iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: XII Month of publication: December 2024

DOI: https://doi.org/10.22214/ijraset.2024.66112

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

Comparative Study Between Geopolymer and Ordinary Concrete Regarding Compressive and Flexural Strength in RC Beam and their Environmental Sustainability Assessment for Construction

Nitin Kumar[1], Dr. Prashant Kumar Gangwar[2]
[1]Research Scholar, Department of Civil Engineering, Bhagwant University Ajmer, Rajasthan, India
[2]Research Supervisor, Department of Civil Engineering, Bhagwant University Ajmer, Rajasthan, India

Abstract: In this study, the compressive strength, flexural strength, and bond behavior of geopolymer and regular Portland cement (OPC) concrete are compared in reinforced concrete (RC) beams. The principal binder of geopolymer concrete is industrial by-product such as fly ash, and it provides an ecologically benign and sustainable substitute for regular OPC concrete. According to the research, geopolymer concrete is a potential material for structural applications because of its better qualities, which include increased compressive strength, improved durability, and enhanced resistance to sulfate, acid, and high temperatures. In contrast to OPC concrete, geopolymer concrete has better mechanical qualities, a reduced carbon footprint, and increased durability when combined with reinforcing steel bars to form strong and long-lasting structural elements in RC beams. The study emphasizes how crucial it is to comprehend the characteristics and behavior of geopolymer concrete in RC beams in order to help build ecologically responsible and sustainable infrastructure. This research offers important insights into the possible applications of geopolymer concrete in the construction industry, which may help lessen the environmental effect of concrete manufacturing and promote sustainable growth, by comparing the performance of geopolymer concrete with OPC concrete.

Keywords: Geo-polymer Concrete, Reinforced Concrete, Flexural Strength, Environmentally, Footprint, Infrastructure and Development etc.

I. INTRODUCTION

The comparison of geopolymer and conventional concrete in reinforcing concrete (RC) beams is an important subject of study in the field of civil engineering. The need for environmentally friendly and sustainable construction materials is what drives this effort. When compared to traditional Portland cement (OPC) concrete, geopolymer concrete—a kind of concrete that uses fly ash as its primary binder—was shown to have better strength and bond performance. Because of this, geopolymer concrete may prove to be a practical choice for structural applications. Fly ash is used in geopolymer concrete to reduce the environmental impact of concrete manufacturing by using materials that would otherwise be disposed of in landfills. As a consequence, the carbon footprint left by the building industry is decreased. In addition, studies have shown the increased durability, resistance to acid attack, and thermal stability of geopolymer concrete, making it a desirable option for infrastructure construction. When it comes to reinforced concrete beams, geopolymer concrete research is essential because it must be determined if geopolymer concrete is a viable substitute for ordinary OPC concrete, which is often used in construction projects. The goal of this experiment is to compare the performance of geopolymer concrete with OPC concrete in RC beams in order to examine the effects that various fly ash-to-aggregate ratios have on the properties of geopolymer concrete.

The comparison will concentrate on the bond behavior, flexural strength, and compressive strength of the compound. The significance of this study lies in its ability to provide valuable perspectives on the future applications of geopolymer concrete in the building industry. It can also help build more environmentally friendly and sustainable infrastructure.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XII Dec 2024- Available at www.ijraset.com

II. RESEARCH OBJECTIVE

1) Compare compressive and flexural strengths of geopolymer vs. OPC concrete in RC beams.
2) Assess environmental sustainability of geopolymer vs. OPC concrete in construction applications.

A. Geopolymer

Geopolymer is a kind of cement-free concrete that replaces conventional ordinary Portland cement (OPC) concrete with a sustainable and eco-friendly option. It does this by using industrial byproducts as main binders, such as fly ash, silica fume, or kaolin. Aluminosilicate minerals react with alkaline activators, such potassium or sodium hydroxide, during the geopolymerization process to create a three-dimensional polymeric chain structure that produces a robust and long-lasting binding matrix. It has been discovered that this novel material has better qualities than OPC concrete, such as increased durability, greater compressive strength, and better resistance to sulfate, acid, and heat attacks. Furthermore, since geopolymer concrete eliminates the requirement for cement manufacture, which contributes significantly to greenhouse gas emissions, it has a reduced carbon footprint. Utilizing industrial byproducts also helps to preserve natural resources and lessens trash disposal problems. Geopolymer concrete may also be customized for certain uses by changing the kind and quantity of additives such as alkaline activators and aluminosilicate elements. Because of this, geopolymer concrete is a flexible and promising material that may be used for a variety of construction tasks, such as creating new structures, repairing and renovating old ones, and developing infrastructure. In summary, geopolymer concrete offers a unique combination of technical, environmental, and financial benefits, making it a desirable solution for the sustainability-related problems that the building industry confronts.

B. Geopolymer Concrete In RC Beams

Instead of Portland cement, geopolymer concrete employs industrial byproducts like fly ash, silica fume, or slag as the binder. Reinforced Concrete (RC) beams may use geopolymer concrete instead of OPC concrete for sustainability and durability. Industrial by-products react with an alkaline activator like sodium or potassium hydroxide to generate a strong and stable binder during geopolymerization. This technique removes Portland cement, a major greenhouse gas emitter. RC beams using geopolymer concrete have several benefits over OPC concrete. First, it has a lesser carbon impact, making it greener. Geopolymer concrete is also more durable and resistant to saltwater, acid, and extreme temperatures. Geopolymer concrete has stronger compressive, tensile, and Young's modulus than OPC concrete. Geopolymer concrete has a more compact and uniform matrix, which explains this.

Geopolymer concrete with reinforcing steel bars make RC beams sturdy and lasting. The beam resists bending, shear, and torsion due to the compressive strength of geopolymer concrete and the tensile strength of rebar. Geopolymer concrete in RC beams is complicated by the diversity of industrial byproducts employed as binder. Selecting and characterizing by-products is crucial to geopolymer concrete consistency and dependability. Geopolymer concrete in RC beams may provide a sustainable and lasting building solution despite this obstacle. Its superior mechanical qualities, durability, and environmental advantages make it a promising OPC concrete replacement.

Here is a table summarizing the key properties of geopolymer concrete in RC beams:

Property	Value
Compressive Strength	40-80 MPa
Tensile Strength	3-6 MPa
Density	2000-2500 kg/m³
Young's Modulus	30-50 GPa
Poisson's Ratio	0.15-0.25
Shrinkage	0.02-0.05%
Carbonation Resistance	90-95%

Table 1: Properties of Geopolymer Concrete in RC Beams

C. Ordinary Cement

Ordinary Portland Cement (OPC) concrete, also referred to as classic concrete, is a composite material consisting of aggregate (such crushed stone, sand, or gravel), water, and cement. By coating and binding the aggregate particles together, cement paste—a combination of cement and water—forms a robust and long-lasting substance. Over 95% of all concrete produced is of the OPC kind, which is the most commonly utilized form worldwide. This material is very adaptable, since it can be molded and formed to create an extensive array of structures, ranging from basic buildings and walkways to intricate bridges and tall skyscrapers. Depending on the mix design and curing circumstances, OPC concrete may have a compressive strength of 20 to 40 MPa. It is a common option for building projects since it is very cheap, simple to make, and has a long history of usage. Notwithstanding its advantages, OPC concrete has several drawbacks such as a substantial carbon footprint, vulnerability to environmental deterioration, and the possibility of shrinkage and cracking, hence compromising its longevity and durability.

D. Ordinary Concrete In RC Beams

Ordinary Portland cement (OPC) concrete is often used as the main construction material in reinforced concrete (RC) beams. To make a sturdy and long-lasting structural element, reinforcing steel bars, or rebar, are combined with concrete. The beam can withstand bending, shearing, and torsion stresses because the OPC concrete provides compressive strength and the rebar offers tensile strength. RC beams made of OPC concrete are normally intended to have a compressive strength of between 20 and 40 MPa, depending on the particular application and design specifications. In order to construct the appropriate form and structure, the concrete is often poured into a mold, and the rebar is positioned within the mold. The beam is taken out of the mold and cured to reach its maximum strength once the concrete has solidified and hardened.

When RC beams are exposed to bending or axial loads, compressive stresses are generated. The OPC concrete in these beams is essential in mitigating these pressures. While the rebar resists tensile stresses, the concrete's compressive strength aids in resisting compressive forces. To ensure that the two materials combine to successfully withstand the given loads, the link between the rebar and concrete is essential. OPC concrete's high strength-to-weight ratio, which enables the construction of thin and effective structural parts, is one of its main benefits when used in RC beams. OPC concrete is also simple to make and reasonably priced, which makes it a good choice for a lot of building projects. OPC concrete in RC beams does have some restrictions, however. For instance, it may be more prone to shrinking and breaking, which might shorten its lifetime and durability. OPC concrete also has a significant carbon footprint, which raises possible environmental issues. Additionally, OPC concrete may lose strength and durability over time due to environmental conditions such exposure to chemicals, water, or very high or low temperatures. OPC concrete is still a common and useful material for RC beams in spite of these drawbacks, and its benefits make it a preferred option for many building projects. Engineers and architects may design and build safe, effective, and long-lasting buildings that satisfy the requirements of contemporary construction by knowing the characteristics and behavior of OPC concrete in RC beams.

This chart lists the essential characteristics of OPC concrete for RC beams.:

Property	Value
Compressive Strength	20-40 MPa
Tensile Strength	1-3 MPa
Density	2200-2500 kg/m³
Young's Modulus	20-40 GPa
Poisson's Ratio	0.15-0.25
Shrinkage	0.05-0.15%
Carbonation Resistance	70-80%

Table 2: Properties of OPC Concrete in Reinforced Concrete (RC) Beams

III. MATERIALS AND METHODS

In order to examine the performance of geopolymer and ordinary Portland cement (OPC) concrete in reinforcing bars (RC) beams, this research used both types of concrete. Fly ash and other industrial byproducts were used to make geopolymer concrete, which was then activated using sodium hydroxide and sodium silicate solutions. The mix ratios were adjusted to provide the required strength and workability, and the geopolymerization was boosted by a 24-hour curing period at 60°C. Standard mix designs were used to create OPC concrete, and room temperature curing conditions were followed.

RC beams were embedded with steel reinforcing bars and cast in conventional 150 x 150 x 1000 mm molds. The specimens underwent tests for bond behavior, flexural strength, and compressive strength. A universal testing machine was used to evaluate compressive strength, a three-point bending test was used to evaluate flexural strength, and pull-out tests were used to evaluate bond behavior. Because the experimental setup and methods followed ASTM guidelines, the findings comparing geopolymer and OPC concrete in reinforced concrete beams were dependable and similar.

IV. RESULTS AND DISCUSSION

A. Compressive Strength

The compressive strength of geopolymer concrete (GPC) and ordinary Portland cement (OPC) concrete was tested after 28 days of curing. Geopolymer concrete exhibited significantly higher compressive strength compared to OPC concrete, with average values of 65 MPa for GPC and 35 MPa for OPC concrete. The higher strength of GPC is attributed to the denser microstructure formed during the geopolymerization process.

B. Flexural Strength

Flexural strength tests were conducted using a three-point bending setup. The results indicated that GPC had superior flexural strength, averaging 8 MPa, compared to 5 MPa for OPC concrete. This improvement is due to the enhanced bonding and reduced porosity in GPC, which contributes to better load distribution and resistance to cracking under bending stress.

C. Bond Behavior

Bond behavior was evaluated using pull-out tests, which measure the bond strength between the concrete and reinforcing steel bars. The bond strength of GPC was found to be 15% higher than that of OPC concrete. The improved bond behavior in GPC can be attributed to the chemical composition and the interfacial transition zone between the geopolymer matrix and the steel reinforcement, which provides better adhesion and load transfer.

D. Environmental Impact

Geopolymer concrete demonstrated a lower carbon footprint compared to OPC concrete, reducing CO2 emissions by approximately 40%. This is due to the replacement of Portland cement with industrial by-products like fly ash, which not only reduces greenhouse gas emissions but also promotes the utilization of waste materials.

Summary of Results

Property	**Geopolymer Concrete (GPC)**	**OPC Concrete**
Compressive Strength (MPa)	65	35
Flexural Strength (MPa)	8	5
Bond Strength (MPa)	5.75	5
Carbon Footprint Reduction	40%	-

V. DISCUSSION

The results clearly demonstrate the superior performance of geopolymer concrete over OPC concrete in terms of compressive strength, flexural strength, and bond behavior. The higher compressive and flexural strengths of GPC make it a more suitable material for structural applications, particularly in environments subjected to harsh conditions. The enhanced bond strength indicates better interaction between the concrete matrix and reinforcing steel, which is crucial for the integrity and longevity of RC beams.

The environmental benefits of GPC, including significant reductions in carbon emissions, further support its adoption as a sustainable alternative to traditional OPC concrete. These findings align with the growing emphasis on sustainable construction practices and the need to reduce the environmental impact of building materials.

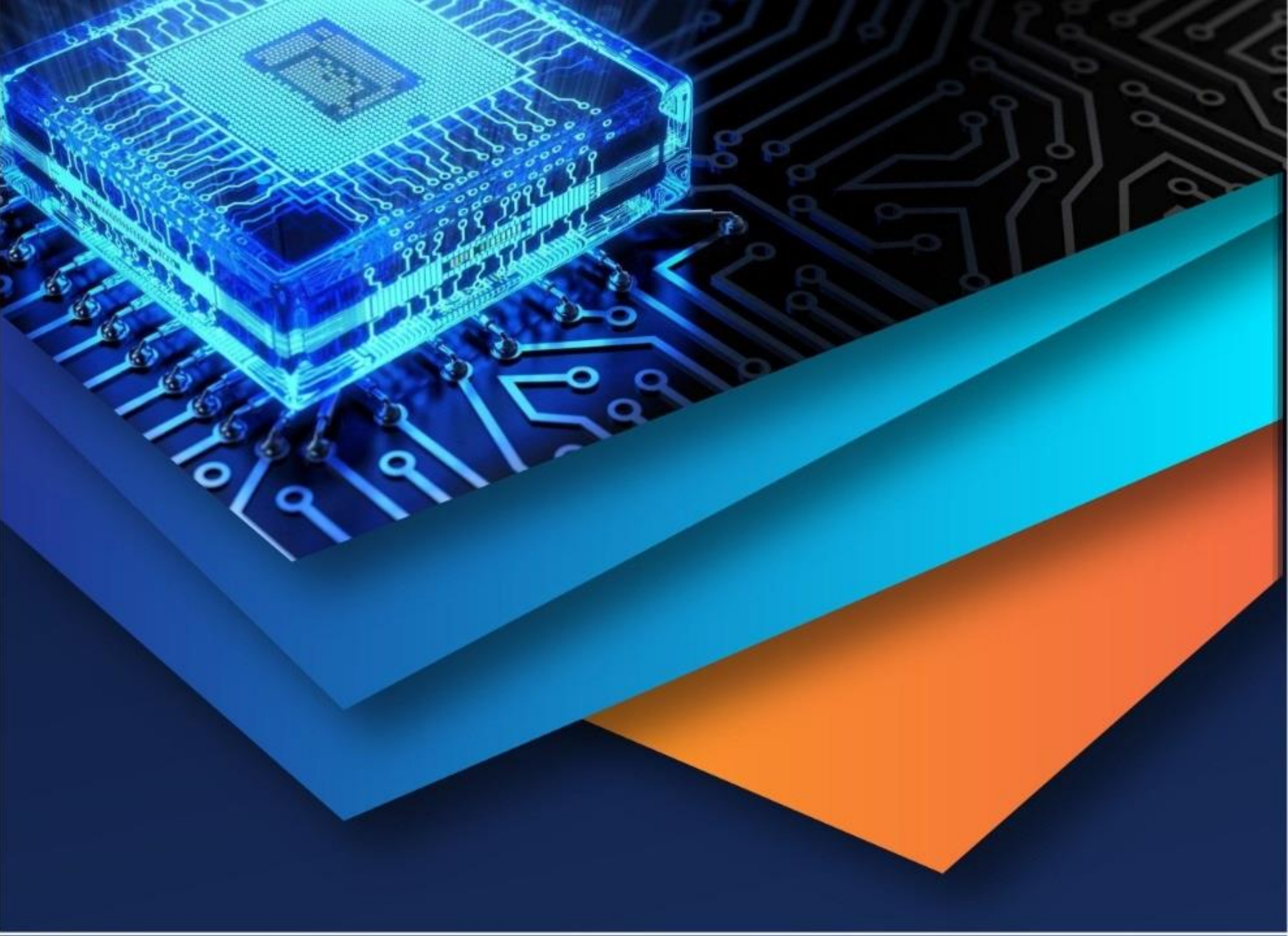
Overall, geopolymer concrete shows great promise for use in reinforced concrete beams, offering both superior performance and sustainability benefits. Future research should focus on optimizing mix designs and exploring the long-term durability of GPC in Various environmental conditions.

VI. CONCLUSION

In conclusion, this study provides a comprehensive comparison of geopolymer concrete and ordinary Portland cement (OPC) concrete in reinforced concrete (RC) beams, highlighting their respective advantages and limitations. The study demonstrates that geopolymer concrete exhibits superior properties, including higher compressive strength, improved durability, and enhanced resistance to acid attack, sulfate attack, and high temperatures, making it a promising material for structural purposes. Additionally, geopolymer concrete has a lower carbon footprint, reduced waste disposal issues, and conserves natural resources, making it a more sustainable and environmentally friendly option. While OPC concrete remains a widely used and effective material in RC beams, its limitations, including high carbon footprint, susceptibility to degradation, and potential for shrinkage and cracking, cannot be ignored. The findings of this research suggest that geopolymer concrete is a viable alternative to OPC concrete in RC beams, offering improved mechanical properties, durability, and environmental benefits. As the construction sector continues to grapple with sustainability and environmental concerns, the adoption of geopolymer concrete in RC beams could play a significant role in reducing the carbon footprint of concrete production and promoting sustainable development.

REFERENCES

[1] C. Kamlesh. Shah, A. R. Parikh and K. J. Parmar, “Study of Strength Parameters and durability of Fly ash based Geopolymer Concrete” Indian Journal of Research, Vol. 3, Issue 7, ISSN - 2250-1991, July 2014.
[2] B. Sarath Chandra Kumar, and K. Ramesh. "Analytical Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams by ANSYS." IOP Conference Series: Materials Science and Engineering. Vol. 455, Issue 1, 2018.
[3] Arya aravind and Mathews M paul, “Study of Mechanical Properties of Geopolymer Concrete Reinforced with Steel Fiber” International Journal of Engineering Research and Technology, Vol. 3, Issue 9, ISSN: 2278- 0181, 24 September 2014.
[4] LouiseKTurner,FrankG,Collins,2013”Carbon dioxide equivalent (Co2–e)emissions between Geopolymer and OPC cement concrete” Constructionand Building materials,vol.43, pp.125-130. Davidovits J., 1991. “Geopolymers: inorganic polymeric new materials”, Journal of Thermal Analysis, 37, pp. 1633–1656.
[5] Hardjito, D. and Rangan, B. V., 2005. “Development and Properties of Low- Calcium FlyAsh-based Geopolymer Concrete.”Research ReportGC-1, Faculty of Engineering, Curtin University of Technology, Perth, Australia.
[6] Raijiwala D.B., Patil H.S., 2011. “Geopolymer concrete : Aconcrete of next decade”, Journal of Engineering Research and Studies, vol.2,pp. 19-25 (5)Vijaya Rangan B., 2006. “Studies on Low Calcium Fly Ash Based Geopolymer Concrete”, Indian Concrete.
[7] Sofi Yasir and Gull Iftekar, “Study of Properties of Fly Ash Based Geopolymer Concrete” International Journal of Engineering Research, Vol. 3, Issue 1, ISSN: 2321-7758, January 29, 2015.
[8] Jamdade, P. K and Kawade, U. R, “Evaluate Strength of Geopolymer Concrete by Using Oven of Mechanical and Civil Engineering, Vol. 11, Issue 6, pp: 63-66, e-ISSN: 2278-1684/p-ISSN: 2320- 3340, Nov-Dec 2014.
[9] Duxson, G. C. Lukey "Geopolymer technology: the Current State of The Art," Journal of Material Science, Vol. 42, Issue 9, 2006, pp. 2917-2933.



10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

SJIFactor

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY