



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 2, February 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

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Use of Industrial by-product to Produce Eco Friendly Geopolymer Concrete

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ABSTRACT: Concrete is one of the most widely used construction materials. The global use of cement concrete is second only to the use of water. The demand for concrete as a construction material is increasing day to day. The production process of cement releases some harmful substances, which adversely affect the environment. Design and experimental investigation on development of geopolymer concrete is important because increase in use of geopolymer concrete leads to reduction in use of regular cement concrete and ultimately production of cement. Also, the fly ash and ground granulated blast furnace slag is used and the problem of dumping of these materials ultimately gets solved.

In this experimental research cement is totally replaced by use of fly ash and ground granulated blast furnace slag (GGBS), and activated by use of Alkali Activated Solution to form a cementitious paste. From the experimental work it is observed that the geopolymer concrete with use of 40% fly ash and 60% GGBS gives 35% more strength than target strength

KEYWORDS: Fly ash, Ground granulated blast furnace slag, Alkali activator solution, Geopolymer concrete

I. INTRODUCTION

Concrete is one of the most common and widely used construction materials. The global use of cement concrete is second only to the use of water. It is mainly related to the Portland cement as the main component for making concrete. The demand for concrete as a construction material is increasing day to day. With infrastructure development growing and the housing sector booming, the demand for cement is also bound to increase. After aluminium and steel, the manufacturing of Portland cement is the most energy intensive process as it consumes 4GJ per tonne of energy. After thermal power plants and the iron and steel sector, the Indian cement industry is the third largest user of coal in the country. The manufacturing of Portland cement is an energy intensive process and releases a large amount of greenhouse gas to the atmosphere. Climate change due to global warming, one of the greatest environmental issues, has become a major concern during the last decade. Global warming is caused by the emission of greenhouse gases, such as CO₂, to the atmosphere by human activities. CO₂ contributes to nearly 2/3rd of global warming. The cement industry is responsible for major CO₂ emissions, because the production of one tonne of Portland cement emits approximately one tonne of CO₂ into the atmosphere.

Producing one tonne of cement requires about 2 tonnes of raw materials (shale and limestone) and releases 0.87 tonnes of CO₂, about 3 kg of Nitrogen Oxide (NO_x) and some other harmful substances also. The cement industry has been making significant progress in reducing CO₂ emissions through improvements in process technology and enhancements in process efficiency, but further improvements are limited because CO₂ production is inherent to the basic process of calcinations of limestone. Mining of limestone has an impact on land-use patterns, local water regimes and ambient air quality and thus remains as one of the principal reasons for the high environmental impact of the industry. Dust emissions during cement manufacturing have long been accepted as one of the main issues facing the industry. The industry handles millions of tonnes of dry material. Even if 0.1 percent of this is lost to the atmosphere, it can cause havoc environmentally. Fugitive emissions are therefore a huge problem, compounded by the fact that there is neither an economic incentive nor regulatory pressure to prevent emissions.

The cement industry does not fit the contemporary picture of a sustainable industry because it uses raw materials and energy that are non-renewable; extracts its raw materials by mining and manufactures a product that cannot be recycled. Through waste management, by utilizing the waste by-products from thermal power plants,

fertilizer units and steel factories, energy used in the production can be considerably reduced. This cuts energy bills, raw material costs as well as greenhouse gas emissions. In the process, it can turn abundantly available wastes, such as fly ash and slag into valuable products, such as geopolymer concrete.

In future use of Portland cement is unavoidable. Efforts are being taken to reduce the use of Portland cement in production of concrete. The effort includes the utilization of supplementary cementing material such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and finding alternative binders to Portland cement.

II. RELATED WORK

The concept of geopolymer concrete was first introduced by French Professor Joseph Davidovits in 1978[1]. The research by T.W. Cheng et.al. [7] describes the use of granulated blast furnace slag as an active filler in the making of geopolymers. During this work it was found that geopolymer setting time correlates well with temperature, potassium hydroxide concentration, metakaolin and sodium silicate addition. The physical and mechanical properties of the geopolymer also correlated well with the concentration of alkaline solution and the amount of metakaolinite that is added. Another research by DjwantoroHardjitoet. al. [2] presents the development of fly ash-based geopolymer concrete. In geopolymer concrete, a by-product material rich in silicon and aluminum, such as low-calcium (ASTM C 618 Class F) fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose course and fine aggregates, and other unreacted materials in the mixture. The test results presented in this paper show the effects of various parameters on the properties of geopolymer concrete. The application of geopolymer concrete and future research needs are also identified. The research on compressive strength by SatputeManesh B. et.al. [12] presents the study of duration and temperature of curing on compressive strength of fly ash based geopolymer concrete is done

III. METHODOLOGY

Following is the methodology adopted for carrying out the research work.

- 1) Collection of Materials
- 2) Preliminary Investigation
 - a) Fixed parameters
 - b) Variable parameters
- 3) Experimental Investigation
 - a) Physical properties of Fly ash, CA & FA
 - b) Chemical properties of Fly ash
- 4) Mix design of GPC
- 5) Compressive & Flexural strength of GPC
- 6) Result and Conclusion

IV. EXPERIMENTAL RESULTS

A) Materials used

- 1) **Fly ash-** Fly ash is a by-product of pulverized coal blown into a fire furnace of an electricity generating thermal power plant. In present research work low calcium fly ash confirmed to IS 3812(Part-1) is used for making geopolymer concrete.

- 2) **GGBS- Ground Granulated Blast Furnace Slag (GGBS)**

GGBS is a by-product from manufacturing of iron and steel-making. Blast furnace slag is formed in the processes of iron manufacture from iron ore, combustion residue of coke, and fluxes such as limestone or serpentine and other materials. If the molten slag is rapidly chilled by immersion in water, a vitreous Ca–Al–Mg silicate fine grain glass is formed with a highly cementitious nature. Due to the presence of SiO₂ and Al₂O₃ in GGBS it can be used in geopolymer as a base material (Yunsheng et al. 2007). A typical chemical composition of GGBS is shown in Table 1.

Table 1. Typical Chemical composition of Fly ash and GGBS

Sr. No.	Chemical	Fly ash	GGBS
1	Silicon Dioxide (SiO ₂)	60.8	27-38
2	Aluminium Oxide (Al ₂ O ₃)	23.57	7-12
3	Iron Oxide (Fe ₂ O ₃)	6.16	0.2-1.6
4	Calcium Oxide (CaO)	4.41	34-43
5	Magnesium Oxide	1.10	7-15

3) Alkaline Solution

Alkaline solution for Geopolymer is a combination of sodium silicate/potassium silicate and sodium hydroxide/potassium hydroxide. There are no fixed guidelines for the proportion of sodium silicate/potassium silicate to sodium hydroxide/potassium hydroxide. Ratios of 0.4 & 2.5 were used by Hardjito and Rangan (Hardjito et al. 2005), 2.5 by Reddy et al., Nuruddin et al., Lloyd and Rangan, and Anuradha et al. Research conducted by Hardjito and Rangan (Hardjito et al. 2005) suggests that higher ratio of sodium silicate solution-to-sodium hydroxide solution by mass, results in higher compressive strength of Geopolymer concrete.

If the proportion of Sodium Silicate to Sodium hydroxide is considered as 2.5 and high molar sodium hydroxide (8M-16M) is used than molar ratio of SiO₂/Na₂O in alkaline solution will be in the range of 1.33 to 1.070. Davidovits (Davidovits 2013) stated that published literature on alkali activated Geopolymer based on fly ashes comprised molar ratio of SiO₂/Na₂O was below 1.20 with an average of 1.0 and most of them propose to use pure NaOH of 8M to 12M without considering safety. A higher ratio of SiO₂/Na₂O is recommended.

In this experiment laboratory grade sodium hydroxide in flake form and sodium silicate is used to make alkali activated solution. From the literature available the ratio of Sodium Silicate and Sodium Hydroxide is kept as 2.0 with 4M sodium hydroxide.

4) Aggregates

Aggregate occupies most of the volume of the concrete. It is the stuff that the cement paste coats and binds together. The composition, shape, and size of the aggregate all have a significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. Aggregate can also influence the appearance of the cast surface, which is an especially important consideration in concrete countertop mixes.

5) Water

Even though water has no role in chemical reaction, it has an effect on fresh and hardened Geopolymer concrete. The water used for development of geopolymer concrete should be potable water and free from chemical or organic impurities.

Preparation of Geopolymer Concrete-

Geopolymer concrete mixes were prepared by fully replacing the cement content by fly ash and alkaline solution of sodium hydroxide and sodium silicate. Preparation of geopolymer concrete is very similar to that of cement concrete. Locally available crushed sand is used in preparation of geopolymer concrete. In which dry mix of fly ash, GGBS and aggregate is made by hand or machine mix then activated solution is added to it and thoroughly mixed for 2 to 3 minutes. If required extra water is added for workability. The fresh mix of geopolymer concrete was viscous, cohesive and dark in colour.

Testing of Geopolymer Concrete-

Physical properties of geopolymer concrete are checked and fresh concrete is then casted in cube of standard size. All cubes are demoulded after 24 hrs and wrapped in aluminium foil and kept for oven curing for 24 hrs. After curing period cubes are tested at normal temperature. The test results for the compressive test are as follows.



Table 2. Compression Test Results

Sr. No.	% Fly Ash	% GGBS	Compressive Strength (N/mm ²)	Average Compressive Strength (N/mm ²)
Trial 1	100	0	14.60	13.16
			13.52	
			11.36	
Trial 2	80	20	18.20	18.06
			19.40	
			16.56	
Trial 3	60	40	24.90	26.56
			28.30	
			26.50	
Trial 4	40	60	35.75	35.67
			34.44	
			36.84	

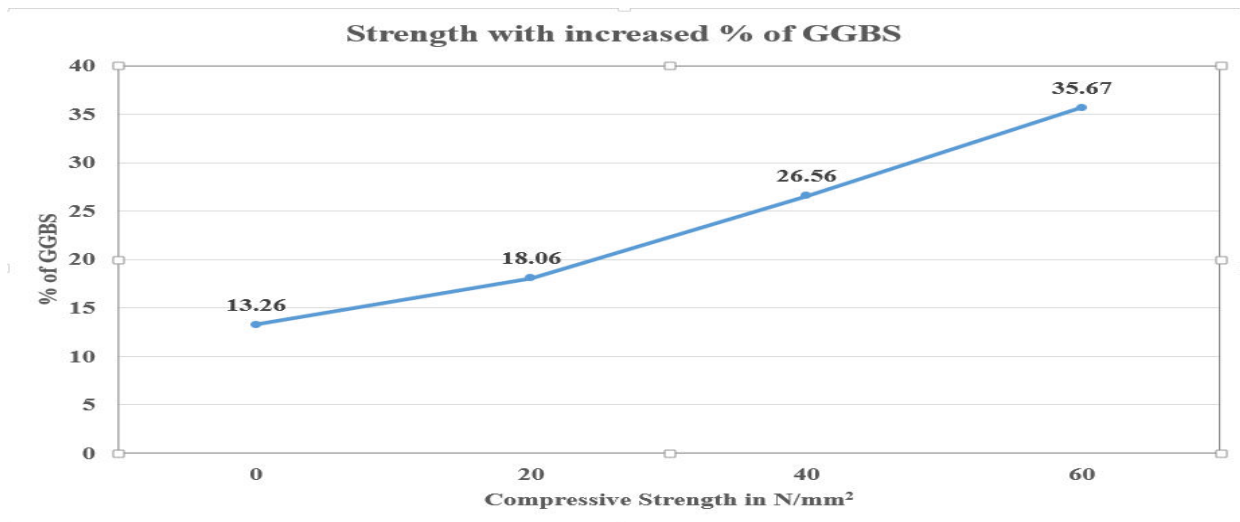


Fig. 1 Variation in strength with percentage increasing in GGBS

From above it is seen that as the GGBS replacement percentage is increased from 0% to 60% the strength of concrete also increased from 13.26N/mm² to 35.67N/mm². Which means strength is the function of % GGBS present in the concrete mix.

V. CONCLUSION

The experimental work on Geopolymer concrete by replacing the cement totally by GGBS and Fly ash indicated that with increase in percentage of GGBS the compressive strength of GPC is observed to be increasing. Geopolymer concrete developed by using 40% of fly ash and 60% of GGBS with 40% of alkali activator solution has maximum compressive strength by 1.71 times, in comparison with normal cement concrete.

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