UTILIZATION OF FLY ASH AND GGBS IN CONCRETE

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Abstract

The rapid development and industrialization in countries like India have led to a surge in concrete usage, resulting in significant solid waste generation. This study proposes the utilization of recycled waste materials, including fly ash, recycled concrete, and ground granulated blast furnace slag (GGBS), as partial substitutes for traditional concrete ingredients. Specifically, Portland cement (PC) is partially replaced with 20% fly ash and varying percentages (10-25%) of GGBS to reduce environmental impact and production costs.

The research aims to investigate the fresh and hardened properties of M30 concrete, including workability, compressive strength, and split tensile tests, in comparison with conventional concrete. Through the integration of recycled waste materials, this study seeks to promote sustainable construction practices and address the challenges of solid waste management and carbon emissions in concrete production within rapidly developing nations.

Keyword: Fly ash, GGBS, Portland cement, Carbon emission, Workability, Compressive, Split tensile.

1.0 INTRODUCTION

Concrete is a super important material in construction because it's strong and easy to find everywhere. People are now looking into ways to make concrete even better while also being kinder to the environment and saving money. One cool idea is to swap out some of the regular cement with materials like fly ash and GGBS (Ground Granulated Blast Furnace Slag).

Fly ash and GGBS are leftovers from industries, so they're eco-friendly options for replacing cement in concrete mixes. When we use fly ash and GGBS instead of only cement, we can cut down on carbon emissions and energy used during concrete production. These materials also bring special qualities to the mix, like making the concrete more durable, stronger, and easier to work with studies have proven that mixing fly ash and GGBS with cement can make concrete better in terms of strength and durability. By adjusting how much fly ash and GGBS we add to the mix, engineers and researchers can create concrete that performs just the way they want it to. This approach helps in creating sustainable buildings and meeting the demand for top-notch materials that are also good for the environment.

Using fly ash and GGBS in concrete not only helps in making construction projects eco-friendly but also supports the idea of recycling industrial waste. As the construction industry focuses more on being sustainable and innovative, experimenting with materials like fly ash and GGBS is key to making stronger, greener, and longer-lasting concrete structures.

Statement of the Problem:

The inconsistent quality and characteristics of fly ash and GGBS pose challenges in achieving predictable concrete performance, including variations in strength, setting time, and durability, thus hindering widespread adoption and confidence in their utilization as supplementary cementitious materials.

The Project Objectives:

- To compare the strength parameter with conventional concrete.
- To study the strength parameters of concrete.
- To increase the strength of concrete.
- To find out durability of concrete with GGBS and Fly ash.
- To study the fresh and hardened properties of concrete.

2.0 LITERATURE REVIEW

Anamika Agnihotri, P.V. Ramana (2022):

They determined the behaviour of concrete in the form of an adhesive made with activated silicon and aluminium in a highly alkaline solution is investigated in this study. Research on concrete based on low calcium fly ash is widely used. The fly ash with high calcium content can also be suitable as a base material for producing geopolymer. In this investigation, the exact ideal substitution amount of GGBS: Fly Ash for PPC concrete mix was determined to be 60:40. For different sodium hydroxide and sodium silicate chemical ratios in the concrete mix, different results were produced. This research adds to our understanding of the performance of various strength concretes and GGBS as partial cement substitutes. Mechanical strength and durability properties and acid attack were discovered in the GGBS and Fly Ash concrete mix. Sodium Silicate and sodium hydroxide have been discovered to affect various combinations as well as strength and durability.

Varun B.K, Harish B.A (2018):

In the experiment they have used fly ash and GGBS as a partial replacement of cement. The main aim of the work is to study the fresh and hardened properties of M-30 grade control concrete and concrete made with partial replacement of fly ash and GGBS with various percentages. To study the fresh properties slump test, compaction factor test and Vee-bee tests are conducted. To study hardened properties compressive and splitting tensile strength tests are conducted.

Azmat Ali, Muhammad Jaffer, S N R Shah, Abdul Razzaque (2019):

In this they have studied the Compressive strength of concrete with Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash in concrete by partial replacement of cement. The incremental demand of cement in the construction field is a concern for environmental degradation, in this regard; replacement of cement is carried out with waste materials by using GGBS and Fly Ash. On optimum level of GGBS and Fly Ash was assessed with varied percentage from 0 to 30% for different curing days. Replaced concrete were tested with the slump, compaction factor, Vee-bee and compressive strength. Cement to water ratio was maintained at 0.47 for all
mixes. The compressive strength tests were conducted for 3, 7, 14 and 28 days of curing on a M_{25} grade concrete.

Ganesan Nagalingam and Ramesh Babu Chokkalingam (2020):

They have studied the effect of Fly ash and Ground Granulated Blast Furnace Slag (GGBS) on the mechanical properties of Geopolymer concrete at different replacement levels of GGBS by fly ash from 0 to 25% with 5% variation. From previous researches on Geopolymer concrete, an optimized mix is identified for testing mechanical behaviour. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) of 12 Molarity is used as activator solution in the ratio of 1:2.5. A carboxylic based admixture called La Hypercrete S25 is added in the mix by 1% of the weight of GGBS for increasing the workability of Geopolymer concrete. Cubes of 100mm size are cast for determining the compression strength behaviour. Cylinders of 100mm dia and 200mm height are cast for splitting tensile strength and beams of size 500mm length with 100mm x 100mm cross section are cast for flexural strength. The specimens are cured at ambient temperature and tested on 7 and 28 days.

3.0 MATERIALS AND METHODS

Materials used:

Cement:

Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269. The specific gravity of cement is 3.15. Cementis an extremely ground material having adhesive and cohesive properties which provide a binding medium for the discrete ingredients. Chemically cement constitutes 60-67% Lime (CaO), 17-25% Silica (SiO_2), 3-8% Alumina (Al_2O_3), 0.5- 6% Iron Oxide (Fe_2O_3), 0.1-6% Magnesia (MgO), 1-3% Sulphur Trioxide (SO_3), 0.5- 3% Soda and Potassium (Na_2O+K_2O).

Fig: Cement

Fly ash:

Fly ash is a by-product of electric power generation that varies from source to source. Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3)

and calcium oxide (Cao) the main mineral compounds in coal-bearing rock strata. There are two types of fly ash (class f &class c). In this experiment, class F fly ash is used as binder material.

Fig: Fly ash

Ground Granulated Blast Furnace Slag (GGBS):
GGBS is obtained by quenching molten iron blast furnace slag in water or Steam, to produce a glassy granular product that is then dried and ground into a fine powder. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production, the flux consists mostly of a mixture of limestone.

Fig: Ground Granulated Blast Furnace Slag (GGBS)

Fine Aggregate: Fine Aggregate used for the project work was River sand should be taken as per the ASTM standard. It should be clean, strong and hard and free of organic impurity. Specific gravity of fine aggregate was 2.74. It confirming to grading zone II with Particles in between 4.75 mm and 150 µm.

FIG: Fine aggregate

Coarse Aggregate: Crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity, and bulk density in accordance with IS: 2386 1963. The individual aggregates were mixed to induce the required combined grading.

Fig: Coarse aggregate

Mix Proportion of the Cellular Lightweight Concrete:

The Mix Proportion for conventional concrete M30 grade arrived as per IS 10262-2009. This Mix proportion of conventional concrete was taken as reference to the Fly ash and GGBS by making partial replacement of Fine aggregate.

- The Specific gravity of cement: 3
- The Specific Gravity of fine aggregate: 2.46

For the Concrete we are replacing fly ash is constant 20% and GGBS varying 10%, 15%,20%,25 in Fine aggregate.

Table: Mix Proportion of the Concrete

Water	Cement	Fine Aggregate	Coarse Aggregate
191.58 Kg/m^3	510.88 Kg/m^3	501.75 Kg/m^3	934.68 Kg/m^3
0.375	**1**	**0.98**	**1.8**

Procedure:

Batching and mixing:

Collection of required materials like fly ash & GGBS and etc., all the materials are weighed with the help of electronic weight balance. The batching was done as per the mix proportion. First, we will mix all the dry materials properly cement, sand, coarse aggregate, fly ash and GGBS. Mix uniformly by adding water to the dry material make sure that lumps should not form and while batching it consumes lot of water due to heat the concrete will too harden in less time. So, the mixing should be done properly in less time.

Placing and compacting:

In this stage we will place the fresh concrete in to moulds. Before placing this fresh concrete in to moulds the moulds should be cleaned and kept oil/grease to the mould. Because to prevent the formation of bonds between concrete and moulds. The fresh concrete is filled in three layers with hand compaction at least 25 blows after adding each layer. After completion of compaction the excess motor is removed with the help of trowel and the surface is levelled.

Demoulding and curing:

After placing the concrete in to moulds. It is allowed to set for 24 hours at room temperature. After setting of the concrete then it is demoulded. the samples are weighted and marked with the help of permanent marker and then the samples are kept in to curing tank for a period of 7 days, 14 days, 2 days, after these days the concrete samples are removed from the curing tank for the purpose of testing the harden concrete.

Fig: Demoulding

4.0 TEST RESULTS AND ANALYSIS

Slump test:

In general, it was observed that workability of a concrete mix increased on addition of fly ash and GGBS. Workability of the mixes was observed to increase with increase in percentage replacement of cement with fly ash and GGBS (as a partial replacement of cement)

Slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the simplest workability test for concrete.

As per IS: 456 the degree of workability is classified as follows

Degree of Workability	Slump
Very low	0 – 25 mm
Low	25 – 50 mm
Medium	50 – 100 mm
High	100 – 175mm
Very high	>175

Fig: Slump Cone Test on Fresh Concrete

Table: Slump Cone Test Values

S. No	% of replacement of Fly Ash	% of Replacement of GGBS	Slump Value in MM
1	20%	10%	98
2	20%	15%	102
3	20%	20%	109
4	20%	25%	105

Compaction factor test:

The Compaction factor test is another method used to find out the workability of fresh concrete. It is more accurate than the slump test from the values obtained it is clear that the workability of concrete increases with the percentage of fly ash and GGBS increases.

Fig: Compaction Factor Test on the Fresh Concrete

Table: Compaction Factor Value

S. No	Grade of Concrete	Compaction Factor
1	M30	0.94

Compression Strength Test Results:

The compression test was conducted according to IS 516-1959. This test helps us in determining the compressive strength of the concrete cubes. The obtained value of compressivestrength can then be used to assess whether the given batch of that concrete cube will meet therequired compressive strength requirements or not. For the compression test, the specimen's cubes of 15 cm x 15 cm x 15 cm were prepared by using crumb rubber concrete as explained earlier. These specimens were tested under universal testing machine after 7 days and 28 daysof curing. Load was applied gradually at the rate of 140kg/cm2 per minute till the specimens failed. Load at the failure was divided by area of specimen and this gave us the compressive strength of concrete for the given sample.

7 Days Compression Strength:

Table: 7 Days Compressive strength of Cube

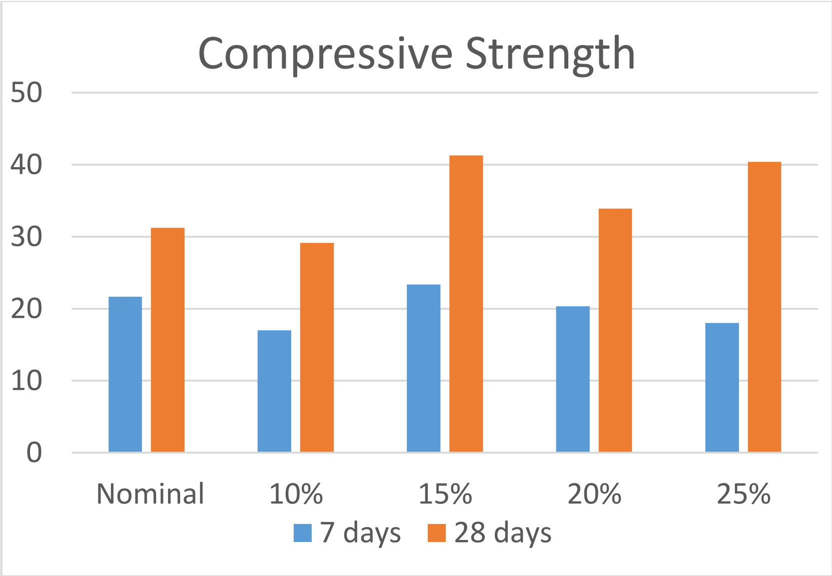
S. No	FLY ASH %	GGBS %	Load (KN)			Avg Compressive strength (KN/m^2)
			Cube 1	Cube 2	Cube 3	
1	0%	0%	390	550	520	21.69
2	20%	10%	380	340	430	17.02
3	20%	15%	600	580	400	23.37
4	20%	20%	625	250	500	20.35
5	20%	25%	420	390	410	18.04

- ## 28 Days Compression Strength:

Table: 28 Days Compressive strength of Cube

S. No	FLY ASH %	GGBS %	Load (KN)			Avg Compressive strength (KN/m^2)
			Cube 1	Cube 2	Cube 3	
1	0%	0%	630	480	1000	31.24
2	20%	10%	680	450	840	29.15
3	20%	15%	880	970	940	41.3
4	20%	20%	740	700	850	33.91
5	20%	25%	870	960	910	40.4

Fig: Compression Strength test



Graph of Compressive Strength of concrete

Split Tensile Strength Test Results:

The split tensile strength at which failure occurs is the tensile strength of concrete. In this Investigation the test is carried out on cylinder by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edges as per IS: 516-1959.

- **7 Days Split Tensile Strength:**

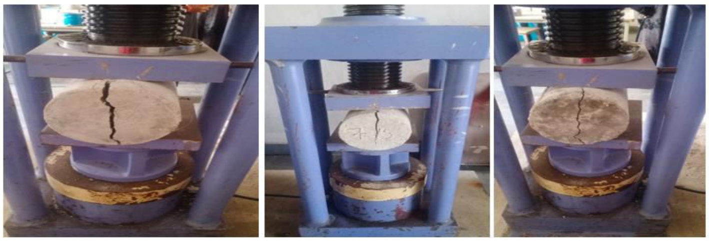
Table: 7 Days Split Tensile Strength of Cylinder

S. No	Fly ash %	GGBS %	Tensile Strength (N/mm^2)
1	0	0%	4.1
2	20	10%	3.25
3	20	15%	3.11
4	20	20%	2.82
5	20	25%	2.82

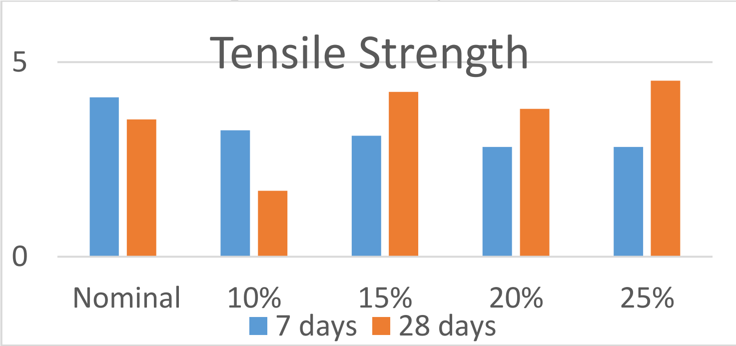
- **28 Days Split tensile Strength:**

Table: 28 Days Split tensile Strength of Cylinder

S. No	Fly ash %	GGBS %	Tensile Strength (N/mm^2)
1	0%	0%	3.53
2	20%	10%	1.69
3	20%	15%	4.24
4	20%	20%	3.8
5	20%	25%	4.52



Split Tensile Strength Test



Graph of Split Tensile Strength of the Concrete

CONCLUSION

- Based on current project, it can be concluded that the use of fly ash and GGBS as a partial replacement for cement can improve the strength and durability of concrete.
- The concrete mixed with the different percentages of fly ash and GGBS shows more workability than conventional concrete due to finely divided good quality of fly ash and granulated particle shape of slag.
- The concrete mixed with Fly ash and GGBS results in more compressive strength than conventional concrete due to the pozzolanic activities of fly ash and GGBS.
- The concrete mix with fly ash and GGBS results in more split tensile strength than conventional concrete. This is because of the increased dense of concrete mix due to the pozzolanic activity of fly ash.
- Maximum and minimum compressive strength after 7 days and 28 days is obtained with fly ash and GGBS (20%+15%) and fly ash and GGBS (20%+10%) respectively.

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