementitious compound specimen, has a compressive resistance value of 57 N/mm2. Mix 2, with a compressive resistance value of 56.9 N/mm2, is another conventional cementitious compound specimen. The third mix, with a compressive resistance value of 58.5 N/mm2, contains a replacement of 40% GGBS instead of cement. Mix 4, with a compressive resistance value of 56.3 N/mm2, is another conventional cementitious compound specimen. The compressive resistance test was conducted in a compression testing machine.
- At 28 days, the test observations indicate that the Mix 3 specimen, which has 40% replacement of cement with GGBS, has a higher resistance than the conventional cementitious compound. The 20% replacement of GGBS also observations in an improvement in resistance compared to the conventional cementitious compound specimens. However, at replacement rates greater than 40%, specifically at 60% of GGBS, the specimens show a reduction in resistance when compared to the resistance obtained at 40% replacement. The time required to reach higher resistance levels was not measured in this test. Therefore, Mix 3 is considered to have achieved the desired resistance level and is stronger than the conventional specimen.

5.2 Split Tenslie Strength

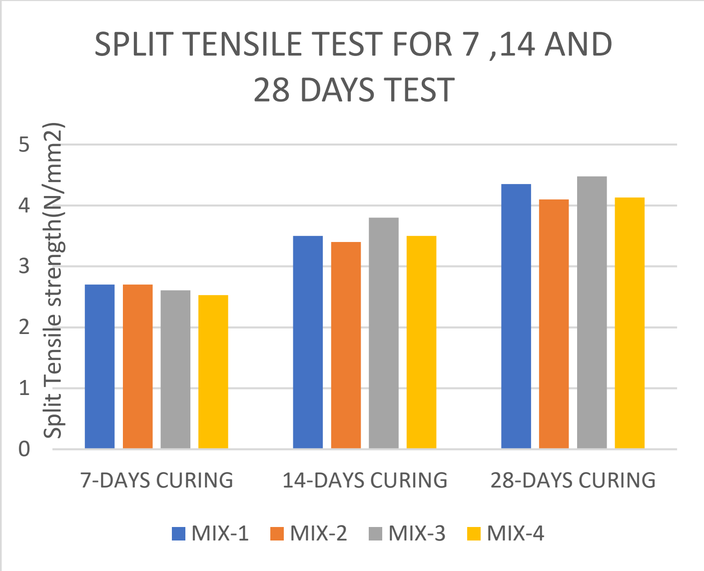

Fig.5.2 Split Tensile Test for 7,14 and 28 days test

The graph represents the split tensile resistance of four different cementitious compound mixes that contain different proportions of cement and GGBS at different curing ages, including 7 days, 14 days, and 28 days. The split tensile resistance of all cementitious compound mixes rises as the curing age rises, and the highest compressive resistance values are observed after 28 days of curing, which is a typical trend in cementitious compound.

Mix 1, which is conventional cementitious compound, has the highest resistance values at all three curing ages, indicating that it is the strongest mix. However, Mix 2 (cement 80% and GGBS 20%), Mix 3 (cement 60% and GGBS 40%), and Mix 4 (cement 40% and GGBS 60%) also show good resistance values, suggesting that GGBS can be used as a portion of replacementfor cement to produce cementitious compound with comparable resistance to conventional cementitious compound. Additionally, Mix 3 (cement 60% and GGBS 40%) has the highest resistance value at 28 days of curing among the GGBS-containing mixes, indicating that a higher proportion of GGBS can enhance the resistance of cementitious compound. The average split tensile resistance values are based on the 28-day resistance of the specimens. Each specimen has a gradual rise in split tensile resistance, and the mix containing 20% GGBS and the mix with 40% GGBS replacement exhibit an rise in resistance.

However, a decrease in split tensile resistance is observed with GGBS replacement above 40%, and the mix with 60% GGBS replacement shows a decrease in every characteristic, including split tensile resistance. In conclusion, the use of GGBS as a portion of replacement for Portland cement can observation in cementitious compound with good resistance values, which can lead to cost savings, reduced environmental impact, and enhanced durability of cementitious compound structures

5.3 Flexure Test

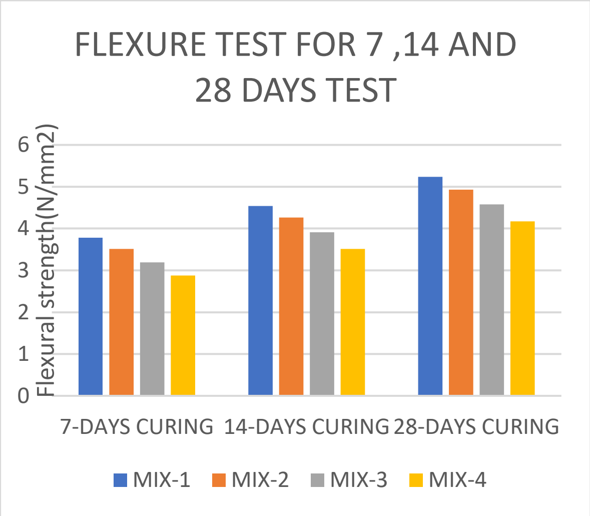

Fig.5.3 Flexure Test for 7,14 and 28 days test

The graph represents the split tensile resistance of four different cementitious compound

Observations:

- Flexural strength **increases** with age for all mixes.
- Higher GGBS replacement leads to **slightly lower early strength** (7 and 14 days).
- **At 28 days**, mixes with GGBS show reasonably good strength, closing the gap with conventional cement.
- **Mix 1** always has the highest strength at every stage.

VI. Summary and Conclusions

6.1 SUMMARY

The study reviewed various journals and literature on the addition of Basalt fibre reinforced bars, the portion of replacementof GGBS, and identified related problems.

Based on the literature survey, the project objectives, scope, and methodology were formulated.

The chosen materials for the project are Ground Granulated Blast Furnace Slag (GGBS) for partial cement replacement and Basalt Fibre Reinforced Polymer (BFRP) rebars for steel rebar replacement in cementitious compound preparation.

Mechanical attributes such as compressive resistance, split tensile resistance, and flexural resistance of the cementitious compound will be tested in this study.

6.2 CONCLUSION:

In this study from the above discussions of hardened attributes, microstructural attributes and flexural behaviour of the cementitious compound the GGBS replaced cementitious compound is examined.

To ensure suitability of fine and coarse aggregates for M50 grade cementitious compound as per Indian Standard (IS) specification, water absorption and sieve analysis tests were performed. The former measures the water retention capacity of aggregates while the latter determines the particle size distribution. The observations showed that both fine and coarse aggregates were of appropriate size and had acceptable water absorption characteristics, indicating their suitability for M50 grade cementitious compound.

By partially replacing cement with 40% GGBS, compressive and split tensile resistance of M50 grade cementitious compound were significantly rised as compared to conventional M50 grade cementitious compound. GGBS reacts with calcium hydroxide in cementitious compound, leading to the formation of additional C-S-H gel which is a key contributor to its resistance. This observations in a denser mix with fewer voids, making it more resistant to tensile and compressive stresses. Additionally, it reduces the formation of cracks in the cementitious compound, observing in a smoother surface finish and improved durability.

Basalt rods provide greater flexibility in M50 grade cementitious compound as compared to steel. This flexibility is beneficial when used in combination with GGBS as it can withstand tension and bending forces in the cementitious compound, leading to a more durable and long-lasting structure.

C-S-H gel in cementitious compound provides significant bearing resistance under compressive loads, which is important for the construction of strong and durable structures capable of withstanding heavy weights and pressures.

Flexural resistance is the ability of cementitious compound to bend or flex without breaking. By using GGBS as a portion of replacement for cementitious compound at 40%, flexural resistance of M50 grade cementitious compound was improved. This can be attributed to the denser and more compact nature of the mix which reduces the formation of voids and improves interlocking of particles.

The design mix was determined to find the optimal combination of materials to achieve desired cementitious compound attributes. The observations showed that replacing 40% of cement with GGBS and adding basalt fibre rods reduced deflection compared to other mixes, making it the most effective combination in reducing bending or sagging of cementitious compound.

Additionally, using GGBS as a portion of replacement for cement in M50 grade cementitious compound reduces carbon dioxide emissions. As cement production is a significant contribute for carbon dioxide emission, using

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