# Parametric Comparison of Geo Polymer Concrete with Plain Cement Concrete

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**Abstract**

**This Report presents an experimental investigation on the comparison of PCC and GPC cubes. Now a days the world is in need of many types of improvements in every field of science. Especially, in order to mere the demand of the advancements. In the field of civil engineering, advancements in the concrete technology is an area in which many researchers are working on. As the concrete is one of the widely used construction material, manufacture of concrete results in CO2 emissions and hence pollution in the universe which results in the global warming problem. So there has evolved the Geo polymer concrete called as green concrete. The Geo polymer materials is an environmental friendly construction materials. This study is based on the use of ground granulated blast furnace slag (GGBS) and fly ash in synthesizing cement free Geo polymer concrete and subsequent study on the durability of Geo polymer concrete have been conducted earlier by many researchers. The geopolymer concrete is manufactured by polymerization of GGBS slag, fly ash with alkali activator fluid (Sodium silicate and sodium hydroxide). An experimental study was performed on the application of the reinforced Geo polymer cubes. Tests are performed in order to show whether they follow any pattern in their properties as that of normal cement concrete, these Geo polymer cubes are tested for the water absorption and the characteristics compressive strength followed by the crack with the normal PCC cubes. Because, we have conventional code of practice for ordinary reinforced cement concrete where as we do not have for the Geo polymer concrete in order to fetch some relation for both the type of concretes whether it becomes overestimate or under estimate the study is conducted to compare the similarity (if any) between GPC and PCC on the mechanical properties mainly like water absorption, shear, etc…. are considered for the comparison. The objective of the study is to assess if the code applicable for normal PCC are also applicable for geopolymer concrete**

**Keywords: Geopolymer, Ground granulated blast furnace slag, Fly ash, PCC, Compressive strength, Sodium silicate, sodium hydroxide**

## INTRODUCTION

Now a days concrete playing vital role in this emerging world and has brought a great change in the evolution of the world. But at present, the making of concrete are affecting the atmospheric conditions. The temperatures got increased to a great extent as a result of the emission of carbon dioxide as the greenhouse gas emissions into the atmosphere. This is creating a great problem in the environment, causing imbalance in the ecosystem, which has brought a mutation in the biodiversity as well. Everybody in the universe emits appropriate amount of carbon dioxide into the atmosphere called as the carbon foot print. But the carbon foot print of cement is comparatively more than the remaining aspects. Most common construction material used in cement from the ancient era after the evolution of that took place. At that time, the evolution of cement is a boon which is done by Willian Aspidin which has brought a great change to the emerging world. Now, the time has changed, the conditions there is a need to change accordingly to the change what have got now. So, many researchers are doing research on various emerging concretes which are suitable for the appropriate conditions one among them is the geo polymer concrete. Concrete is used globally in the construction of building, bridges, pavements, runways, side walks, and dams. It is usually associated with Portland cement as the main component for making concrete. Portland cement concrete industry has grown universally in recent years. With the over growing urbanization and industrialization the infrastructural development is responsible for huge amount utilization of concrete as the construction material. It is estimated that the production of cement will increase from 1.5 billion tons in 1995 to 2.5 billion tonne in 2015.

A brief history and review of geopolymer technology with the aim of introducing the technology and the vast categories of materials that may be synthesized by alkali activation of Alumino silicates. Cement is indispensable for construction activity, so it is tightly linked to the global economy. Cement production has a growth of 2.5% annually, and is expected to rise from 2.55 billion tons in 2006 to 3.7-4.4 billion tons by 2050. In the context of increased awareness regarding ill effects of the over exploitation of natural resources, eco-friendly technologies are to be developed for effective management of these resources. Concrete usage around the world is second only to water cement is conventionally used as the primary binder to produce concrete. The environmental problems associated with the production of cement are well known. The amount of the carbon dioxide released during the manufacture of cement due to the calcination of limestone and combustion of fossil fuel is in the order of one tone for every ton of cement produced

**LITERATURE SURVEY**

1. S.J. Aher & Prof. A.H. Jamale (Feb 2024) Studied at the sustainability from the perspective of comparison between Geopolymer concrete and ordinary cement concrete. It considers significant factors such as $CO_2$ emissions and mechanical properties. The paper presents Geopolymer mortar from alkaline solution-activated fly ash as an alternative binder. It also looks at various curing methods, with a consideration of ambient curing for Geopolymer concrete. Lastly, it considers the susceptibility of the cast samples to strength as well as durability.

2. Prakhar Srivastava, et al (July-Aug 2024) Concluded that given the environmental concerns that are being raised due to the manufacturing of cement, the present work compares Geopolymer concrete with conventional cement concrete on the basis of its mechanical properties. Fresh-state workability and hardened-state strength (including flexural strength) are studied in the work. Destructive and non-destructive test methods are employed on the material with regression analysis employed to fit the test results. The study, therefore, gives insight into the early-age behavior as well as long-term performance of Geopolymer concrete3. “A cheap and open source alternat ive to househ old applian ce's”, Bassamru waida ,Toni mink kinen, This project around creating automation prototype with thw focus being the ability lock/unlock a door through the internet the consist of a device, a server android application

3. Sanjay Kumar & Rakesh Kumar (July 2024) Studied Geopolymer concrete as a viable sustainable option for traditional cement. It describes the Geo polymerization reaction, in which industrial waste materials like fly ash and GGBS react with alkaline liquids to form a binder, and emphasizes the vastly lower $CO_2$

emissions compared to Portland cement. The discussion also includes the potential commercial uses and benefits of utilizing Geopolymer concrete in reaching a low-carbon economy.

4.Smita Patil, et al (April 2023) Summarized the recent research progress in Geopolymer concrete. The paper discusses the applications of different supplementary cementitious materials (e.g., fly ash, GGBS, metakaolin, and rice husk ash) and their impacts on the physical and mechanical properties of Geopolymer concrete. The paper contrasted Geopolymer concrete with conventional OPC-based concrete on its sustainability, decrease in shrinkage, and increased durability but concluded the difficulty of standardizing the mix designs.

5. Shubham Dubey, et al (June 2023) Investigated contrasts reinforced Geopolymer concrete (GPC) beams with reinforced cement concrete (RCC) beams. It contrasts significant performance factors in the forms of compressive, flexural, and shear strengths. The research paper submits the environmental advantages of Geopolymer concrete based on its low $CO_2$ emission and explores its mix design as a potential alternative to traditional cement-based concrete for various structural uses.

6. M.I. Abdul Aleem & P.D. Arumairaj (Feb 2022) Encapsulates the experience and potential of Geopolymer concrete as a robust substitute for traditional Portland cement concrete. It acknowledges the environmental problems of traditional cement manufacture, such as high energy use and high $CO_2$ emissions, and presents Geo polymerization as a possible solution. The argument then proceeds to the importance of fly ash as a major source material, describes the chemistry of the alkali activation process, and discusses the resultant benefits in terms of mechanical properties and sustainability, thus making a robust case for the use of Geopolymer concrete in future construction.

## METHODOLOGY

In this study, two types of concrete cubes were prepared – one with regular cement (PCC) and the other using geopolymer materials (GPC). For PCC, a standard mix of cement, sand, gravel, and water was used. For GPC, instead of cement, fly ash and ground granulated blast furnace slag (GGBS) were combined with alkaline liquids like sodium hydroxide and sodium silicate. Concrete cubes of standard size were cast for both types. After casting, the PCC cubes were cured in water for 28 days, while the GPC cubes were cured based on their specific requirements, sometimes using heat curing. Once cured, the cubes were tested to compare their properties. These tests included compressive strength, water absorption, and observing how cracks formed. This helped to evaluate whether GPC behaves similarly to PCC and whether the same construction codes could apply to both.

## MIX DESIGN

### 3.3.1 Mix Design Proportion for M25 Concrete by using IS Code 456:2000 And 10262:2019

Cement content = 415.91 Kg/m3
Fine aggregate = 660.39 Kg/ m3
Coarse aggregate = 1111 Kg/ m3
Water content (Liter) = 187.16 Liter
W/C ratio = 0.45
i.e. Cement : Fine aggregate : Coarse aggregate =

**1:1.58:2.67**

**3.3.2 A Mix proportion for a nominal mix of 1:1.58:2.67 Geo polymer concrete mix for one cube of size (0.15mx0.15m) with alkali binder ratio of 0.8**

Mix proportion: 1:1.58:2.67
Total mix proportion: 1+1.58+2.67= 5.25
Volume of Concretes be= 0.15×
0.15x 0.15
= 3.375x10-3m

Assumed density = 2350kg/m³ Weight of one cube 8.43kg.

Weight 2350× $3.375\times10^{-3}$ = 7.93 kg.

Geo polymer material = (1/5.25)*7.93 =1.510kg

Fine aggregate content = (1.58/5.25)*7.93
= 2.387kg

Coarse aggregate content = (2.67/5.25)*7.93
= 4.033kg

Geo polymer material content.
GGBS content is (80%) of gee polymeric material= 1.208 kg
Fly ash is (20%) of geo polymeric material= 0.302 kg
Alkaline binder ratio = 0.8
Alkaline Solution = 0.8×1.510 = 1.208 kg Na2si03
Na0H = 2.5/(2.5+1.0) = 0.714
Sodium silicate solution (2.5/3.5)*1.208 = 0.863 kg
Sodium hydroxide solution (1.0/3.5)*1.208 = 0.345 kg
Sodium silicate solution contain 35% of Na2Sio3 and
65% water so Na2Sio3 = 0.302 kg water = 0.560kg
The solution is 14 molar
For a litter of solution the proportion is preferred in 4:6 ratio
Na0H = 400g water = 600g
Na0H flakes/water =0.667
Na0H Flakes = 0.667 of water
Na0H Solution = Na0H Flakes + water
Na0H Solution = 0.667 of water + water
0.345 = 1.667 of water
= 0.207kg (water)
NaOH Flakes = 0.677*0.207
= 0.139 kg

OVERALL CALCULATION:

GGBS: 1.208 kg

Fly Ash: 0.302 kg

Fine Aggregate: 2.387 kg

Coarse Aggregate:4.033 kg

Alkaline Solution (Total):1.208 kg

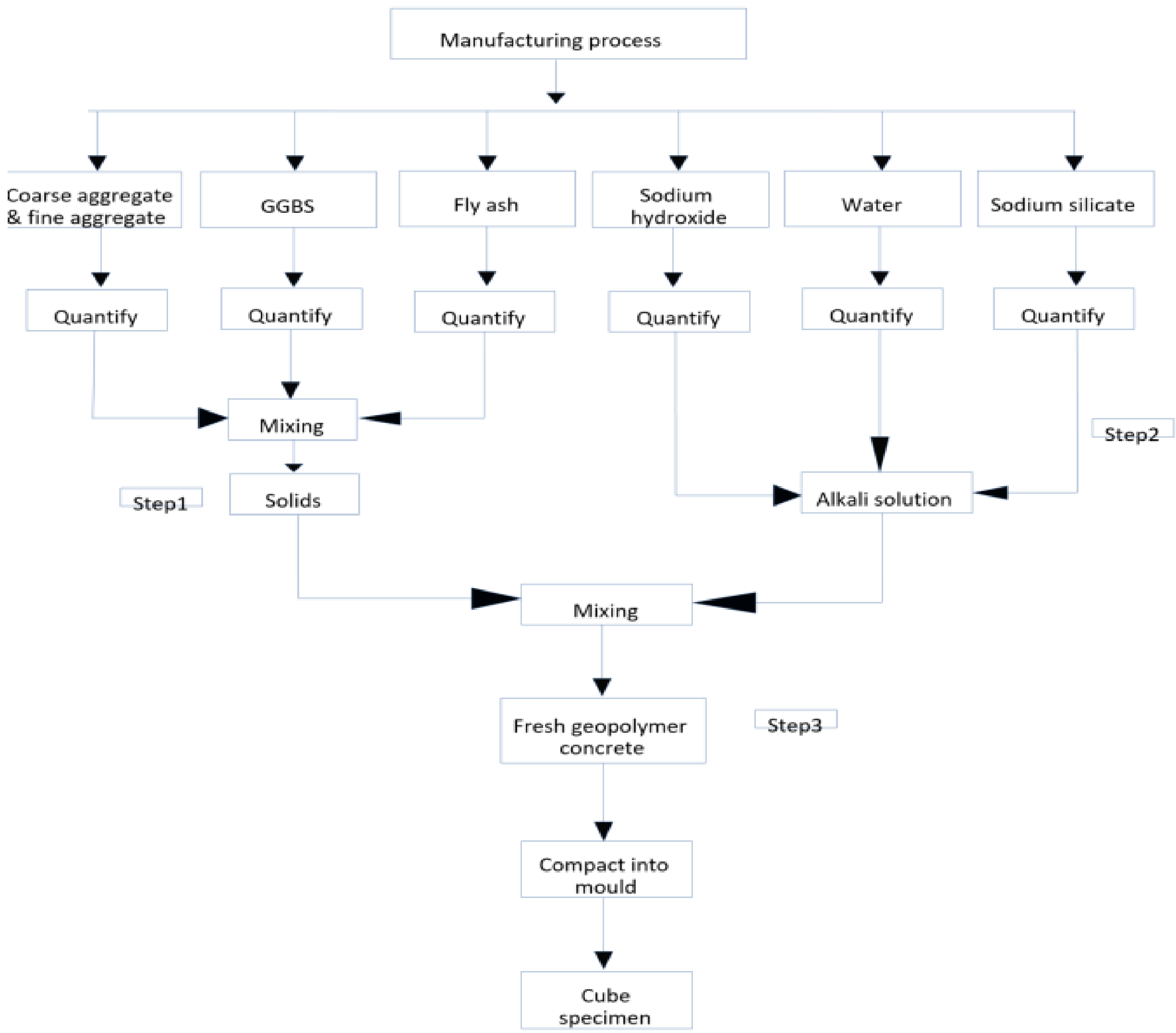
Sodium Silicate Solution Component: 0.863kg

Containing: 0.302 kg of $Na_2SiO_3$ and 0.561 kg of water.

Sodium Hydroxide Solution Component: 0.345 kg

Prepared using: 0.138 kg of NaOH flakes and 0.207 kg of water.

A Compression test uses compression testing machines to determine material behavior under constantly increasing compressive loading. Compression tests examine the safety, durability, and integrity of materials and components. A compression testing machine is a universal testing machine (UTM)equipped with application-specific compression test tools or compression platens. The tools are selected and dimensions, test temperature and maximum force values expected.




**PROBLEM DEFINATIONS**

Concrete is one of the most widely used materials in the construction industry, but its production involves the use of cement, which significantly contributes to carbon dioxide ($CO_2$) emissions and environmental pollution. This leads to serious issues like global warming. To address this problem, researchers have developed an alternative material known as Geopolymer Concrete (GPC), also referred to as green concrete, which is more environmentally friendly as it uses industrial by-products like fly ash and GGBS (Ground Granulated Blast Furnace Slag) instead of cement.

However, since GPC is a relatively new material, there are no established standard codes or guidelines available for its use in structural applications, unlike Plain Cement Concrete (PCC) which follows well-established codes. This creates uncertainty regarding its reliability, performance, and whether it can replace PCC in construction.

Therefore, this study aims to experimentally compare the mechanical and durability properties of PCC and GPC cubes, such as compressive strength, water absorption, and crack behavior, to determine if the existing codes for PCC can also be applied to GPC or if new standards need to be developed.

**RESULT**

**Table 5:1 Compressive strength of PCC**

| Sr.no | Days of curing | Initial weight (kg) | Load (KN) | Strength (N/mm$^2$) | Average strength (N/mm$^2$) |
|---|---|---|---|---|---|
| 1 | 7 | 8.65 | 406 | 18.04 | 18.68 |
| 2 | 7 | 8.94 | 425 | 18.89 | |
| 3 | 7 | 8.87 | 420 | 18.67 | |
| 1 | 28 | 8.88 | 692 | 30.76 | 30.85 |
| 2 | 28 | 8.95 | 729 | 32.40 | |
| 3 | 28 | 9.09 | 740 | 32.39 | |

**Table 5.2: Compressive strength of GPC**

| Sr.no | Days of curing | Initial weight (kg) | Load (KN) | Strength (N/mm$^2$) | Average strength (N/mm$^2$) |
|---|---|---|---|---|---|
| 1 | 7 | 8.35 | 406 | 20.5 | 20.0 |
| 2 | 7 | 8.30 | 425 | 20.0 | |
| 3 | 7 | 8.25 | 420 | 19.5 | |
| 1 | 28 | 8.60 | 692 | 32.8 | 32.01 |
| 2 | 28 | 8.59 | 729 | 32.36 | |
| 3 | 28 | 8.47 | 740 | 31.8 | |

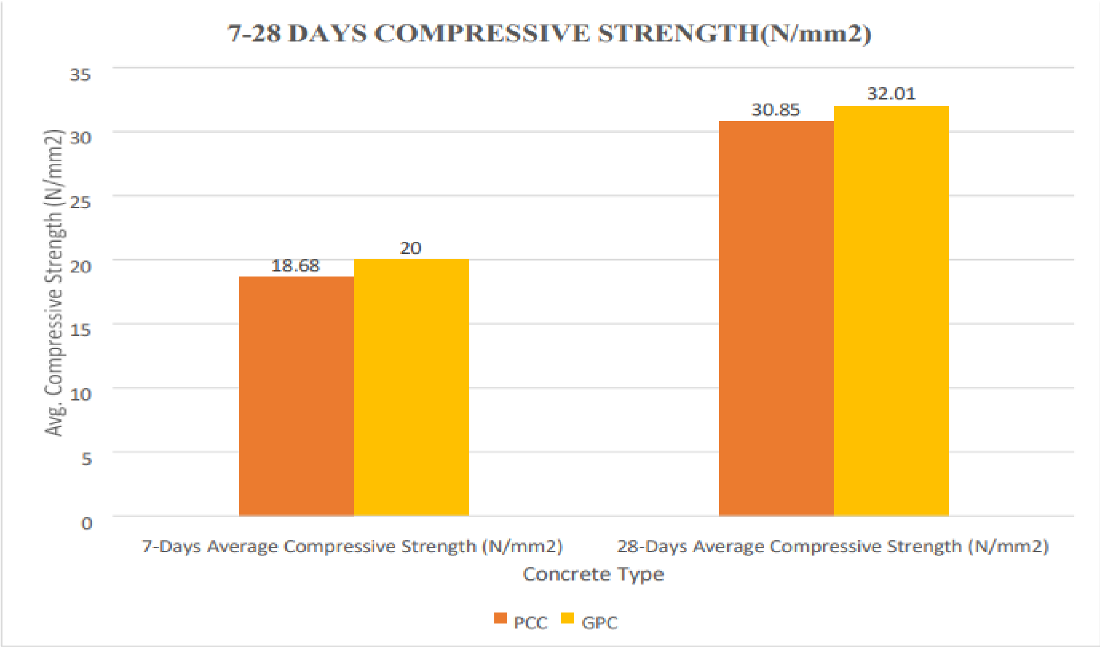
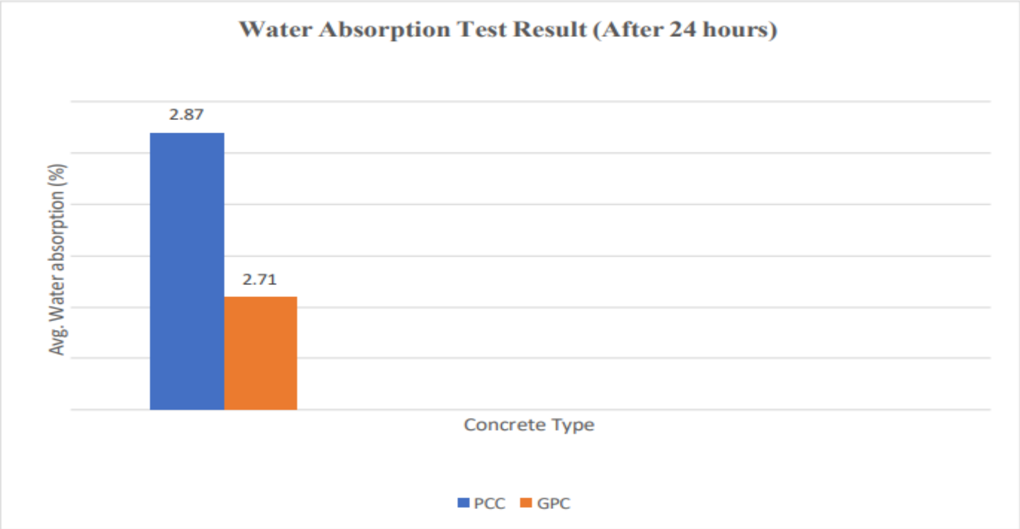



**Table 5.3: Water Absorption Test Result**

| Types of concrete | Wet cube weight | Dry cube weight | Gain (%) | Avg. Water absorption (%) |
|---|---|---|---|---|
| PCC | 8.68 | 8.47 | 2.48 | 2.87 |
| | 8.67 | 8.45 | 2.60 | |
| | 8.52 | 8.23 | 3.52 | |
| GPC | 8.53 | 8.28 | 3.01 | 2.71 |
| | 8.46 | 8.24 | 2.69 | |
| | 8.40 | 8.20 | 2.43 | |

Formula:

**(Wet Weight - Dry Weight) / Dry Weight × 100**




Graph 5.2: Water Absorption Test Result (After 24 hours)

## CEMENT CARBON EMISSION CALCULATION

STEP 1: carbon emission from conventional concrete of cement

The general formula applied for each material is:

$Emissions_{material}$ = Quantity of Material*Emission Factor of Material

The total CO2e emissions for the concrete mix are then calculated by summing the emissions from all individual materials.

Concrete Mix Design Breakdown for 1 m^3:

- Cement (CEM II/A-L): 415.91 kg/$m^3$
- Fine Aggregate (Sand): 660.39 kg/$m^3$
- Coarse Aggregate (Gravel): 1111 kg/$m^3$
- Water: 187.16 kg

Emission
Factors Used:

- Cement (CEM II/A-L): 0.65 kg CO2e/kg
- Ground Granulated Blast-furnace Slag (GGBS): 0.035 kg CO2e/kg
- Fine Aggregate (Sand): 0.012 kg CO2e/kg
- Coarse Aggregate (Gravel): 0.015 kg CO2e/kg
- Water: 0.0002 kg CO2e/kg

Step-by-Step Calculation:

1. Calculate Emissions from Cement:
The quantity of Cement (CEM II/A-L) used is 319 kg, and its emission factor is 0.65 kg CO2e/kg.
Emissions from Cement = 415.91kg* 0.65 kg CO2e/kg = 270.34 kg CO2e

2. Calculate Emissions from Fine Aggregate (Sand):
The quantity of Fine Aggregate (Sand) used is 660.39 kg, and its emission factor is 0.012 kg CO2e/kg.
Emissions from Fine Aggregate = 660.39 kg* 0.012 kg CO2e/kg = 7.924 kg CO2e

3. Calculate Emissions from Coarse Aggregate (Gravel): The quantity of Coarse Aggregate (Gravel) used is 1111 kg, and its emission factor is 0.015 kg CO2e/kg.
Emissions from Coarse Aggregate = 1111 kg* 0.015 kg CO2e/kg =16.665 kg CO2e

4. Calculate Emissions from Water:

The quantity of Water used is 187.16 kg, and its emission factor is 0.0002 kg CO2e/kg.
Emissions from Water = 187.16 kg* 0.0002 kg CO2e/kg = 0.0374 kg CO2e

Total Carbon Emissions for 1 m^3 of Concrete Mix :

To determine the total carbon emissions, we sum the individual emissions from each material:

Total CO2e Emissions = (Emissions from Cement) + (Emissions from Fine Aggregate) + (Emissions from Coarse Aggregate) + (Emissions from Water)

Total CO2e Emissions = 270.34 + 7.924+ 16.665 + 0.0374 = 294.966 kg CO2e

Therefore, the calculated embodied carbon emissions for 1 cubic meter of Concrete Mix are approximately 294.966 kg CO2e.

STEP 2: Carbon emission from GGBS and Flyash from GPC mix calculation

1. Calculate Emissions from GGBS: 1.208 kg *0.07 kg CO2e/kg = 0.0845 kg CO2e
2. Calculate Emissions from Flyash:0.302 kg * 0.027 kg CO2e/kg = 0.0081 kg CO2e

Total carbon emission = Calculate Emissions from GGBS + Calculate Emissions from Flyash
= 0.0845 kg CO2e + 0.0081 kg CO2e
= 0.0927 kg CO2e

STEP 3: Total carbon emission reduction

Total carbon emission reduction =Emission from conventional concrete of cement – Emission from GGBS and Flyash from GPC mix calculation
= 294.966 kg CO2e - 0.0927 kg CO2e
= 353.52 kg CO2e

## CONCLUSION

- Geopolymer concrete has emerged as a viable and environmentally friendly alternative to conventional cement concrete. According to the research in this project, geopolymer concrete exhibits high compressive strength and durability, especially at elevated temperatures. With the appropriate mix of sodium hydroxide and sodium silicate, it is possible to achieve excellent performance in geopolymer concrete compared to traditional concrete. Overall, this study highlights the potential of geopolymer concrete, which helps to mitigate the negative environmental impacts of cement production. It demonstrates that geopolymer concrete can be used as a practical and efficient material for various construction applications
- GPC (Geopolymer Concrete) shows higher early compressive strength (20.0 N/mm²) compared to PCC (Portland Cement Concrete) (18.68 N/mm²).This indicates that GPC gains strength more rapidly in early curing stages.
- GPC again outperforms PCC with an average strength of 32.01 N/mm², while PCC reaches 30.85 N/mm².This suggests that GPC not only gains strength faster but also achieves slightly higher final strength

- Geopolymer Concrete (GPC) has 7.06% more strength than Plain Cement Concrete (PCC) after 7 days. After 28 days, GPC shows a 3.76% increase in strength compared to PCC
- GPC absorbs 5.57% less water than PCC, which means it is more durable.
- GPC shows a lower average water absorption than PCC. suggests that GPC has a denser microstructure, reducing its ability to absorb water
- Lower water absorption in GPC implies better durability and resistance to water ingress, which can be beneficial for structures exposed to moisture or harsh environmental conditions.
- GPC may thus offer enhanced long-term performance and lower maintenance requirements compared to PCC
- The fly ash & GGBS can be used to produce the geopolymer binder phase which can be bind the aggregate to form GPC. Therefore these concrete can be considered as ecofriendly materials.
- Total carbon emission reduction approximately 353.52 kg CO2e.
- Results obtained from experimental work are summarized that the GPC significantly reduces $CO_2$ emissions by eliminating cement use, offering a sustainable alternative to PCC.

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