Use of Geopolymer Concrete for Reinforced Beam

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ABSTRACT. Geopolymer concrete (GPC) is been known as a sustainable alternative to Portland cement concrete that emits high CO_2 emission rate. The current application of GPC in structural components is limited and thus attempt has been to study the properties of geopolymer concrete in reinforced structures. The paper combines the application of geopolymer concrete to investigate the structural behaviour of reinforced members. The use of flyash along with sodium hydroxide and sodium silicate solutions are combined to create geopolymer concrete. This paper mainly focuses on reinforced geopolymer concrete beams and the objective is to experimentally study the compressive and flexural strength. The experimental study includes investigation of nine geopolymer cubes of 150x150x150mm for compressive testing at an age of 7, 14 and 28 days. The final results of geopolymer cubes had a slight reduction of 7.7% as compared to conventional concrete. The flexural behaviour of three geopolymer beams over an effective span of 700x150x150mm were tested on two-point load test to determine the deflection of the beams. The load deflection characteristics obtained from RCC beams and Geopolymer beams showed almost similar curvature. Also, NDT testing was done on the beams to understand the quality of geopolymer concrete. The rebound hammer test of geopolymer beam suggested that the rebound hammer number was 48 which indicated a very good hard layer.

Keywords: Geopolymer, Flyash, Sodium hydroxide, Sodium silicate

I. INTRODUCTION

Cement production requires high energy consumption rates. Hence there has been always a need of new sustainable technology with the increasing need for infrastructure we must make a balance between human need for preserving the environment and human need of using up the resources. For manufacturing each tone of Portland cement as the primary component of concrete, about 1.5 tonnes of raw materials is needed. In this process about 1 ton of carbon-di-oxide is released into the atmosphere. It is estimated that 7% of total greenhouse gases and emissions is done by OPC production and is about to increase by 50% by the year 2020. But nowadays, there is a search for alternative materials because the ordinary Portland cement concrete structures when built in corrosive environment start deteriorating after 20-30 years though they have been designed to service for more than 50 years. It would be better if manufacturing of a concrete without OPC can be achieved.

Geopolymer concrete production would release carbon dioxide approximately 1/6th of OPC concrete production emission. Hence, we should utilise the by products from the other industry like Fly Ash, GGBS, Silica Fumes, Red Mud, Rice Husk Ash, etc in GPC to reduce carbon footprint as well as waste products. One of the commonly used products in geopolymer binder is fly ash. This material is available in all the continents and only 15% amount of its production is fully utilized. In near future the amount of production of fly ash is expected to increase. The efforts of utilizing this by-product material in concrete manufacture are important to make concrete more eco-friendly.

II. NEED FOR STUDY

The Geopolymer concrete research has demonstrated its effectiveness to OPC with respect to its various mechanical properties such has high early strength, fire resistance, sulphate attack resistance, etc. Thus, geopolymer concrete is a potential alternative as a sustainable construction material, but the current application of GPC in structural components is limited due to lack of codes and standards for structural design. There has been very little research done on the mechanical properties of reinforced geopolymer concrete.

The structural properties of the concrete members are one of the most vital components in effectively introducing geopolymer concrete for actual buildings and applications. The application of geopolymer concrete to investigate the structural behaviour of geopolymer concrete in reinforced members such as beams, columns, slabs is needed.

III. MATERIALS SELECTED

i. Flyash:

The Coal Combustion Product (CCP), often known as flyash, is the finer particle product of coal combustion that is collected by electrostatic precipitators in coal-fired thermal plants. The experimental approach made use of Class F flyash. Typically, flyash from India fits into this category. Fly ash's colour can range from tan to dark grey, depending on the chemical and mineral components.

ii. Alkaline solution:

As an alkaline activator, sodium hydroxide flake and sodium silicate solution were combined during the experiment. The two solutions were combined to create the solution, which was then left to sit for twenty-four hours for the mix.

iii. Aggregates:

The aggregates provide 75% of the mass of the concrete and majorly influence the strength. Sieve analysis and other tests in conformance with IS 2836 were done at the site from where the aggregates were procured and these aggregates conformed to the standards specified in IS 370(1970).

iv. Water:

For the experiment to make the concrete workable, potable water from the college's grounds was used. The water that was used complied with IS 456:2000.

IV. CASTING PROCEDURE:

Sodium hydroxide in flake form and sodium silicate were together used as alkaline activators. To avoid the effect of unknown contaminants and for uniform mixing of chemical in mix, sodium hydroxide flakes were dissolved in water. The solution evolved a lot of heat. The activator solution was prepared 24 hours prior to casting of the cubes. To prepare sodium hydroxide flakes were dissolved in one litre of water. The mass of sodium hydroxide flakes in solution will vary depending upon the molar concentration of the solution required for every mix. Studies have shown that a stronger solution gives better results. Locally available aggregates and crushed sand were mixed in standard surface dry condition after weighting it in proportion required as per the mix design. There are two steps to the mixing process: dry mix and wet mix. This mixture was mixed with fly ash in dry pan for 3 minutes. The alkaline solution was then added to the solid particles and mixed for another 3-5 minutes. The fresh concrete had stiff consistency and is glossy in appearance. The beam moulds were well cleaned and lubricant was applied for easy stripping. The fresh geopolymer concrete was casted in the beam moulds and compacted properly. For compacting using vibration, each layer was vibrated by the means of electric or pneumatic hammer or vibrating table until required compaction was achieved.

V. PERFORMANCE ANALYSIS

1. Compressive Strength of Geopolymer Cubes

To ascertain the compressive strength of the planned geopolymer concrete, nine 150X150X150 mm cubes were cast. To determine the gain in strength with respect to time, three were tested at the 7th, 14th, and 28th days. UTM (Universal Testing Machine) was utilised for this. The universal testing machine was used to apply the load to the concrete cube specimen in accordance with Indian Standards for testing concrete. Constant loads were applied, and the load at which the cube failed was recorded.

In a comparative study between conventional concrete and geopolymer concrete, the compressive strength of both materials was evaluated through cube testing at different ages. The study examined the compressive strength of the cubes at different stages of 7th, 14th, and 28th days. For conventional concrete cubes, the results showed that the compressive strength increased as the curing period progressed. At the 7th day, the average compressive strength was found to be 24.7 MPa. By the 14th day, the strength increased to 32.3 MPa, and further increased to 48.4 MPa by the 28th day.

In the case of geopolymer concrete cubes, a similar trend was observed. The compressive strength of geopolymer cubes also improved with increasing curing time. At the 7th day, the average compressive strength was 20.1 MPa, which was slightly lower than that of conventional concrete. However, by the 14th day, the strength increased to 28.5 MPa, and at the 28th day, the geopolymer cubes exhibited a significant increase in compressive strength, reaching a value of 44.8 MPa.

This indicates that geopolymer concrete may offer improved performance in terms of strength development over time, making it a viable alternative to conventional concrete in various applications.

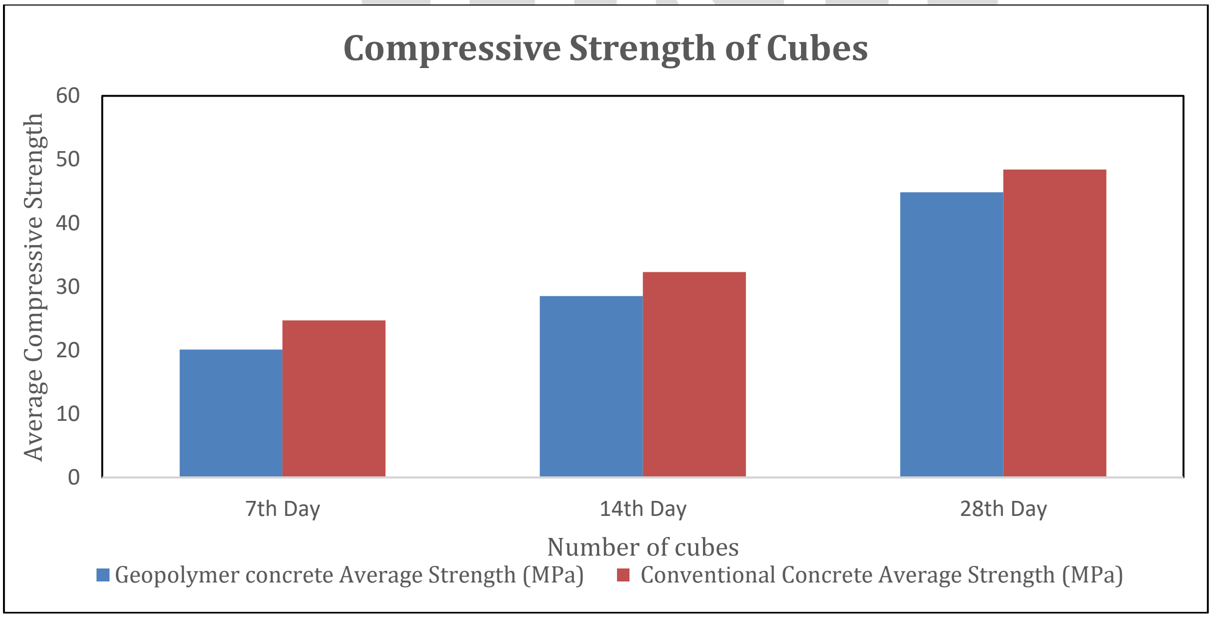
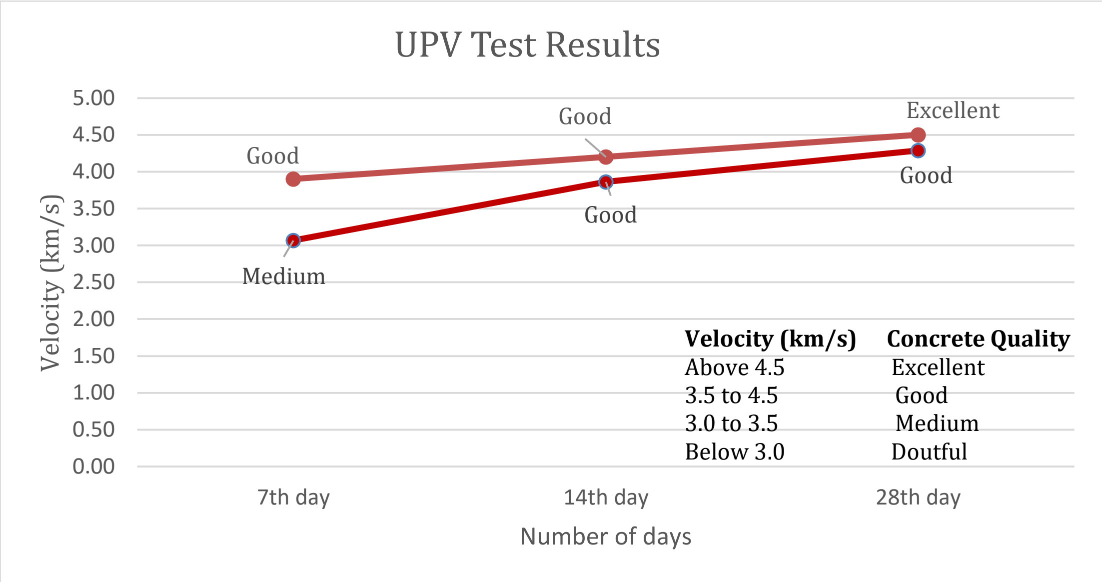


Fig 1: Results of conventional concrete cubes and geopolymer concrete cubes.

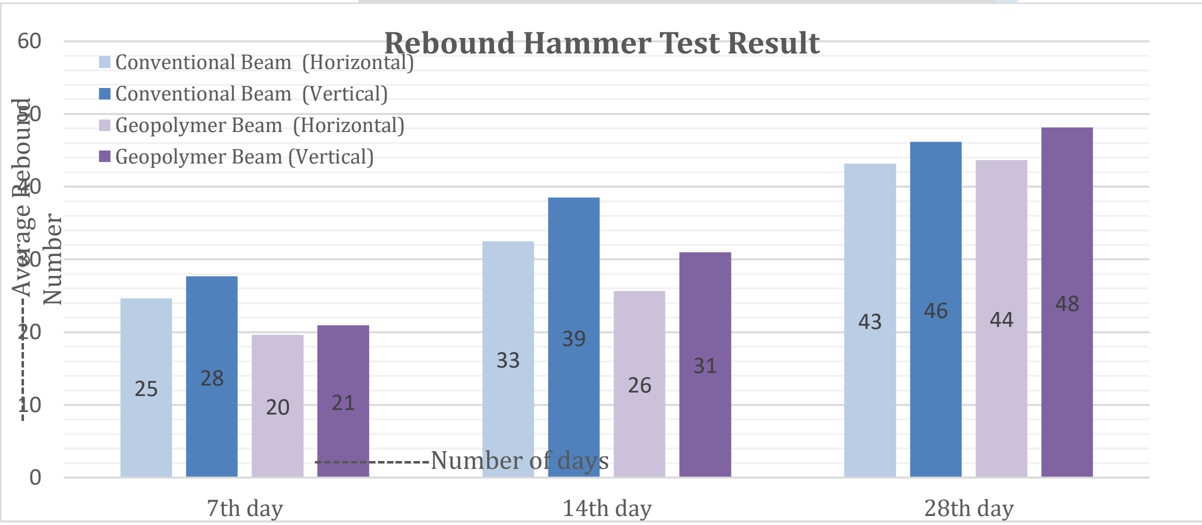
2. The Ultrasonic Pulse Velocity Test

The ultrasonic pulse velocity test is a non-destructive test. It is used to examine the homogeneity and quality of concrete. The test was conducted by passing a pulse of ultrasonic through the concrete beam having dimensions 750x150x150mm.
The UPV test results suggest that both conventional concrete and geopolymer concrete exhibit similar trends in terms of material integrity and homogeneity. The UPV values for geopolymer concrete were comparable to or even higher than those of conventional concrete at the same ages. This indicates that geopolymer concrete can offer good quality and structural integrity, making it a potential alternative to conventional concrete in various applications.



3. Rebound Hammer Test

The rebound hammer test was conducted on beam of 700x150x150mm to understand the quality of concrete. The rebound hammer test results suggest that both conventional concrete and geopolymer concrete exhibit similar trends in terms of surface hardness and quality. The rebound hammer numbers for geopolymer concrete were comparable to or even higher than those of conventional concrete at the same ages. This indicates that geopolymer concrete can achieve good surface hardness and quality, making it a viable alternative to conventional concrete in various applications.



VI. COST ANALYSIS

The cost of manufacture of GPC is about 25% lower than the cost of manufacture of OPC concrete. This cost saving is important to reduce the project cost as well as the carbon emissions. Carbon credits thus earned can give monetary benefits and get LEED certification. The objective of creating a sustainable and cheaper alternative to OPC concrete is thus achieved.

VII. FURTHER SCOPE OF STUDY

The study can be used to establish easier manufacture of geopolymer concrete at ambient temperature. This same mix can be used to get higher strength in presence of heat curing or steam curing. The study can be taken for further improvements in the procedure of manufacture and improvements in the control procedures.

VIII. CONCLUDING REMARKS

From the literature available and the experimental procedure, it is concluded that

High early strength is obtained for M40 grade of Geopolymer concrete. The geopolymer concrete manufactured under controlled and quality environment has exhibited good resistance to deflection and high quality of concrete mix is obtained. The properties of the hardened concrete is similar to that of the properties of the OPC concrete. The use of two-point load test to estimate the bending load effect on beam exhibits good flexural strength. The geopolymer concrete members such as beams and columns could be designed using design codes for conventional reinforced concrete members.

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