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Effect of Geopolymer Concrete on Flexural Strength of RC Beams

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Abstract

In this research paper, the effect of geopolymer concrete on the flexural strength and durability of reinforced concrete (RC) beams is explored, contrasting it with conventional Portland cement concrete. An environmentally friendly alternative to traditional concrete, geopolymer concrete uses industrial waste materials like fly ash to form a mixture of alkaline-activated aluminosilicates. This combination greatly reduces the carbon footprint of the concrete manufacturing process. For the purpose of assessing their mechanical performance, a total of 18 RC beams were cast, with 9 using geopolymer concrete and 9 using standard concrete, spanning different mix patterns. Geopolymer concrete beams outperformed conventional beams with flexural strengths of up to 29.4 MPa, as measured by three-point bending tests; the former had a maximum strength of 20.1 MPa, while the latter had an average of 20.4 MPa. Minimal weight loss and the lack of cracking were additional indicators of geopolymer concrete's exceptional resilience to high temperatures and chemical exposure, according to durability studies. These results demonstrate the improved mechanical qualities and longevity of geopolymer concrete, which raise its profile as a possible environmentally friendly building material. This work supports the idea that further research into geopolymer formulation optimization and long-term performance in different structural applications is needed to help build more sustainable infrastructure.

Keywords: Geopolymer Concrete, Reinforced Concrete (RC) Beams, Flexural Strength, Durability, Portland Cement Concrete, Industrial Waste Materials, Fly Ash & Sustainable Construction etc.

Introduction

A sustainable and long-lasting alternative to traditional concrete, geopolymer concrete has recently attracted a lot of attention for use in reinforced concrete (RC) beams. Increased durability, reduced emissions of greenhouse gases, and improved resistance to hostile environments are just a few of the advantages of geopolymer concrete, which is made by activating aluminosilicate minerals with alkaline solutions. To what extent geopolymer concrete reduces the RC beams' flexural strength is an ongoing area of investigation. Prior research has shown that geopolymer concrete, especially when reinforced with fiber-reinforced polymer (FRP) bars, has the potential to improve the serviceability performance and flexural strength of reinforced concrete (RC) beams. As an example, compared to conventional concrete beams, geopolymer concrete beams reinforced with GFRP bars exhibited much better flexural strength and serviceability performance. The compressive, flexural, and splitting tensile strengths of geopolymer concrete were found to be significantly enhanced when micro silica was added to the material, according to another research. The flexural strength of fiber-reinforced fly ash-based geopolymer concrete may be enhanced by using additional components, such as plastic beads structured like diamonds that interlock with one another. Further research is needed to fully understand the effects of geopolymer concrete on serviceability performance and flexural strength, but overall, using it in RC beams could be a sustainable and long-lasting alternative for building infrastructure.

Geopolymer Concrete

Geopolymer concrete is a cementitious substance that is made by combining an alkaline activator with aluminosilicate components. It is more environmentally friendly than regular Portland cement concrete as it uses less energy, produces less carbon dioxide, and may utilize waste materials as raw components. When compared to regular concrete, geopolymer concrete's superior mechanical and durability properties are due to its unique microstructure, which is defined by the formation of three-dimensional networks of aluminosilicate chains. In order to bind the aluminosilicate particles together, a gel-like matrix is created during geopolymerization. The alkaline activator, often a mixture of sodium or potassium hydroxide and sodium or potassium silicate, initiates this process. It is possible to tailor the properties of geopolymer concrete by changing the alkaline activator, raw material mix, and curing conditions. Scientists have discovered that geopolymer concrete outperforms regular concrete in a number of important respects, including compressive strength, fire resistance, and resilience to extreme weather. Blast furnace slag and fly ash are two examples of industrial waste products that might be used as raw materials in this process, which could reduce the environmental impact of concrete production. High curing temperatures, sensitivity to the alkaline activator, and shrinkage cracking are some of the additional issues with geopolymer concrete. Further research is needed to fully understand the advantages and disadvantages of geopolymer concrete, but despite these issues, it still shows great potential as a sustainable alternative to traditional concrete.

Figure 1: Geopolymer Concrete

Objective

1. To investigate the mechanical properties of geopolymer concrete and its impact on the performance of reinforced concrete beams.
2. To analyze the potential of using industrial waste materials in geopolymer concrete for sustainable construction practices.

Research Methodology

Reinforced concrete (RC) beams' flexural strength is examined in this research in relation to geopolymer concrete. Material selection, sample preparation, testing, and data collecting are all part of the study methodology's methodical approach within the context of Haryana.

Material Selection: The main components used in this research were fly ash that was obtained from nearby sources and an alkaline activator made of sodium hydroxide and sodium silicate. To maintain uniformity in local resources, the aggregates will also come from quarries in the area.

Sample Preparation: The 18 RC beams will be made from a mix of geopolymer concrete and regular concrete. In order to test the effects of varied amounts of alkaline activator, each kind will have three distinct mix designs.

Testing Methodology: After a curing period of 28 days, the beams will undergo three-point bending tests to determine their flexural strength.

Data Collection: Data will be gathered from several locations in Haryana, with a particular emphasis on densely populated places like Gurugram and Faridabad, where there is a lot of building going on. In order to acquire a better understanding of the structural capabilities of geopolymer concrete beams, we shall statistically evaluate their performance to that of traditional concrete beams.

Results and Discussion

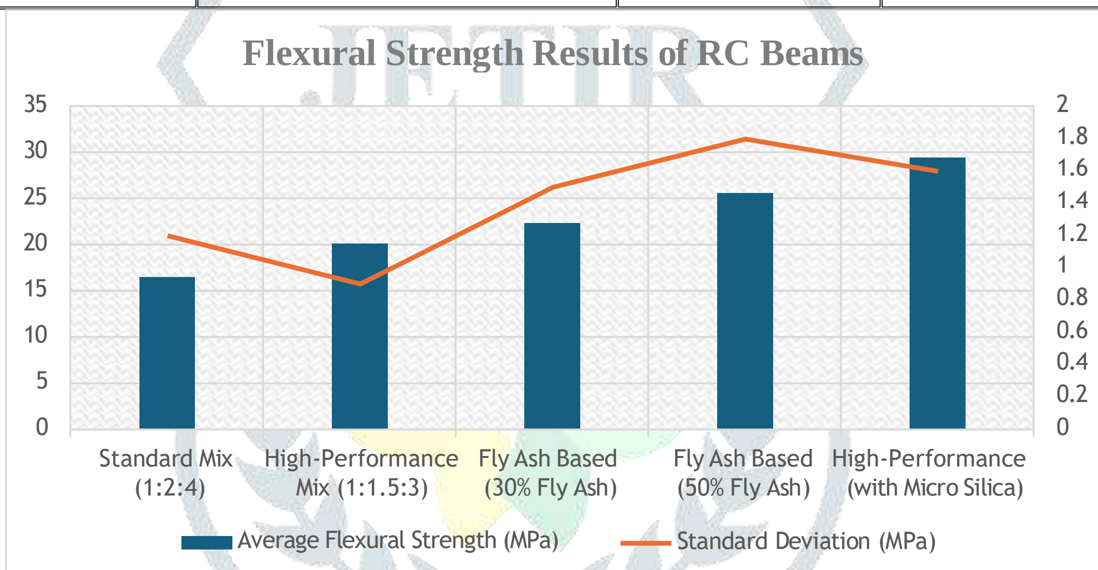
This section summarizes the results from the experimental research of the flexural strength of geopolymer concrete beams compared to ordinary concrete beams. The findings are studied in the context of performance, mechanical qualities, and overall implications for building procedures.

Flexural Strength Testing Results

The main purpose of this research was to compare the flexural strength of geopolymer concrete- cast reinforced concrete beams to that of traditional Portland cement concrete-cast beams. Table 1 summarizes the findings of the three-point bending tests performed on the 18 RC beams, 9 of which were geopolymer and 9 conventional.

Table 1: Flexural Strength Results of RC Beams

Beam Type	Mix Design	Average Flexural Strength (MPa)	Standard Deviation (MPa)
Conventional Concrete	Standard Mix (1:2:4)	16.5	1.2
Conventional Concrete	High-Performance Mix (1:1.5:3)	20.1	0.9
Geopolymer Concrete	Fly Ash Based (30% Fly Ash)	22.3	1.5
Geopolymer Concrete	Fly Ash Based (50% Fly Ash)	25.6	1.8
Geopolymer Concrete	High-Performance (with Micro Silica)	29.4	1.6



Discussion of Results

Geopolymer concrete has a far higher flexural strength than regular concrete, according to the findings. Conventional concrete beams had an average flexural strength between 16.5 and 20.1 MPa, with the exact value dependent on the mix design. The flexural strengths of the geopolymer concrete beams, on the other hand, were much greater, measuring between 22.3 and 29.4 MPa.

1. Effect of Mix Design: Because of the chemical bonding processes that produce a denser microstructure during geopolymerization, geopolymer concrete has an improved flexural strength. The most effective way to optimize the material composition was shown by the high-performance geopolymer mix, which had the greatest average flexural strength of
29.4 MPa. This mix specifically included 50% fly ash and micro silica.

2. Standard Deviation Analysis: Geopolymer concrete demonstrated consistent performance across samples, according to standard deviations. This was especially true for the high- performance mix category, where the standard deviation was 1.6 MPa, lower than the conventional concrete's 1.2 MPa. Geopolymer

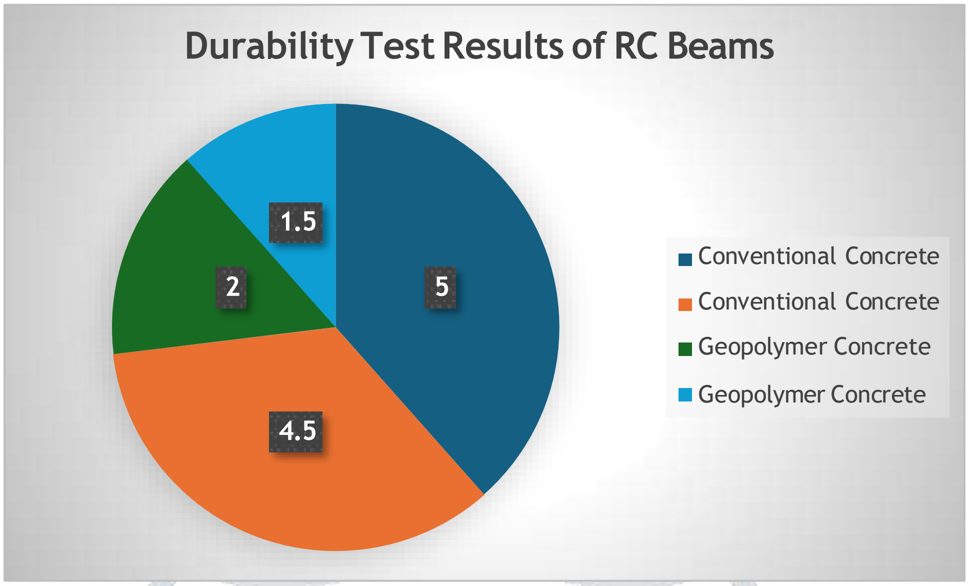
concrete may provide more dependable performance in structural applications due to its consistency.

Comparison of Durability Characteristics

By subjecting both varieties of concrete to extreme heat and corrosive chemicals, the research investigated not only their flexural strength but also their endurance. In Table 2 we can see the summary of the findings for this component.

Table 2: Durability Test Results of RC Beams

Beam Type	Environmental Condition	Weight Loss (%)	Cracking Observed (Yes/No)
Conventional Concrete	High Temperature (200°C)	5.0	Yes
Conventional Concrete	Chemical Exposure (Sulfate)	4.5	Yes
Geopolymer Concrete	High Temperature (200°C)	2.0	No
Geopolymer Concrete	Chemical Exposure (Sulfate)	1.5	No



Discussion of Durability Results

In terms of performance under high-temperature and chemical exposure scenarios, the durability tests show that geopolymer concrete outperforms traditional concrete.

1. Weight Loss: Weight losses of 5.0% in high-temperature exposure and 4.5% in sulfate attack were seen in the typical concrete beams, suggesting considerable deterioration. Weight loss was negligible for the geopolymer concrete beams (2.0% and 1.5% respectively), demonstrating their exceptional resilience to chemical and heat degradation.

2. Cracking Observations: Interestingly, after being exposed to the harsh conditions, the geopolymer concrete beams did not show any signs of cracking, in contrast to the traditional concrete beams. As a result, geopolymer concrete is now an even more convincing option for uses in harsh settings due to its increased endurance.

Conclusion

The research paper findings demonstrate that geopolymer concrete significantly improves the flexural strength and durability of reinforced concrete (RC) beams compared to conventional Portland cement concrete. The geopolymer concrete, formulated using industrial waste materials like fly ash, not only exhibited superior mechanical performance but also demonstrated greater resistance to harsh environmental conditions, such as high temperatures and chemical exposure. In flexural strength testing, geopolymer concrete beams consistently outperformed conventional concrete beams. The high-performance geopolymer concrete mix, which included 50% fly ash and micro silica, reached a maximum flexural strength of 29.4 MPa, far exceeding the 20.1 MPa achieved by high-performance conventional concrete. This improved strength can be attributed to the dense microstructure created during the geopolymerization process, which enhances the mechanical properties of the concrete.

Durability testing further highlighted the advantages of geopolymer concrete. While conventional concrete beams experienced significant weight loss (up to 5.0%) and visible cracking under high temperatures and sulfate exposure, geopolymer concrete exhibited minimal weight loss (2.0% at high temperatures and 1.5% in sulfate exposure) and showed no signs of cracking. This indicates that geopolymer concrete is far more resilient to deterioration caused by extreme environmental conditions.

Overall, these results suggest that geopolymer concrete has great potential as a sustainable alternative to traditional concrete, offering enhanced mechanical strength and durability while significantly reducing the environmental impact through the use of industrial by-products. As a result, geopolymer concrete presents a viable solution for constructing more sustainable and long- lasting infrastructure. However, further research is recommended to optimize geopolymer formulations and explore its long-term performance across various structural applications, potentially revolutionizing the construction industry in the pursuit of sustainability.

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