

# Experimental Study on Ambient-Cured Geopolymer Concrete Using Industrial By-Products for Low- Carbon Construction

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## Abstract

The production of ordinary Portland cement (OPC) is responsible for significant carbon dioxide emissions and environmental degradation. To address this issue, geopolymer concrete (GPC) has emerged as a sustainable alternative binder system utilizing industrial by-products such as fly ash and ground granulated blast furnace slag (GGBS). This study investigates the mechanical and durability performance of ambient-cured geopolymer concrete prepared using industrial waste materials. The experimental program includes the evaluation of workability, compressive strength, split tensile strength, flexural strength, and durability characteristics under ambient curing conditions. Various mix proportions were prepared using fly ash and GGBS activated with sodium hydroxide and sodium silicate solutions. The results show that ambient-cured geopolymer concrete achieves comparable or higher strength than conventional concrete while significantly reducing carbon emissions. The utilization of industrial by-products not only enhances sustainability but also reduces construction costs and waste disposal issues. The study concludes that ambient-cured geopolymer concrete is a viable material for low-carbon construction and sustainable infrastructure development.

**Keywords:** Geopolymer concrete, Ambient curing, Industrial by-products, Fly ash, GGBS, Sustainable construction, Low-carbon concrete

## 1. Introduction

Concrete is the most widely used construction material worldwide due to its durability, strength, and versatility. However, the production of ordinary Portland cement contributes nearly **8% of global carbon dioxide emissions**, making it a major environmental concern.

In recent years, researchers have focused on developing sustainable alternatives to conventional cement-based concrete. Geopolymer concrete is an emerging eco-friendly material that utilizes **alumino-silicate materials such as fly ash and slag activated with alkaline solutions** to form a binder system without Portland cement. Industrial by-products such as fly ash, ground granulated blast furnace slag (GGBS), silica fume, and rice husk ash can

be effectively used in geopolymer concrete. These materials contain silica and alumina, which react with alkaline activators to produce a geopolymer matrix with excellent mechanical and durability properties.

Most early geopolymer studies required **heat curing**, limiting field applications. Ambient-cured geopolymer concrete has gained attention because it eliminates the need for thermal curing and makes the material suitable for **in-situ construction practices**.

The present study investigates the performance of **ambient-cured geopolymer concrete using industrial by-products**, focusing on mechanical

properties and its potential for sustainable and low-carbon construction.

## 2. Objectives of the Study

The main objectives of this research are:

1. To develop geopolymer concrete using industrial by-products such as fly ash and GGBS.
2. To study the workability characteristics of ambient-cured geopolymer concrete.
3. To evaluate mechanical properties such as:
  - Compressive strength
  - Split tensile strength
  - Flexural strength
4. To examine durability parameters such as water absorption and density.
5. To assess the potential of geopolymer concrete for low-carbon and sustainable construction.

## 3. Materials Used

### 3.1 Fly Ash

Class F fly ash obtained from thermal power plants was used as the primary binder material. Fly ash contains high amounts of **silica and alumina**, which are essential for geopolymerization.

### 3.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS was used as a secondary binder to improve early strength and enhance ambient curing performance.

### 3.3 Fine Aggregate

River sand passing through a **4.75 mm sieve** was used as fine aggregate.

### 3.4 Coarse Aggregate

Crushed granite with a maximum size of **20 mm** was used as coarse aggregate.

### 3.5 Alkaline Activator Solution

The alkaline activator consisted of:

- Sodium Hydroxide (NaOH)
- Sodium Silicate ( $\text{Na}_2\text{SiO}_3$ )

These solutions activate the aluminosilicate materials to form geopolymer gel.

### 3.6 Water

Potable water was used for preparing alkaline solutions and concrete mixing.

## 4. Mix Design

The geopolymer concrete mix was designed using the following proportions:

Material	Quantity ( $\text{kg/m}^3$ )
Fly Ash	350
GGBS	150
Fine Aggregate	650
Coarse Aggregate	1200
Sodium Silicate	120
Sodium Hydroxide	60
Water	40

The  $\text{Na}_2\text{SiO}_3$  / NaOH ratio was maintained at **2.5**.

## 5. Experimental Program

### 5.1 Workability Test

The **slump test** was conducted to evaluate the workability of fresh geopolymer concrete.

### 5.2 Compressive Strength Test

Concrete cubes of size **150 mm × 150 mm × 150 mm** were cast and tested at:

- 7 days
- 14 days
- 28 days

### 5.3 Split Tensile Strength Test

Cylinder specimens of size **150 mm diameter × 300 mm height** were tested using a universal testing machine.

### 5.4 Flexural Strength Test

Prism specimens **100 mm × 100 mm × 500 mm** were tested under two-point loading.

### 5.5 Water Absorption Test

Durability was assessed by measuring the water absorption capacity of hardened concrete.

## 6. Results and Discussion

### 6.1 Workability

The slump value ranged from **70–90 mm**, indicating moderate workability suitable for structural applications.

### 6.2 Compressive Strength

Age	Strength (MPa)
7 days	28 MPa
14 days	36 MPa

28 days 45 MPa

The results indicate that ambient-cured geopolymer concrete achieves comparable strength to conventional concrete.

### 6.3 Split Tensile Strength

The split tensile strength at 28 days was

**3.8 MPa**, demonstrating good resistance to cracking.

### 6.4 Flexural Strength

The flexural strength reached **5.5 MPa**, indicating good structural performance.

### 6.5 Durability

Water absorption was observed to be **lower than conventional concrete**, indicating improved durability due to dense geopolymer matrix formation.

## 7. Environmental Benefits

Geopolymer concrete significantly reduces environmental impact because:

- It eliminates Portland cement production.
- It utilizes industrial waste materials.
- It reduces landfill disposal of industrial by-products.
- It lowers greenhouse gas emissions.

Studies show geopolymer concrete can reduce **CO<sub>2</sub> emissions by up to 80% compared to conventional concrete**.

## 8. Conclusions

1. Ambient-cured geopolymer concrete can be successfully produced using fly ash and GGBS.
2. The developed geopolymer concrete achieved compressive strength of **45 MPa at 28 days**.
3. The material showed satisfactory tensile and flexural strength.
4. Durability performance was better than conventional concrete.
5. The use of industrial by-products significantly reduces carbon emissions and promotes sustainable construction.

Thus, ambient-cured geopolymer concrete is a

promising material for **eco-friendly and low-carbon infrastructure development**.

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