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An Experimental Investigation on Strength Properties of Concrete Using Waste Materials as a Partial Replacement of OPC

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Abstract:

One of the most crucial parts of the construction industry is concrete and cement is the most important component of this concrete but massive amounts of carbon dioxide (CO_2) gas are released into the atmosphere during cement production, contributing significantly to the greenhouse effect and global warming. It is impossible to stop the use of cement completely but it is possible to partially replace the cement with other materials. In this research, cement was partially replaced with waste materials such as groundgranulated blast furnaceslag (GGBS) and fly ash in different percentages (0%, 10%, 20%, 30%, 40%, and 50%). The mix design was done for the M30 grade of concrete. To investigate the strength properties in this study, compressive and split tensile strength were tested on concrete. It is concluded that GGBS and fly ash concrete mix showed significantly more compressive strength and split tensile strength than control concrete mix.

Keywords **—**Ground Granulated Blast Furnace Slag, Fly Ash, Ordinary Portland Cement, Compressive Strength, Split Tensile Strength, Concrete, Replacement, Carbon Dioxide.

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I. INTRODUCTION

1.1 General

The most widely utilized human-made construction material on the planet is concrete. It is a construction material determined of cement, fine aggregate (sand), and coarse aggregates mixed with water which hardens with time. Concrete is a construction material that gains strength over time. Concrete is a long-lasting material. It prevents weathering, erosion, and natural disasters, needs few repairs, and little maintenance, adding up to a solid investment.

At this time, we need to reduce cement production and find some alternatives to cement because the cement industry is one of the main producers of carbon dioxide (CO_2). To reduce the production of cement, some pozzolanic materials that can be used in concrete as a partial replacement for cement include fly ash, groundgranulated blastfurnace slag(GGBS), metakaolin,rice husk ash, silica fume, and glass powder.GGBS and fly ash are waste products obtained by the steel and coal industries, respectively.

1.2 Advantage of GGBS

For its advantage in concrete durability, GGBS has been widely used in Europe, and increasingly in North America and Asia, extending the lifespan of structures from fifty to a hundred years. The use of GGBS minimizes the risk of alkali-silica reaction (ASR) damage, increases resistance to chloride intrusion, lowering the risk of reinforcement corrosion, and increases resistance tosulfate and other chemical attacks. GGBS can be used as a substitute for cement, lowering construction costs and reducing cement use. The use of industrial waste products helps to protect the environment and natural resources.

1.3 Advantage of Fly Ash

The strength and durability of hardened concrete are improved, when fly ash is combined with conventional cement. Fly ash use in concrete improves the workability of concrete. It reduces the problem of cracks, permeability, and bleeding in concrete. It also reduces the heat of hydration.Using it has various advantages, including reduced cost of concrete, increased resistance to sulfate attack, resistance to alkali-silica reaction, and reduced carbon dioxide emission.

1.4 Objective

1. To determine the strength properties of concrete using GGBS and fly ash as a partial replacement with cement.
2. To compare between control concrete mix and concrete with GGBS and fly ash mix.

II. METERIAL USED

2.1 Cement

Ordinary portland cement (OPC), 53 grade was used for this experiment. It was confirmed by IS 12269:1987. The cement used was new and free of lumps.The specific gravity of cement used was 3.15.

2.2Fine Aggregate

If aggregates pass through 4.745 mm grade and retain on 75-micron sieve then they are called fine aggregates. Locally available river sand was used for this research work. It was used in this experiment is locally available river sand which conforms to zone II as per IS 383:1970. The specific gravity of fine aggregate used was 2.67.

2.3Coarse Aggregate:

If aggregate remain on 4.75 mm sieve, then they are called coarse aggregates. Crushed granite of 20 mm maximum size was used as coarse aggregate. The specific gravity of coarse aggregate used was 2.70.

2.4 Water

The water used in the research was potable water, as specified by IS 456:2000. The water was clear and free of obvious contaminants.

2.5 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag (GGBS) is an environmentally friendly product and made from a by-product of iron manufacturing.The specific gravity of ground granulated blast furnace slag used was 2.88.

2.6 Fly Ash

Fly ash (FA) is a fine powder that is a by-product of burning pulverized coal in electric generation power plants. Class F fly ash was used for this investigation.The specific gravity of fly ash used was 2.00.

III. EXPERIMENTAL PROGRAMS

3.1 Mix Proportioning of Concrete

In this experiment, the M30 grade of concrete was designed as per IS 10262:2009. Following obtaining the proportions of concrete, the trial mix was determined to be 1:1.45:2.5 for a water-cement ratio of 0.45. The results of the mix design of the concrete are shown in table 1.0.In this experimental study, total of six concrete mixes was investigated. In this experimental study, a total of six concrete mixes was investigated. One was control concrete mix (0%), and the other five were GGBS and fly ash concrete mixes. Cement was partially replaced by 5%, 10%, 15 %, 20 %, and 25 % GGBS and fly ash by weight basis.The details of concrete mix designation are given in table 2.0.

Table 1.0: Mix Specification for 1 m^3 Control Concrete

Cement (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)
438	636	1095	197
1	1.45	2.5	0.45

Table 2.0: Mix Designation of Concrete

Mix Designation	Description
M0	100% OPC
M10	90% OPC + 7.5% GGBS +2.5% FA
M20	80% OPC + 15% GGBS + 5% FA
M30	70% OPC + 22.5% GGBS + 7.5% FA
M40	60% OPC + 30% GGBS + 10% FA
M50	50% OPC + 37.5% GGBS + 12.5% FA

3.2 Test Procedure

The 54 concrete cubes and 54concrete cylinders specimen were made. All the concrete specimens were properly cured in clean water for 7, 14, and 28 days.The Compressive strength and split tensile strength were tested after all specimens were cured for 7, 14, and 28 days.The compressive strength test was done as per IS 516:1959 and the split tensile strength test was as per IS 5816:1999.All the concrete specimens were tested in a universal testing machine (UTM).

IV. RESULTS & DISSCUTIONS

4.1 Compressive Strength

The outcomes of the compressive strength of concrete are shown in table 3.0 and the effects of replacement on overall compressive strength are shown in graphical form in figure 4.0.

Table 3.0: Compressive strength of Concrete (N/mm^2)

Mix Designation	7 Days	14 Days	28 Days
M0	24.11	29.80	33.90
M10	26.85	31.14	38.20
M20	24.66	28.96	37.56
M30	22.32	26.17	35.30
M40	19.15	23.75	32.87
M50	16.37	21.14	28.30

4.1.1 Discussion on 7 Days Compressive Strength When the cement was substituted with GGBS and fly ash by 10% (M10), the maximum strength increase on the 7 days was 26.85 N/mm^2. It has higher compressive strength than the control concrete mix. Theoutcomes of compressive strength at 7 days are shown in graphical form in figure 1.0.

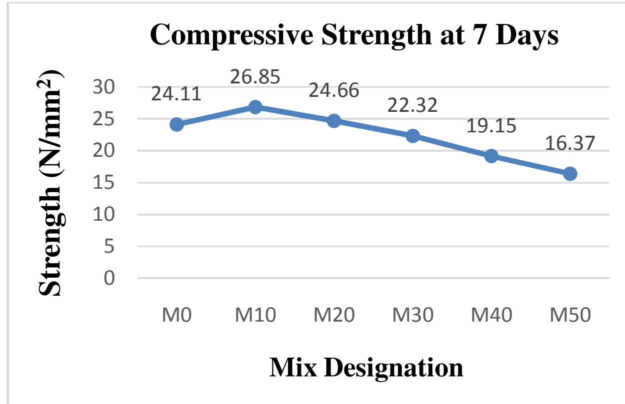

Figure 1.0: Compressive Strength at 7 Days

4.1.2 Discussion on 14 Days Compressive Strength

When the cement was substituted with GGBS and fly ash by 10% (M10), the maximum strength increase on the 14 days was 31.14 N/mm^2. It has higher compressive strength than the control concrete mix. The outcomes ofcompressive strength at 7 days are shown in graphical form in figure 2.0.

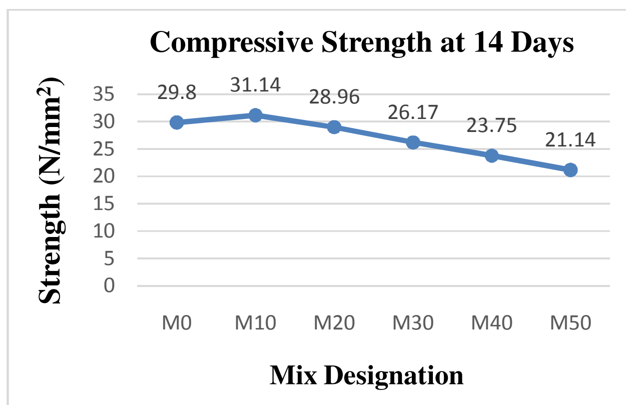

Figure 2.0: Compressive Strength at 14 Days

4.1.3 Discussion on 28 Days Compressive Strength

When the cement was substituted with GGBS and fly ash by 10% (M10), the maximum strength increase on the 28 days was 38.20 N/mm^2. It has higher compressive strength than the control concrete mix. The outcomes ofcompressive strength at 7 days are shown in graphical form in figure 3.0.

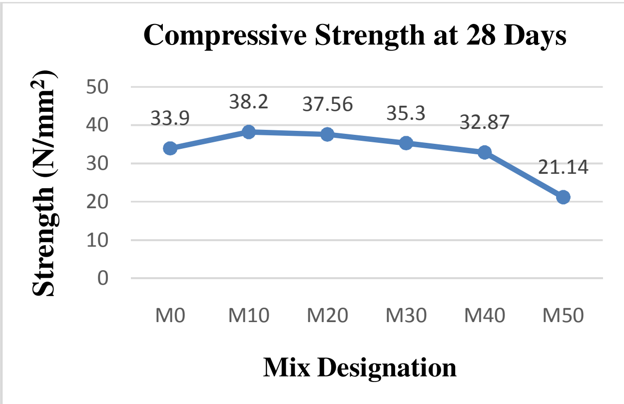

Figure 3.0: Compressive Strength at 28 Days

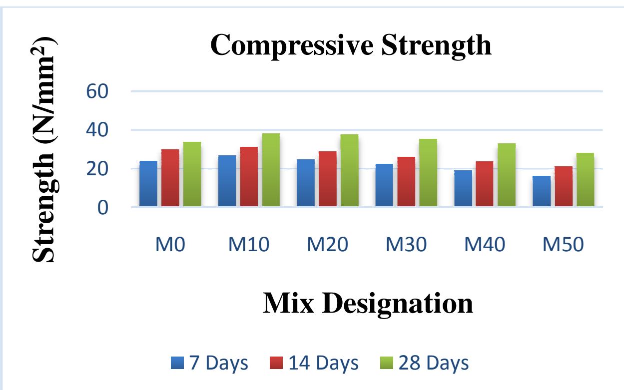

Figure 4.0: Effect of Replacement on Compressive Strength

4.2 Split Tensile Strength

The outcomes of the split tensile strength of concrete are shown in table 4.0 and the effects of replacement on overall compressive strength are shown in graphical form in figure 8.0.

Table 4.0: Split Tensile strength of Concrete (N/mm^2)

Mix Designation	7 Days	14 Days	28 Days
M0	2.48	2.99	3.42
M10	2.71	3.24	3.83
M20	2.52	2.93	3.81
M30	2.38	2.68	3.55
M40	2.12	2.40	3.36
M50	1.75	2.18	2.86

4.2.1 Discussion on 7 Days Split Tensile Strength

When the cement was substituted with GGBS and fly ash by 10% (M10), the maximum strength increase on the 7 days was 2.71 N/mm^2. It has higher split tensile strength than the control concrete mix. Theoutcomes of split tensile strengths at 7 days are shown in graphical form in figure 5.0.

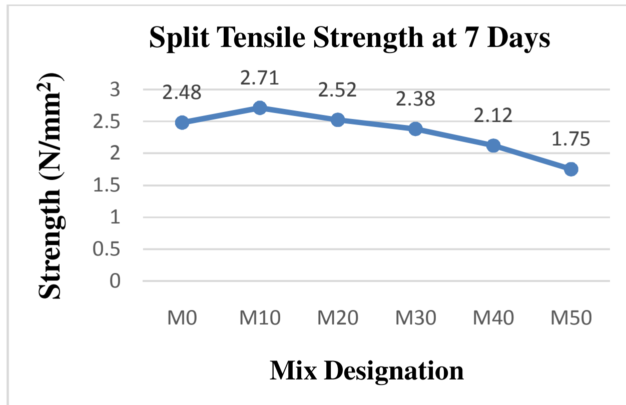

Figure 5.0: Split Tensile Strength at 7 Days

4.2.2 Discussion on 14 Days Split Tensile Strength

When the cement was substituted with GGBS and fly ash by 10% (M10), the maximum strength increase on the 14 days was 3.24 N/mm^2. It has higher split tensile strength than the control concrete mix. The outcomes ofsplit tensile strengths at 14 days are shown in graphical form in figure 6.0.

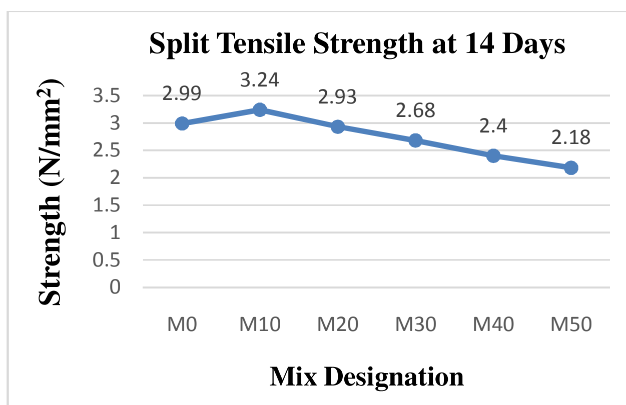

Figure 6.0: Split Tensile Strength at 14 Days

4.2.3 Discussion on 28 Days Split Tensile Strength

When the cement was substituted with

GGBS and fly ash by 10% (M10), the maximum strength increase on the 14 days was 3.24 N/mm^2. It has higher split tensile strength than the control concrete mix. Theoutcomes of split tensile strengths at 28 days are shown in graphical form in figure 7.0.

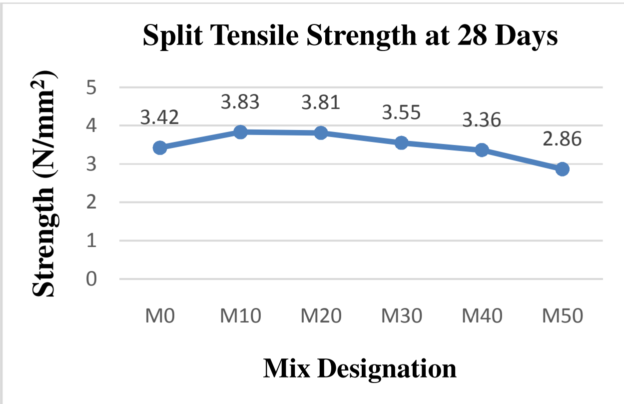

Figure 7.0: Split Tensile Strength at 28 Days

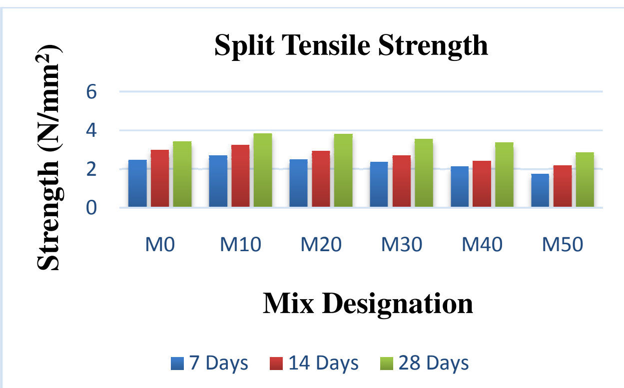

Figure 8.0: Effect of Replacement on Split Tensile Strength

V. CONCLUSIONS

The investigation yielded the following conclusions:

1. When cement was replaced with GGBS and fly ash, the compressive strength of concrete is enhanced. At 10% replacement, the compressive strength reaches its maximum.

2. When cement was replaced with GGBS and fly ash, the split tensile strength of concrete is enhanced. At 10% replacement, the split tensile strength reaches its maximum.
3. The compressive strength of GGBS and fly ash concrete was higher than that of conventional concrete until 30% cement replacement.

4. The split tensile strength of GGBS and fly ash concrete was higher than that of conventional concrete until 30% cement replacement.

5. The compressive strength of GGBS and fly ash concrete was above 30 N/mm^2 till 40% cement replacement.

6. The GGBS and fly ash-based concrete contributes to pollution reduction (lower CO_2 emissions) and conservation of natural resources.
7. From this research demonstrated, GGBS and fly ash are the ideal waste materials for partial replacement with cement.

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