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Experimental Study on Partial Replacement of Cement with GGBS in Ultra High-Performance Concrete

[1]R.Rajeshkumar, [2]A.Manivannan

[1]PG Student, [2]Assistant Professor, Dept. of Civil Engineering, B.S. Abdur Rahman Crescent Institute of Science & Technology, Chennai, India, [1]karthirajesh15@gmail.com , [2]manivannancivil@crescent.education

Abstract **Concrete has become an important aspect of our lives, and its use is rapidly increasing. Portland cement is one of the most important components of concrete. Large amounts of CO_2 are emitted during the cement manufacturing process. The main research the behavior of M30 concrete by partially replacing the cement. This research an experimental study of compressive strength and Split strength test of concrete prepared with Ordinary Portland cement, partially replaced with GGBS in various proportions from 0% to 30%. It is observed from the research that the strength of concrete is inversely proportional to the % replacement of cement with GGBS. It's Concluded that the 10% replacement of cement concrete.**

***Keywords* – Ultra High-Performance Concrete, Ground Granulated Blast Furnace Slag, Compressive Strength Test, Split Tensile Strength Test**

I. INTRODUCTION

Ultra-High Performance of Concrete is an Advanced Concrete material with specifically tailored properties. As normal strength concrete has failed to full fill the workability and durability criteria the development of this UHPC has been introduced in recent decades which provides good mechanical properties and long-term durability with excellent workability. To overcome the problem of a chemical attack, porosity, creep and permeability in the concrete can be reduced by making concrete dense by use of additives and fibre in the concrete with a low water/binder ratio which enhances superior resistance against chemical attack and provide outstanding durability. Hence to achieve the economical Ultra-High-Performance Concrete, the experimental investigation is to be done by using locally available materials with Mineral Admixtures, Steel Fibre, and Super Plasticizers to achieve strength and to study mechanical properties.

A.Role Of GGBS (Ground Granulated Blast Furnace slag)

In combination with standard Portland cement or other pozzolanic materials, GGBS is used to create long-lasting concrete buildings. The reduces heat of hydration and temperature increases, making it easier to avoid cold joints, but it may also affect construction timelines when a rapid setting is necessary.

B.Objective

The Objective of the study is identified as under.

1. The Feasibility of using GGBS as a partial replacement for cement in UHPC.
2. To investigate the effect of partial replacement cement o certain properties of UHPC such as compressive Strength Test and Split Tensile Strength Test.

II. LITERATURE REVIEW

Martin O'Connell, et.al (2012) Concrete is traditionally used as the main component of wastewater facilities. The sulphate and acidic environment present significant challenges. The expansion was not found to be an important parameter in sulfuric acid-based degradation. The 1%sulfuric acid solution (pH _ 1.5) represents the most severe condition that the concrete will encounter in service and the rate of visual deterioration of a 1% solution of sulfuric acid attack greatly exceeded that of a 5% sodium sulfate solution. In actuality, however, actual pH levels may vary depending on time, temperature, and bacterial activity. There was no substantial difference between the cement tested when subjected to sulfuric acid testing, though specimens containing GGBS outperformed all other mixes independent of cement type. It was evident that these concretes cannot adequately address the durability threat to all parts of wastewater infrastructure over a significant life span (e.g. 100 years) due to the extraordinarily harsh nature of this form of attack

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K Sravani Roopa, Ev Raghava Rao (2015) The OPC is one of the main ingredients used for the production of concrete. However, in the context of increased awareness regarding over-exploitation of natural resources to manufacture cement, an eco-friendly technology has to be developed for the effective management of resources. The replacement of natural resources in the manufacture of cement is the present issue in the present construction scenario.

Christina Mary. V, et.al, (2015) This study examines the advantages of GGBS concrete and gives the assurance to those in the construction industry to enable people to use it helpfully. This research studies the characteristics of M40 grade concrete with GBS (replacement of cement by GBS with 10%, 20%, 30%, 40%, and 50%) and M-sand (replacement of natural sand by M-sand with 50%) to evaluate how strength and durability compare to the maximum compressive strength (14-days, 28-days, and 56-days) obtained for the same concrete at (M1)10% Ggbs and 50% M-sand When it came to split tensile strength, a mix containing 10% Gg and 50% M-sand (M1) performed better than concrete containing 50% M-sand (M1). Conventional concrete achieves a 0.85% increase in performance compared to an M1 concrete mix. modern concrete In the study conducted to measure flexural strength, it was found that concrete with 30% Ggbm and 50% M-sand (M3) has the highest flexural strength. When flexural strength is compared to conventional concrete, the flexural strength increase is 75.36 percent greater.

ShambhaviShirur, et.al (2019), The fundamental properties of natural and recycled aggregate have been determined. The mix design was completed to produce a concrete mix (control mix) of grade M40. Recycled aggregates were used to substitute 40, 50, and 60% of the natural aggregates in the mixes. From test results concrete with40 percent and 50 percent replacement of cement with GGBS together with 50 percent replacement of recycled aggregates shows adequate strength compared to the control mix.

Gautham Kishore Reddy G. et. al,(2020) This paper a study on the development of ultra-high performance concrete (UHPC) by incorporating alccofine. Quartz powder, and ground granulated blast furnace slag are used separately along with alccofine and silica fume to design UHPC mixtures. The cumulative values of the UHPC mixture of alccofine and ground granulated blast furnace slag for compressive strength, split tensile strength, and flexural strength are respectively 136.67 MPa, 15.2 MPa, and 31.88 MPa, at 28 days of normal curing. Although coarse aggregates have been used in UHPC, mechanical performance gradually declined while slump values of the concrete improved. The response surface model was used to assess the strength values and validate them against experimental results using statistical and mathematical analysis. The results of this study indicate that UHPC developed by blending alccofine has yielded an overall better performance.

III. MATERIAL PROPERTIES

The material selected and the properties are to be obtained as a fine aggregate by different tests for the glass waste, and the various micro additives are to be performed in the laboratory. Based on properties the mix proportion by weight of each constituent material is also to be discussed for polymer mortar. The mix proportion should be determined based on properties such as void material, void ratio, and fineness modulus.

This section presents the details of the various tests conducted on the materials used in concrete.

- **A.** Cement
- **B.** Water
- **C.** Fine aggregate
- **D.** Coarse aggregate

A. Cement: Ordinary 53-grade Portland cement available on the local market will be used in the investigation. The cement used has been tested in different properties following This is: 4031-1988 and has been verified by different IS: 12269-19888 specifications. Having specific gravity of 3.15

B. Fine Aggregates The sand created requires fines to be graded, physical characteristics such as size, smooth surface textures, and consistency that make it the best sand suitable for construction. These physical properties of sand add extra strength to the concrete by reducing segregation, bleeding, honeycombing, voids, and capillaries. Since manufactured sand (M-Sand) is made from high-quality granite, it has balanced physical and chemical properties which are perfect for the construction of concrete structures. The use of manufactured sand eliminates a need to discard river beds to obtain river sand, which could result in environmental disasters such as groundwater depletion, water shortages, and a hazard to bridge protection.

C. Coarse Aggregates The coarse aggregate of 20 mm size graded confirming to IS: 383 – 1970 is used. The properties of coarse aggregate such as specific gravity and fineness modulus are calculated

PHYSICAL PROPERTIES

- A. Sieve Analysis
- B. Specific Gravity

A. Sieve Analysis The coarse aggregate fineness modulus represents the average size of the particles in the coarse aggregate by an index number. It is measured by sieve analysis using regular sieves. Coarse aggregate is classified

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as the aggregate that is retained after sieving through a 4.75mm sieve.

TABLE 1 Sieve Analysis of Fine Aggregate

S.no	Sieve size	Weight of retained on the sieve	Cumulative mass retained	Cumulative % of Passing %	% of passing
1	4.75 mm	1.2	0.12	0.12	99.88
2	2.36 mm	72.2	73.4	7.34	92.66
3	1.18 mm	553.6	627	62.7	37.3
4	600 µ	180.8	807.8	80.7	19.22
5	300 µ	98.2	9.82	88.6	9.4
6	150 µ	49	955	95.5	4.5
7	Pan	45	4.5	100	0

TABLE 2 Sieve Analysis of Coarse Aggregate

S.no	Sieve size	Weight of retained on the sieve	%Weight retained (%)	% weight passing (%)	Cumulative % retained (%)
1	40 mm	0	0	0	100
2	20 mm	1310	1310	65.5	34.5
3.	12.5 mm	615	1925	96.25	3.75
4	10 mm	39	1964	98.2	1.8
5	6.3 mm	10.5	1974.5	98.725	1.275
6	Pan	25.5	2000	100	0

B. Specific Gravity

TABLE 3 Specific Gravity Test

Description	Specific Gravity
Cement	3.15
Fine Aggregates	2.5
Coarse Aggregates 20mm	2.7
GGBS	2.6

IV. RESULT & DISCUSSION

The mechanical properties such as compression, and split tensile were conducted on the casted specimens.

A. Compressive Strength Test
B. Spilt Tension Strength Test

TABLE 4 Strength of Conventional Concrete

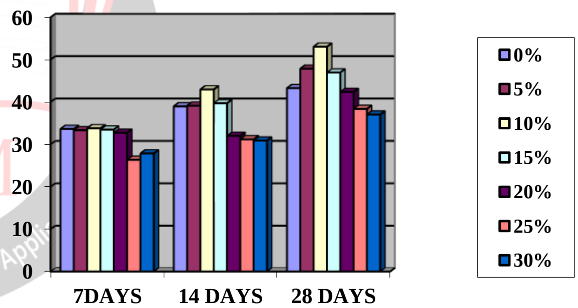
Days	Compressive Strength (mpa)	Split Tensile Strength (mpa)
7 Days	33.63	5.22
14 Days	38.96	5.63
28 Days	43.26	5.92

A. Compressive Strength Test The tests on concrete under compression are conducted on the concrete cube of size 150x150x150mm prepared following IS 516-1959 at 7,14 and 28 days using a compression testing machine.

TABLE 5 Compressive Strength Test of Concrete at 7,14, and 28 Days

S.No	Percentage of GGBS	Compressive Strength Test @ 7 days (N/mm^2)	Compressive Strength Test @ 14 days (N/mm^2)	Compressive Strength Test @ 28 days (N/mm^2)
1	Replacement cement with GGBS 5 %	33.33	39.11	47.85
2	Replacement cement with GGBS10 %	33.78	42.96	53.04
3	Replacement cement with GGBS 15 %	33.48	39.70	46.96
4	Replacement cement with GGBS 20 %	32.19	32.00	42.37
5	Replacement cement with GGBS 25 %	26.19	31.19	38.37
6	Replacement cement with GGBS 30 %	27.85	30.89	37.04

Graph 1 Compressive Strength Test 7,14, and 28 Days



The results on the variation of compressive strength test of concrete concerning the age of Concrete for different percentage of replacement cement with GGBS and a constant percentage as cementitious material is shown in the graph.

1. Comparing all the compressive strength tests of Replacement of cement with GGBS with the Conventional Concrete after 7 days, it is concluded that the compressive strength test of
   - Replacement of cement with GGBS 5 % 33.33 (mpa) less than the Conventional Concrete.
   - Replacement of cement with GGBS 10 % 33.73(mpa) less than Conventional Concrete.
   - Replacement of cement with GGBS 15 % 33.48(mpa) less than the Conventional Concrete.
   - Replacement of cement with GGBS 20 % 32.00(mpa) less than the Conventional Concrete.

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- Replacement of cement with GGBS 25 % 26.37(mpa) less than Conventional Concrete.
- Replacement of cement with GGBS 30 % 27.85(mpa) less than Conventional Concrete.

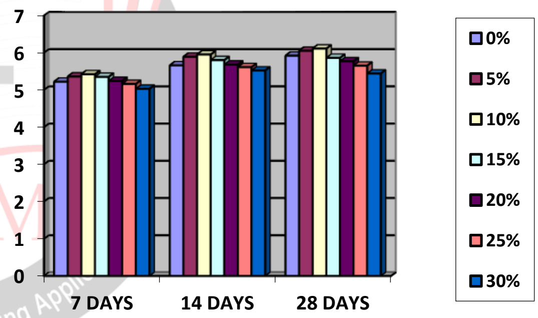
2. Replacement of Cement with GGBS 10 % has the maximum compressive value of 7 days of curing. (i.e 33.78 (mpa) of the Conventional concrete)
3. Replacement of cement with GGBS 25% has the minimum value after 7 Days of Curing. (i.e 26.37 (mpa) of the Conventional Concrete)
4. Replacement of cement with GGBS 25 % has the least compressive value on the 7th day and the maximum strength on the 14th day
5. Comparing all the compressive strength of Replacement of Cement with GGBS with Conventional Concrete after 14 days.
   - Replacement of cement with GGBS 5 % 39.11 (mpa) less than the Conventional Concrete.
   - Replacement of cement with GGBS 10 % 42.96 (mpa) less than Conventional Concrete.
   - Replacement of cement with GGBS 15 % 39.70 (mpa) less than Conventional Concrete.
   - Replacement of cement with GGBS 20 % 38.14 (mpa) less than Conventional Concrete.
   - Replacement of cement with GGBS 25 % 37.19 (mpa) less than the Conventional Concrete.
   - Replacement of cement with GGBS 30 % 36.89 (mpa) less than the Conventional Concrete.
6. Replacement cement with GGBS 30 % has the least compressive value on the 7th,14th day and the maximum strength on the 28th day.
7. Comparing all the compressive strength Tests of Replacement cement with GGBS with the Replacement cement with GGBS after 28 days.
   - Replacement cement with GGBS 5 % 47.85 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 10 % 53.04 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 15 % 46.96 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 20 % 42.37 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 25 % 38.37 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 25 % 38.37 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 30 % 37.04 (mpa) less than the Conventional Concrete.
8. Replacement cement with GGBS 10 % has the compressive strength test valve after 28 days curing (i.e.53.04 (mpa) of the Conventional concrete).
9. Replacement cement with GGBS 30 % has the compressive strength test value after 28 days curing (i.e 37.04 (mpa) of the Conventional concrete).

B.Split Tensile Strength Test The test on concrete under split tension is conducted in the concrete cylinder of size 200mm depth and 100mm diameter

TABLE 6 Split Tensile Strength Test t of Concrete at 7,14,and 28 Days

S.No	Percentage of GGBS	Split Tensile Strength Test @ 7 days (N/mm^2)	Split Tensile Strength Test @ 14 days (N/mm^2)	Split Tensile Strength Test @ 28 days (N/mm^2)
1	Replacement cement with GGBS 5 %	5.37	5.77	6.05
2	Replacement cement with GGBS10 %	5.44	5.84	6.11
3	Replacement cement with GGBS 15 %	5.35	5.69	5.86
4	Replacement cement with GGBS 20 %	5.24	5.58	5.77
5	Replacement cement with GGBS 25 %	5.16	5.46	5.65
6	Replacement cement with GGBS 30 %	5.03	5.41	5.44

Graph 2 Split Tensile Strength Test 7,14, & 28 Days



The results on the variation of Split Tensile Strength Test of concrete concerning the age of concrete for different percentages of replacement cement with GGBS and a constant percentage as cementitious material is shown in the graph.

1. Comparing all the Split Tensile Strength Test of Replacement cement with GGBS with the Conventional concrete after 7 days, it is concluded that the Split Tensile Strength Test of
   - Replacement cement with GGBS 5 % 5.37 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 10 % 5.44 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 15 % 5.35 (mpa) less than the Conventional Concrete.

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- Replacement cement with GGBS 20 % 5.27 (mpa) less than the Conventional Concrete.
- Replacement cement with GGBS 25 % 5.16 (mpa) less than the Conventional Concrete.
- Replacement cement with GGBS 30 % 5.12 (mpa) less than the Conventional Concrete.

2. Replacement cement with GGBS 10% has the maximum Split Tensile Strength Test value after 7 days of curing. (i.e.5.44 (mpa) of the Conventional Concrete).
3. Replacement cement with GGBS 30 % has the minimum value after 7 days of curing. (i.e. 5.16 (mpa)of the Conventional Concrete).
4. Replacement cement with GGBS 25 % has the least Split Tensile Strength Test value on the 7th day and the maximum strength on the 14th day.
5. Comparing the Split Tensile Strength Test of Replacement cement with GGBS with the Replacement cement with GGBS after 14 days.
   - Replacement cement with GGBS 5 % 5.77 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 10 % 5.84 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 15 % 5.69 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 20 % 5.58 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 25 % 5.46 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 30 % 5.41(mpa) less than Conventional Concrete.
6. Replacement cement with GGBS 30 % has the least Split Tensile Strength Test value between the 7th,14th days and the maximum strength on the 28th day.
7. Comparing all the Split Tensile Strength Test of Replacement cement with GGBS with the Replacement cement with GGBS after 28 days.
   - Replacement cement with GGBS 5 % 6.05 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 10 % 6.11 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 15 % 5.86 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 20 % 5.77 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 25 % 5.64 (mpa) less than the Conventional Concrete.
   - Replacement cement with GGBS 30 % 5.44 (mpa) less than the Conventional Concrete.
8. Replacement cement with GGBS 10 % has the Split Tensile Strength Test valve after 28 days curing (i.e.6.11 (mpa) of the Conventional concrete).
9. Replacement cement with GGBS 30 % has the Split Tensile Strength Test value after 28 days curing (i.e 5.44 (mpa) of the Conventional concrete).

V. CONCLUSION

From the above, the study Concludes using GGBS of utilization in construction. The Influence of partial replacement of GGBS on Fresh hardened Concrete mixes is experimentally Investigated. From the experimental data obtained during this research, the following conclusion and recommendations can be drawn.

Compression Strength Test

- For 7 days replacement cement with ggbs 10% has the maximum strength than all the other mixes with 33.78 (mpa) less than the conventional concrete and for 28 days replacement has the maximum strength with 26.37 (mpa) greater than the conventional concrete
- According to the test result after 7 days, the strength increases proportionally with the increase of the amount of replaced ggbs presented in the concrete
- For 14,28 days replacement cement with ggbs with 33.78 (mpa) greater than the conventional concrete
- It is concluded that attained compressive strength of concrete replacement of cement with ggbs 15% & 20% are appreciable and the results are nearly the same when compared to the conventional concrete

Split Tensile Strength Test

- For 7 days Replacement cement with GGBS 10% has the maximum Split Tensile value with 5.44 (mpa) of the Conventional concrete and for 14, 28 days Replacement cement with GGBS 30 % has the maximum Split Tensile value with 5.12 (mpa) of the Conventional concrete
- The 14th,28th day's Split Tensile strength of both the Replacement cement with GGBS 15 % & 20% are less than that of the 7thday's values, which means the strength may reduce as its age increases.

The results presented in this paper within the limited study of the structural grade concrete can be produced using a mixed proportion of GGBS as a partial replacement.

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