Nile Higher Institute
of Engineering and Technology

Department of Civil Engineering

"Properties and Strength of Materials Project"

Effect of Sodium Hydroxide to Sodium Silicate Ratio on Fly Ash Geopolymer Concrete

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Abstract

Geopolymer concrete is an innovative and environmentally friendly building material and alternative to Portland cement concrete. The use of geopolymer reduces the demand for Portland cement, which is responsible for high carbon dioxide emissions. This project investigates the properties and performance of geopolymer concrete made from fly ash, especially the molarity ratios of 8M, 10M, and 12M, with a ratio of sodium hydroxide to sodium silicate in a ratio of 1 to 2

This project comply with Egyptian code ECP: 203 (2020), Egyptian standard specification ES requirements (4756-1/2005) (Appendix A). the results showed that the mechanical properties of geopolymer concrete improved with increased retio of sodium hydroxide to sodium silicate

Chapter 1 : Initial Report

1.1 Project Definition

The development of a country may be directly related to the development of the cement industry. Portland cement is the most man-made material on Earth used to make concrete, and it is the most widely used building material on the planet. The demand for cement is constantly increasing, and the production of cement and concrete is expected to increase in the coming decades. Some economists use concrete production as a measure of a country's economic strength. The cement industry consumes huge amounts of raw materials and energy. Apart from this, a large amount of solid waste and gaseous emissions, especially carbon dioxide, are produced

1.2 The problem

The cement industry is one of the emitters of greenhouse gases, as 0.83 kg of carbon dioxide is produced per kg of cement production, which leads to 8% of the total global anthropogenic carbon dioxide emissions. The aforementioned defects of concrete forced researchers to find new bonds as an alternative to traditional cement-concrete so that better and less energy-consuming raw materials could be obtained with less emissions of greenhouse gases. Now, one of the most important new bonding materials is geopolymer cement

1.3 Study Objectives

In this research, the focus was on changing the concentration of sodium hydroxide and the stability of the ratio of sodium hydroxide to sodium silicate, and the effect of this on the mixture of geopolymer concrete, and knowing the extent of the importance of geopolymer concrete to use it instead of cement concrete

1.4 Existing Solutions

Using the Fly ash , we compare the results of the tests with

other research or previous work to reach a better judgment of such material. To understand the effect of using such materials in different fields, the following parameters have been investigate :

• The type and properties of geopolymer concrete.

▪The configuration of the tests and their results

1.5 Composition Of Geopolymer Concrete

The following materials are required for the production of geopolymer concrete:

1_Fly Ash: It is a by-product of thermal power plant.

2_ Activator Solution: The catalytic liquid system is used as an activator solution. It is a mixture of silicate and hydroxides along with distilled water.

3_Aggregates: Fine and coarse aggregates as required for normal concrete.

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4_ water

Chapter 2 : Geopolymer Concrete

2.1 Introduction

Geopolymer concrete is a type of concrete that is made using a

different binding agent than traditional Portland cement. Instead of using Portland cement, which is made from limestone and clay and is responsible for a significant amount of greenhouse gas emissions, geopolymer concrete uses a geopolymer binder.The geopolymer binder is typically made from industrial waste materials, such as fly ash, slag, or silica fume, which are rich in silicon and aluminum. The waste materials are mixed with an alkaline solution, such as sodium hydroxide or potassium hydroxide, to trigger a chemical reaction that forms a geopolymer.Geopolymer concrete has several advantages over traditional Portland cement concrete, including:Lower carbon footprint: Geopolymer concrete can significantly reduce the carbon footprint of construction projects because it uses industrial waste materials instead of mined materials.Higher strength and durability: Geopolymer concrete can have higher compressive and flexural strength than traditional Portland cement concrete, and it can be more resistant to chemical and thermal damagepermeability than traditional Portland cement concrete, which can make it more resistant to water and other fluids.Faster curing time: Geopolymer concrete can cure faster than traditional Portland cement concrete, which can help to reduce construction time and costs.Fire resistance: Geopolymer concrete can be more fire-resistant than traditional Portland cement concrete because it does not contain organic materials that can burn.Despite these advantages, geopolymer concrete is still a relatively new technology and there are some challenges to its widespread adoption. For example, the production process can be more complex than traditional concrete, and the high alkalinity of the curing process can be difficult to manage. However, ongoing research and development are working to address these challenges and improve the viability of geopolymer concrete as a sustainable building material.

2.2 Geopolymer Concrete Production

There are a number of challenges associated with producing geopolymer concrete. Some of the main challenges include:

1- Raw material quality and consistency: The quality and consistency of the raw materials used to produce geopolymer concrete can have a significant impact on the performance of the final product. The chemical composition and particle size of the raw materials must be carefully controlled to ensure that the geopolymerization process occurs correctly.

2- High alkalinity: The alkaline environment required for the geopolymerization process can be challenging to manage, as it can be hazardous to workers and can cause corrosion of equipment.

3- Curing time: Geopolymer concrete typically has a faster curing time than traditional Portland cement concrete, which can be an advantage in some applications. However, the rapid hardening can also make it difficult to work with the material and can limit the time available for placement and finishing.

4- Lack of standards and regulations: Unlike traditional Portland cement concrete, there are currently no standardized specifications or regulations for geopolymer concrete. This can make it difficult for engineers and contractors to determine appropriate mix designs and construction practices

5- Limited availability of raw materials: The availability and cost of raw materials used to produce geopolymer concrete can vary depending on location and market demand. This can make it challenging to scale up production and make geopolymer concrete cost-competitive with traditional concrete.

- In addition to the challenges mentioned earlier, there are several other factors that can impact the production and use of geopolymer concrete. Some of these include:

1- Lack of industry acceptance: Geopolymer concrete is a relatively new technology and has not yet been widely adopted by the construction industry. This can make it difficult to secure funding and investment for research and development, and can limit the availability of trained personnel and specialized equipment.

2- Compatibility with existing infrastructure: The use of geopolymer concrete may require changes to existing construction practices and infrastructure. For example, the high alkalinity of the curing process can cause corrosion of steel reinforcement, which may require the use of alternative reinforcement materials or coatings.

3- Long-term durability: While geopolymer concrete has shown promise in terms of strength and durability, there is still relatively little data available on its long-term performance. More research is needed to determine how geopolymer concrete will perform over time in different environmental conditions and exposure scenarios.

4- Public perception: The use of industrial waste materials in the production of geopolymer concrete may raise concerns among some members of the public about the safety and environmental impact of the material. More education and outreach may be needed to address these concerns and build public acceptance

5- Geopolymer concrete has the potential to significantly reduce the carbon footprint of the construction industry. The production of traditional Portland cement is responsible for approximately 7% of global carbon dioxide emissions, so the adoption of geopolymer concrete could have a significant impact on greenhouse gas emissions.

6- Geopolymer concrete can be used in a wide range of applications, including structural and non-structural elements such as walls, floors, and countertops. It can also be used in precast concrete products and as a repair material for existing concrete structures.

7- The use of geopolymer concrete can lead to cost savings over the long term. While the initial production costs may be higher than traditional concrete, the material's durability and resistance to damage can result in reduced maintenance costs and longer service

life.

8- Geopolymer concrete can be produced using a wide range of industrial waste materials, which can help to divert these materials from landfills and reduce the use of finite natural resources.

9- Ongoing research is exploring new applications for geopolymer concrete, such as in the production of 3D-printed structures and as a material for road construction.Overall, geopolymer concrete has the potential to be a game-changer.

in the construction industry, offering a sustainable alternative to

- traditional Portland cement concrete. While there are still challenges to overcome, ongoing research and development are working to improve the performance and viability of geopolymer concrete and make it a more widely adopted building material

2.3 Types Of Waste Materials Used In Geopolymer Concrete Production

Geopolymer concrete can be produced using a wide range of waste materials, which can vary in composition and properties. This can make it challenging to develop standardized mix designs and construction practices.

One of the key advantages of using waste materials in geopolymer concrete production is that it can help to reduce the use of finite natural resources, such as limestone and clay, which are used to produce traditional Portland cement.

The use of waste materials in geopolymer concrete production can also help to reduce the carbon footprint of construction projects. The production of traditional

Portland cement is responsible for a
significant amount of greenhouse gas emissions, whereas the use of
waste materials can significantly reduce the carbon footprint of the construction industry.

1-Fly ash: Fly ash is a fine powder that is a byproduct of burning
pulverized coal in electric power generating plants. It is one of the most commonly used materials in geopolymer concrete production.Fly ash is one of the most commonly used materials in geopolymer concrete production due to its abundance and availability. It is estimated that the world generates more than 500 million tons of fly ash annually, much of which is currently disposed of in landfills.

2- Slag: Slag is a byproduct of the iron and steel industry that is produced during the smelting process. It is rich in silicon and aluminum and can be used as a source material for geopolymer binders.Slag is another material that is commonly used in geopolymer concrete production. It is estimated that the steel industry alone produces more than 400 million tons of slag per year, much of which is currently disposed of in landfills.

3- Silica fume: Silica fume is a byproduct of silicon and ferrosilicon metal production. It is a fine powder that is rich in silicon dioxide and can be used as a source material for geopolymer binders Silica fume is a relatively expensive material compared to other waste materials used in geopolymer concrete production.

- However, it has a very high silica content and can be used in

smaller quantities to achieve the same strength and durability as other materials.

1- Red mud: Red mud is a waste material that is produced during the production of alumina from bauxite ore. It is rich in aluminum and can be used as a source material for geopolymer binders.Red mud is a waste material that is generated in large quantities during the production of alumina. It contains large amounts of aluminum and iron, which makes it a promising material for geopolymer concrete production.

2- Rice husk ash: Rice husk ash is a byproduct of burning rice husks for energy production. It is rich in silica and can be used as a source material for geopolymer binders.

Rice husk ash is a waste material that is generated during the production of rice. It is a promising material for geopolymer concrete production due to its high silica content and availability in many parts of the world.

3- Glass powder: Glass powder is a waste material that is produced during the recycling of glass bottles and other glass products. It can be used as a source material for geopolymer binders due to its high silica content.

Glass powder is a relatively new material that is being explored for use in geopolymer concrete production. Its high silica content and availability make it a promising option for sustainable building materials

2.4 Used of Geopolymer Concrete

Geopolymer concrete can be used in a wide range of construction projects, including both structural and non-structural applications. Here are some examples:

1- Foundations: Geopolymer concrete can be used to construct foundations for buildings, bridges, and other structures. Its high strength and durability make it an ideal material for supporting heavy loads.

2- Walls: Geopolymer concrete can be used to construct load-bearing and non-load-bearing walls. Its low permeability and resistance to chemical and thermal damage make it an attractive option for walls that will be exposed to harsh environmental conditions.

3- Floors: Geopolymer concrete can be used to construct floors for industrial and commercial buildings. Its high compressive strength and low permeability make it ideal for areas that will be subject to heavy traffic or exposure to chemicals.

4- Precast concrete products: Geopolymer concrete can be used to produce precast concrete products such as pipes, pavers, and panels. Its fast curing time and high strength make it an attractive option for precast products that need to be produced quickly and efficiently.

5- Repair and rehabilitation: Geopolymer concrete can be used to repair and rehabilitate existing concrete structures. Its low shrinkage and excellent bonding properties make it an effective material for repairing cracks and spalling in concrete structures.

6- Road construction: Geopolymer concrete can be used in road construction as a sustainable alternative to traditional Portland cement concrete. Its high strength and durability make it an attractive option for roads that will be subject to heavy traffic and exposure to harsh environmental conditions.

7- Bridges: Geopolymer concrete can be used in the construction of bridge decks, piers, and abutments. Its high strength and durability make it an ideal material for structures that will be exposed to a wide range of environmental conditions, including freeze-thaw cycles, saltwater corrosion, and heavy traffic loads.

8- Tunnels: Geopolymer concrete can be used in the construction of tunnels and underground structures. Its low permeability and resistance to chemical and thermal damage make it well-suited for structures that will be exposed to harsh underground environments.

9- High-rise buildings: Geopolymer concrete can be used in the construction of high-rise buildings as a sustainable alternative to traditional concrete. Its high strength and durability make it suitable for supporting the weight of tall structures, and its low carbon footprint can help to reduce the environmental impact of large-scale construction projects.

10- Dams and reservoirs: Geopolymer concrete can be used in the construction of dams and reservoirs. Its ability to withstand high compressive and tensile stresses and resist water penetration make it an attractive option for structures that will be exposed to high hydrostatic pressure.

11- Coastal structures: Geopolymer concrete can be used in the construction of coastal structures, such as seawalls, jetties, and breakwaters. Its resistance to saltwater corrosion and ability to withstand high wave loads make it an ideal material for structures that will be exposed to the harsh marine environment.

12- Disaster-resistant structures: Geopolymer concrete can be used to construct disaster-resistant structures that can withstand earthquakes, hurricanes, and other natural disasters. Its high strength and durability can help to reduce the risk of structural damage and collapse, and its low permeability can help to prevent water damage.

13- Urban infrastructure: Geopolymer concrete can be used in the construction of urban infrastructure, such as sidewalks, curbs, and gutters. Its low permeability and resistance to chemical and thermal damage make it an attractive option for infrastructure that will be exposed to heavy traffic and harsh environmental conditions.

14- Green roofs: Geopolymer concrete can be used to construct green roofs, which are becoming increasingly popular in urban areas. Its high strength and durability can support the weight of the green roof system, and its low permeability can help to prevent water damage to the building.

15- Infrastructure rehabilitation: Geopolymer concrete can be used to rehabilitate existing infrastructure, such as bridges and roads, by repairing and strengthening deteriorated structures. Its low shrinkage and excellent bonding properties make it an effective material for repairing cracks and spalling in concrete structures.

16- Fire-resistant structures: Geopolymer concrete has excellent fire-resistant properties, making it an attractive option for structures that require high fire resistance, such as tunnels, high-rise buildings, and industrial facilities.

17- Energy-efficient buildings: Geopolymer concrete can be used to construct energy-efficient buildings by incorporating insulation materials into the geopolymer matrix. This can help to reduce the energy required for heating and cooling, and can lower the overall carbon footprint of the building.

18- Sustainable infrastructure: Geopolymer concrete can help to create sustainable infrastructure by reducing the carbon footprint of construction projects and conserving natural resources. In addition, the use of waste materials in geopolymer concrete production can help to reduce the amount of waste sent to landfills.

19- Reduced maintenance costs: Geopolymer concrete has excellent durability and resistance to chemical and thermal damage, which can help to reduce the maintenance requirements and associated costs of infrastructure and buildings.

20- Improved air quality: Geopolymer concrete can help to improve air quality by reducing the amount of carbon dioxide emissions associated with the production of traditional Portland cement concrete. This can have a positive impact on human health and the environment.

Overall, the potential benefits of geopolymer concrete are vast, and ongoing research and development are working to explore new applications and improve the performance of this sustainable building material. As the construction industry continues to seek out more sustainable and cost-effective solutions, geopolymer concrete is likely to play an increasingly important role.

2.5 Geopolymer Development

Geopolymer cements develop through a series of several distinct reaction processes from initial pozzolanic activation to final microstructure development. The major processes involved are dissolution of the alumino silicate species within a highly basic, alkaline environment, polymerization of the dissolved minerals into short-lived structural gel, precipitation of formed hydration products similar to natural zeolites and final hardening of the matrix by excess water exclusion and the growth of crystalline structures. Figure 2.5 shows the overall polymerisation process in alkali activated geopolymer concrete

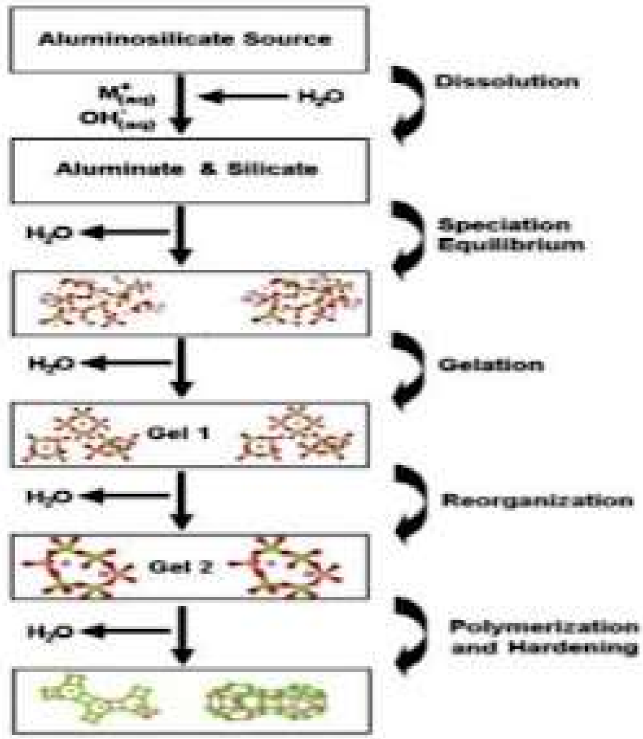

Fig2.1 Geopolymer Development

2.6 Difference Between Geopolymer Concrete And Cement Concrete

The cost of geopolymer concrete can vary depending on several factors such as the type of waste material used, the availability of raw materials, and the transportation costs. Generally, geopolymer concrete can be more expensive to produce than traditional Portland cement concrete due to the higher cost of some of the raw materials used, such as sodium silicate and sodium hydroxide.

However, it is important to consider the long-term costs and benefits of using geopolymer concrete compared to traditional Portland cement concrete. While geopolymer concrete may have a higher initial cost, it can offer several potential benefits that can offset this cost over the life cycle of the structure. For example, geopolymer concrete has excellent durability and resistance to chemical and thermal damage, which can reduce the maintenance costs associated with concrete structures. In addition, the use of waste materials in geopolymer concrete production can help to reduce the environmental impact of construction projects and reduce the amount of waste sent to landfills.

Certainly, here are some additional details about the cost of geopolymer concrete compared to traditional Portland cement concrete:

1- Raw materials: The cost of raw materials can be a major factor in the cost of producing geopolymer concrete. While some waste materials used to produce geopolymer concrete may be inexpensive or even free, other materials such as sodium silicate and sodium hydroxide can be more costly than the raw materials used to produce traditional Portland cement concrete.

2- Manufacturing process: The manufacturing process for geopolymer concrete can be more complex and require more specialized equipment than the manufacturing process for traditional Portland cement concrete, which can increase the production cost.

3- Transportation: The transportation costs of raw materials and finished products can also affect the overall cost of geopolymer concrete. If the raw materials are not readily available locally, transportation costs can be higher, which can increase the cost of producing geopolymer concrete.

4- Long-term costs and benefits: While geopolymer concrete may have a higher initial cost than traditional Portland cement concrete, it can offer several potential long-term benefits that can offset this cost. For example, the durability and resistance to chemical and thermal damage of geopolymer concrete can help to reduce maintenance costs over the life cycle of the structure.

5- Scale of production: The cost of geopolymer concrete can also depend on the scale of production. As the technology continues to develop and become more widely adopted, the cost of producing geopolymer concrete may decrease as economies of scale are achieved.

Overall, the cost of geopolymer concrete can be influenced by several factors, and it is important to consider the long-term costs and benefits when evaluating the economic feasibility of using this sustainable building material. As the technology continues to develop and become more widely adopted, the cost of producing geopolymer concrete may decrease, making it a more cost-effective alternative to traditional Portland cement concrete.

2.7 Applications of Geopolymer Concrete

Geopolymer mortars and concretes possess a high potential for use in commercial applications due to their enhanced durability, thermal and chemical 22 resistance properties, rapid development of mechanical strength, adherence to reinforcements aggregates and economic benefit as an industrial by-product material.

2.7.1 Concrete Pipes

The use of geopolymer concretes for commercial sewer piping is a good option from the basis of their resistance to sulphates and acidic products. Sulphuric acid is generated in conventional sewer systems through the breakdown of hydrogen sulphide by aerobic bacteria in the system and is the main factor in corrosion and structural deterioration of the piping networks over time. Approximately 40 percent of the damage to PCC pipes can be attributed to corrosion by biogenous sulphuric acid attack as a result of long flow periods and insufficient ventilation of wastewater.

Fig2.2 precast geopolymer concrete pipes

2.7.2 Structural Elements

Geopolymer concrete is used for the casting of both columns and beams. The load capacity of geopolymer columns is influenced by load eccentricity, concrete compressive strength values and longitudinal reinforcement ratios. Decreased eccentricity loading and reinforcement ratio increases favour an increase in overall column load capacity.

Fig2.3 geopolymer columns

Fig2.4 geopolymer beam

2.7.3 pavements

Geopolymer concrete is used for the construction of heat resistant pavement due to its thermal capacity. Pozzolan-based geopolymer cements do not readily decompose when exposed to high temperatures and appear to be more structurally stable under such conditions than PCC. Geopolymer cements utilize more and store less water from solution during particle reaction, and therefore, prevent aged dry shrinkage and strength degradation due to rapid water loss under extreme heat.

2.7.4 retaining Wall

A total of over fifty 40 MPa geopolymer precast panels were used a retaining wall for a private residence. The panels were up to 6 metres long by 2.4 metres wide and were designed to retain earth pressure of 3 metres.

2.8 Structures That Used Geopolymer Concrete

There have been several structures that have used geopolymer concrete in their construction. Here are a few examples:

1- The Sydney Harbour Bridge: In 2018, geopolymer concrete was used to repair the Sydney Harbour Bridge in Australia. The geopolymer concrete was used to repair the bridge's concrete pylons, and the project was completed in just four months.

2- The Melbourne Metro Rail Tunnel: The Melbourne Metro Rail Tunnel in Australia is currently under construction and will be the first rail tunnel in the world to use geopolymer concrete lining segments. The use of geopolymer concrete is expected to reduce the carbon footprint of the project by up to 80%.

3- The Nîmes-Montpellier high-speed rail line: The Nîmes-Montpellier high-speed rail line in France used geopolymer concrete for the construction of several structures, including bridge decks and retaining walls. The use of geopolymer concrete helped to reduce the overall carbon footprint of the project.

4- The San Francisco-Oakland Bay Bridge: Geopolymer concrete was used in the construction of the San Francisco-Oakland Bay Bridge in California. The geopolymer concrete was used to construct the foundation piles for the bridge's main tower.

5- The Kwinana Freeway Extension: The Kwinana Freeway Extension project in Western Australia used geopolymer concrete for the construction of a noise wall. The use of geopolymer concrete helped to reduce the project's carbon footprint and reduce the amount of waste sent to landfills.

6- The Marina Barrage: The Marina Barrage in Singapore used geopolymer concrete for the construction of its floodgates. The geopolymer concrete was hosen for its high strength and durability in the harsh marine environment.

7- The University of Queensland's Advanced Engineering Building: The University of Queensland's Advanced Engineering Building in Australia is one of the largest geopolymer concrete structures in the world. The building's facade, walls, and columns were constructed using geopolymer concrete, which helped to reduce the carbon footprint of the project.

8- The Toulouse-Blagnac Airport: The Toulouse-Blagnac Airport in France used geopolymer concrete for the construction of its new terminal building. The geopolymer concrete was used for the facade panels and contributed to the overall sustainability of the building.

9- The Fujairah 2 Reverse Osmosis Desalination Plant: The Fujairah 2 Reverse

Osmosis Desalination Plant in the United Arab Emirates used geopolymer concrete for the construction of its intake structures. The geopolymer concrete was chosen for its high strength and durability in the harsh marine environment.

10- The London Olympic Park: The London Olympic Park used geopolymer concrete for the construction of several structures, including some of the bridges and retaining walls. The use of geopolymer concrete helped to reduce the carbon footprint of the project and enhance its sustainability.

11- The La Geode: The La Geode in Paris, France, is a large spherical building that houses an IMAX theater. The geodesic structure was constructed using geopolymer concrete, which helped to reduce the overall weight of the structure and enhance its durability.

12- The Adelaide Desalination Plant: The Adelaide Desalination Plant in Australia used geopolymer concrete for the construction of its intake structures and outfall pipes. The use of geopolymer concrete helped to reduce the carbon footprint of the project and increase its sustainability.

13- The Rostov Arena: The Rostov Arena in Russia, a stadium built for the 2018 FIFA World Cup, used geopolymer concrete for the construction of its foundation piles. The use of geopolymer concrete helped to reduce the environmental impact of the project and enhance its sustainability.

14- The Yarra Valley Water Treatment Plant: The Yarra Valley Water Treatment Plant in Australia used geopolymer concrete for the construction of its sedimentation tanks. The use of geopolymer concrete helped to reduce the carbon footprint of the project and increase its durability.

15- The Tonsley Innovation District: The Tonsley Innovation District in Australia used geopolymer concrete for the construction of several structures, including precast panels and retaining walls. The use of geopolymer concrete helped to reduce the carbon footprint of the project and increase its sustainability.

Overall, the use of geopolymer concrete is becoming more widespread in the construction industry, and its potential applications continue to expand. As research and development efforts continue, we can expect to see more structures using geopolymer concrete in the future, as the industry continues to seek out more sustainable and durable building materials.

2.9 Advantages Of Geopolymer Concrete

- Lower carbon footprint: Geopolymer concrete can have a significantly lower carbon footprint than traditional Portland cement concrete due to its lower cement content and the use of industrial waste materials as raw materials. This can make it a more sustainable option for construction projects.
- Durability: Geopolymer concrete can be more durable than traditional Portland cement concrete in certain applications, due to its higher compressive strength, lower permeability, and resistance to chemical and environmental degradation.
- Fire resistance: Geopolymer concrete can have better fire resistance than traditional Portland cement concrete due to its lower thermal conductivity and higher fire resistance rating.
- Reduced waste: The use of industrial waste materials in geopolymer concrete production can help to reduce the amount of waste sent to landfills and can contribute to a more circular economy.
- Versatility: Geopolymer concrete can be used in a wide range of applications, including buildings, bridges, tunnels, and other infrastructure projects.
- Higher strength: Geopolymer concrete can have higher compressive strength than traditional Portland cement concrete, which can make it more suitable for certain structural applications.
- Resistance to chemical attack: Geopolymer concrete can be more resistant to chemical attack than traditional Portland cement concrete, which can make it more suitable for applications where exposure to harsh chemicals or

environments is a concern.

- Lower maintenance costs: Due to its greater durability and resistance to chemical and environmental degradation, geopolymer concrete can require less maintenance over its lifespan compared to traditional Portland cement concrete. This can result in cost savings for owners and operators of structures made from geopolymer concrete.
- Improved thermal performance: Geopolymer concrete can have better thermal performance than traditional Portland cement concrete, due to its lower thermal conductivity. This can help to reduce energy consumption and improve the energy efficiency of buildings and other structures made from geopolymer concrete.
- Reduced water usage: The production of traditional Portland cement concrete requires significant amounts of water, both in the production process and in the curing process. Geopolymer concrete, on the other hand, can have lower water requirements, which can help to conserve water resources.
- Better resistance to freeze-thaw cycles: Geopolymer concrete can be more resistant to damage from freeze-thaw cycles than traditional Portland cement concrete, due to its lower permeability and greater resistance to chemical attack. This can make it a more suitable option for use in colder climates or in applications where exposure to freeze-thaw cycles is a concern.

- Improved workability: Geopolymer concrete can have better workability than traditional Portland cement concrete, which can make it easier to handle and place during construction. This can result in improved construction efficiency and can reduce the risk of worker injuries

Potential for enhanced aesthetics: Geopolymer concrete can be produced in a range of colors and finishes, which can allow for greater design flexibility and potential for enhanced aesthetics in construction projects. This can result in more visually appealing structures made from geopolymer concrete

2.10 Disadvantages Of Geopolymer Concrete

- While geopolymer concrete offers several advantages over traditional Portland cement concrete, there are also some potential disadvantages to consider. Here are a few:
- Complexity of production: The production process for geopolymer concrete can be more complex than that for traditional Portland cement concrete, requiring specialized equipment and processes. This can increase the cost and time required to produce geopolymer concrete.
- High alkalinity: Geopolymer concrete can have a high alkalinity, which can be harmful to human skin and eyes. Proper protective equipment and precautions must be taken during the production and handling of geopolymer concrete.
- Limited availability of raw materials: Some of the raw materials used in geopolymer concrete production, such as fly ash, can have limited availability in certain regions. This can make it difficult to produce geopolymer concrete on a large scale in those areas.
- Limited research and development: The use of geopolymer concrete is still a relatively new technology, and there is limited research and development in this area compared to traditional Portland cement concrete. This can make it more difficult for engineers and contractors to design and construct structures using geopolymer concrete.
- Lack of standardization: The lack of standardized testing and certification methods for geopolymer concrete can make it more difficult to ensure consistent quality and performance across different projects and manufacturers.
- Curing time: Geopolymer concrete can have a longer curing time than traditional Portland cement concrete, which can increase the time required for construction projects. This can also require specialized curing methods, such as high-temperature curing, which can add to the cost of production.
- Variability of properties: The properties of geopolymer concrete can be more variable than those of traditional Portland cement concrete. This can make it more difficult to predict and control the performance of geopolymer

concrete in different applications.

- Lack of standardization: As mentioned earlier, there is currently a lack of standardized testing and certification methods for geopolymer concrete. This can make it more difficult for engineers and contractors to design and construct structures using geopolymer concrete, and can also make it more difficult to compare the performance of different geopolymer concrete products.
- Limited design options: The use of geopolymer concrete can be limited by the availability of raw materials and the complexity of the production process. This can limit the range of design options and applications for geopolymer concrete.

Cost: While the cost of geopolymer concrete has been decreasing as the technology becomes more widely adopted, it can still be more expensive than traditional Portland cement concrete in some cases. This can make it more difficult for some construction projects to justify the use of geopolymer concrete.

Chapter 3 : Experimental Work

3.1 Introduction

In this chapter, laboratory mixtures were made to identify the properties of geopolymer concrete using fly ash and the use of some materials. These materials will be identified in this chapter

The following materials are required for the production of geopolymer concrete:

1_Fly Ash: It is a by-product of thermal power plant.

2_ Activator Solution: The catalytic liquid system is used as an activator solution. It is a mixture of silicate and hydroxides along with distilled water.

3_Aggregates: Fine and coarse aggregates as required for normal

concrete.

4- sikament 163m superiorly increase workability with concrete and is highly workable and fluied

4_ water

3.2 Fly Ash

3.2.1 Definition

Fly ash is a fine powder that is a byproduct of coal combustion in power plants. When coal is burned, the combustion process produces a variety of waste materials, including fly ash. The fly ash is carried up the smokestack and captured by pollution control devices, such as electrostatic precipitators or baghouses.
Fly ash is composed of small, lightweight particles that are typically spherical in shape. The particles range in size from less than 1 micron to more than 100 microns in diameter. The exact composition of fly ash varies depending on the type of coal that is burned and the combustion conditions, but it generally consists of silica, alumina, iron, and calcium.
Fly ash has several beneficial properties that make it useful in a variety of applications. One of the most common uses of fly ash is as a pozzolan in the production of concrete. When combined with water and an alkaline activator, such as sodium hydroxide or potassium hydroxide, the fly ash reacts to form a

cementitious material known as geopolymer. Geopolymer concrete made with fly ash can have several advantages over traditional Portland cement-based concrete, including higher strength, greater durability, and lower carbon footprint.
Fly ash can also be used as a component in the production of other building materials, such as bricks and blocks. In addition, fly ash can be used as a soil amendment to improve soil fertility and reduce soil acidity. It can also be used as a component in the production of ceramics, glass, and other materials.

Figure 3.1 fly ash

3.2.2 Properties Of Fly Ash

Fly ash is a key component in the production of geopolymer concrete and contributes to several beneficial properties of the resulting material. Here are some of the properties of fly ash in geopolymer concrete:

1- Pozzolanic activity: Fly ash is a pozzolanic material, which means it can react with an alkaline activator to form a cementitious material. The pozzolanic activity of fly ash allows it to be used as a replacement for traditional Portland cement in geopolymer concrete, reducing the carbon footprint of the construction industry.

2- Improved durability: Geopolymer concrete made with fly ash has been found to have greater durability and resistance to chemical attack, abrasion, and erosion compared to traditional Portland cement-based concrete. This is because the geopolymer binder formed with fly ash has a more stable and durable chemical structure compared to the calcium silicate hydrate (C-S-H) binder in Portland cement-based concrete

3- Higher strength: Geopolymer concrete made with fly ash can have higher compressive strength compared to traditional Portland cement-based concrete. This is due to the more stable and durable chemical structure of the geopolymer binder.

4- Reduced shrinkage: Fly ash can help reduce shrinkage in geopolymer concrete, which can improve the durability and longevity of the material.

5- Lower permeability: Geopolymer concrete made with fly ash has been found to have lower permeability compared to traditional Portland cement-based concrete. This can improve the resistance of the material to water and chemical penetration.

3.2.3 Compare Cost Between Fly Ash And Cement

- The cost of geopolymer concrete can vary depending on several factors, such as the availability and cost of materials, the complexity of the mix design, and the specific application of the concrete. In general, the cost of geopolymer concrete can be higher than traditional Portland cement-based concrete, but there are also several factors that can help offset this cost.

- One factor that can help reduce the cost of geopolymer concrete is the use of waste materials as a component in the mix design. For example, fly ash, a waste material generated by coal-fired power plants, is commonly used as a component in geopolymer concrete. By using waste materials as a component, the cost of raw materials can be reduced, and the environmental impact of the construction industry can be reduced.

- Another factor that can help reduce the cost of geopolymer concrete is its improved durability and longevity compared to traditional concrete. Geopolymer concrete made with fly ash has been found to have greater durability and resistance to chemical attack, abrasion, and erosion, which can reduce the need for costly repairs and maintenance over the life of the structure.

In addition, the use of geopolymer concrete can help reduce the carbon footprint of the construction industry. This can be particularly important in regions where carbon taxes or other environmental regulations are in place, as the reduced emissions associated with geopolymer concrete can help offset the higher initial cost

3.3 Sodium Silicate

3.3.1 Definition Of Sodium Silicate

Sodium silicate, also known as water glass, is an inorganic chemical compound that is used in many industrial applications. It is a colorless, odorless liquid that is soluble in water and has a high pH. Sodium silicate is commonly used in the production of geopolymer concrete as an alkaline activator.

In geopolymer concrete production, sodium silicate is typically mixed with another alkaline compound, such as sodium hydroxide, to create an activator solution. When mixed with pozzolanic materials, such as fly ash or slag, the activator solution triggers a chemical reaction that forms a geopolymer binder. This geopolymer binder binds the aggregate together to form the concrete.

Sodium silicate is a key component in the production of geopolymer concrete because it helps to activate the pozzolanic materials and form the geopolymer binder. The alkalinity of the sodium silicate is important because it helps to break down the silica and alumina in the pozzolanic materials, allowing them to react and form a cementitious material.

In addition to its use in geopolymer concrete production, sodium silicate is used in a variety of other industrial applications, such as in the production of detergents, paper, and textiles. It is also used as a binding agent in the production of refractory materials, such as fire bricks and furnace linings

Figure 3.2 sodium silicate

3.3.2 Properties Of Sodium Silicate

The activator solution is a critical component of geopolymer concrete production and has a significant effect on the properties of the resulting material. Here are some of the ways that the activator solution can affect the properties of geopolymer concrete:

1- Compressive strength: The activator solution can have a significant impact on the compressive strength of the geopolymer concrete. The alkalinity of the activator solution helps to activate the pozzolanic materials and form the geopolymer binder, which binds the aggregate together to form the concrete.

The concentration and type of alkaline activators used in the solution can affect the strength and durability of the resulting material

2- Setting time: The activator solution can also affect the setting time of the geopolymer concrete. The setting time is the time it takes for the concrete to harden and reach its final strength. The concentration and type of alkaline activators in the solution can affect the setting time of the concrete, as well as the workability and flowability of the mix

3- Durability: The activator solution can also affect the durability of the geopolymer concrete. The geopolymer binder formed by the activator solution has been found to have greater durability and resistance to chemical attack, abrasion, and erosion compared to traditional Portland cement-based concrete. The type and concentration of activators used in the solution can affect the durability and resistance of the material to different types of chemical and physical stresses.

4- Shrinkage: The activator solution can also affect the shrinkage of the geopolymer concrete. Shrinkage is the change in volume of the concrete as it dries and hardens. The type and concentration of activators used in the solution can affect the amount of shrinkage that occurs in the concrete, which can affect the durability and longevity of the material.

5- Overall, the activator solution is a crucial component of geopolymer concrete production and has a significant effect on the properties of the resulting material. The type and concentration of alkaline activators used in the solution can affect the strength, durability, setting time, and shrinkage of the concrete. Therefore, careful selection and optimization of the activator solution is important for producing high-quality geopolymer concrete with the desired properties.

3.4 Sodium Hydroxide

3.4.1 Definition Of Sodium Hydroxide

Sodium hydroxide, also known as caustic soda, is a strong base that is commonly used as an alkaline activator in the production of geopolymer concrete. Sodium hydroxide is a highly caustic and reactive substance that can cause severe burns and should be handled with care.

In geopolymer concrete production, sodium hydroxide is typically mixed with another alkaline compound, such as sodium silicate, to create an activator solution. When mixed with pozzolanic materials, such as fly ash or slag, the activator solution triggers a chemical reaction that forms a geopolymer binder. This geopolymer binder binds the aggregate together to form the concrete. Sodium hydroxide is a key component in the production of geopolymer concrete because it helps to activate the pozzolanic materials and form the geopolymer binder. The high pH of the sodium hydroxide solution is important because it helps to break down the silica and alumina in the pozzolanic materials, allowing them to react and form a cementitious material.

In addition to its use in geopolymer concrete production, sodium hydroxide is used in a variety of other industrial applications, such as in the production of soaps, detergents, and paper. It is also used in the production of textiles, petroleum products, and food.

Overall, the use of sodium hydroxide as an alkaline activator in geopolymer concrete production is a promising technology that can lead to more sustainable, durable, and cost-effective construction materials. However, it is important to handle this substance with care and follow proper safety procedures when using it

Figure 3.3 sodium hydroxide

3.4.2 Benefits Of Sodium Hydroxide

Sodium hydroxide, also known as caustic soda, is a strong base that has several benefits in various industrial applications, including the production of geopolymer concrete. Here are some of the benefits of sodium hydroxide:

1- Alkaline activation: Sodium hydroxide is a key component in the alkaline activation of pozzolanic materials, such as fly ash or slag, to form a geopolymer binder. The high pH of the sodium hydroxide solution helps to break down the silica and alumina in the pozzolanic materials, allowing them to react and form a cementitious material.

2- Increased strength: The use of sodium hydroxide as an alkaline activator in geopolymer concrete production can lead to increased compressive strength compared to traditional Portland cement-based concrete. This is because the geopolymer binder formed with sodium hydroxide has a more stable and durable chemical structure compared to the calcium silicate hydrate (C-S-H) binder in Portland cement-based concrete.

3- Improved durability: Geopolymer concrete made with sodium hydroxide has been found to have greater durability and resistance to chemical attack, abrasion, and erosion compared to traditional Portland cement-based concrete. This is because the geopolymer binder formed with sodium hydroxide is more resistant to chemical and physical degradation compared to the C-S-H binder in Portland cement-based concrete.

4- Reduced carbon footprint: The use of sodium hydroxide as an alkaline activator in geopolymer concrete production can help reduce the carbon footprint of the construction industry. Geopolymer concrete made with sodium hydroxide can have a lower embodied carbon footprint compared to traditional Portland cement-based concrete, reducing the environmental impact of construction.

Overall, the use of sodium hydroxide as an alkaline activator in geopolymer concrete production has several benefits, including increased strength, improved durability, and reduced environmental impact. However, it is important to handle this substance with care and follow proper safety procedures when using it.

3.4.3 Safety Producers For Handling Sodium Hydroxide

Sodium hydroxide, also known as caustic soda, is a highly caustic and reactive substance that can cause severe burns and other health hazards if not handled properly. Here are some of the safety procedures that should be followed when handling sodium hydroxide:

Personal protective equipment: It is important to wear appropriate personal protective equipment (PPE) when handling sodium hydroxide. This includes gloves, safety goggles or a face shield, and a lab coat or other protective clothing.

Ventilation: Sodium hydroxide can release harmful fumes when it reacts with certain materials. Therefore, it is important to work in a well-ventilated area or use a fume hood when handling sodium hydroxide.

Handling: Sodium hydroxide should be handled with care to avoid spills or splashes. It should be stored in a secure, labeled container and dispensed using a pipette or other appropriate dispensing equipment.

Mixing: When mixing sodium hydroxide with water or other substances, it is important to add the sodium hydroxide slowly and stir constantly to avoid splashing or spilling. It is also important to use appropriate containers for mixing and to avoid using glass containers, which can break or shatter.

Disposal: Sodium hydroxide should be disposed of properly according to local regulations. It should never be poured down the drain or disposed of in the trash

3.5 Fine Aggregates And Coarse Aggregates

Fine aggregates and coarse aggregates are two types of materials commonly used in the production of concrete. Here's an overview of each:

Fine aggregates: Fine aggregates are materials that are smaller than 5mm in size and typically consist of sand, crushed stone, or gravel. They are commonly used in the production of concrete to improve workability, reduce shrinkage, and increase the strength of the concrete. Fine aggregates fill the voids between larger particles, helping to create a dense and compact material. They also provide a smooth surface finish to the concrete.

Coarse aggregates: Coarse aggregates are materials that are larger than 5mm in size and typically consist of crushed stone, gravel, or recycled concrete. They are commonly used in the production of concrete to provide structural support and increase the strength of the concrete. Coarse aggregates provide bulk to the concrete, reducing the amount of cement required and making the concrete more economical. They also help to prevent cracking and provide better drainage in certain applications.

Both fine and coarse aggregates play important roles in the production of concrete, and the proper selection and combination of these materials is key to producing high-quality concrete with the desired properties. The specific type and size of aggregates used will depend on a variety of factors, including the application, climate conditions, and desired strength and durability of the concrete.

Figure 3.4 fine aggregates

Figure 3.5 coarse aggregates

3.6 Sikament 163m
3.6.1 Definition Of Sikament

Sikament 163M is a type of water-reducing admixture commonly used in the production of concrete to improve workability and reduce the water content of the mix. It is manufactured by Sika AG, a Swiss-based company that specializes in the development and production of chemicals for the construction industry.

Sikament 163M is a high-performance admixture that can improve the flow and slump of the concrete, making it easier to place and finish. It works by reducing the surface tension of the water in the mix, allowing the particles to move more freely and reducing the amount of water needed to achieve the desired workability.

3.6.2 Benefits Of Sikament

Some of the benefits of using Sikament 163M in concrete production include:

Improved workability: Sikament 163M can improve the workability of the concrete, making it easier to place and finish. This can help increase productivity and reduce labor costs

Reduced water content: Sikament 163M can reduce the water content of the concrete, which can improve the strength and durability of the material. This can also help reduce the risk of cracking and shrinkage.

Increased strength: Sikament 163M can improve the strength of the concrete by reducing the water content and improving the distribution of the cement particles in the mix. This can lead to a denser and more durable material.

Improved surface finish: Sikament 163M can help produce a smoother and more consistent surface finish on the concrete, reducing the need for additional finishing work.

3.6.3 Properties Of Sikament

Sikament 163M is a type of water-reducing admixture that is commonly used in the production of concrete to improve workability and reduce the water content of the mix. Here are some of the properties of Sikament 163M:

1- Water reduction: Sikament 163M can reduce the water content of the concrete mix by up to 25%, which can help improve the strength and durability of the concrete.

2- Improved workability: Sikament 163M can improve the workability and flow of the concrete, making it easier to place and finish. This can help increase productivity and reduce labor costs.

3- Increased strength: Sikament 163M can improve the compressive strength, flexural strength, and durability of the concrete by reducing the water content and improving the distribution of the cement particles in the mix.

4- Reduced shrinkage: Sikament 163M can help reduce the shrinkage of the concrete by reducing the water content and improving the distribution of the cement particles in the mix.
5- Improved surface finish: Sikament 163M can help produce a smoother and more consistent surface finish on the concrete, reducing the need for additional finishing work.
6- Compatibility: Sikament 163M is compatible with a wide range of cementitious materials, including Portland cement, blended cement, and supplementary cementitious materials such as fly ash and slag

3.7 Tests

18 cubes (100 x 100 x 100) mm, 6 concrete cylinders

(100 x 200) mm, three beams (100 x 100 x 500) were cast from each batch and processed to a degree Temp 70 compressive strength of concrete. Compressive strength test was performed

According to ECP 203-2018 and E.S 1658-1988.

Such as :

Compressive strength , tensil strength, flexural strength,rebound hammer and density of geopolymer concrete

3.7.1 Compressive Strength

Compressive strength is a measure of the ability of a material to resist compression or being squeezed. In the case of concrete, compressive strength is one of the most important properties and is typically measured in pounds per square inch (psi) or megapascals (MPa).

The compressive strength of concrete is determined by testing a standard specimen of concrete in a compression machine. The test involves applying a load to the specimen until it fails, and the maximum load that it can withstand before failure is recorded as the compressive strength.

The compressive strength of concrete can vary depending on a variety of factors, including the mix design, curing conditions, and the age of the concrete.

The compressive strength of concrete is an important factor in determining the structural integrity and load-bearing capacity of concrete structures, such as buildings, bridges, and roads. The compressive strength of concrete is typically used as a quality control measure during the production of concrete, and is also used to assess the perform

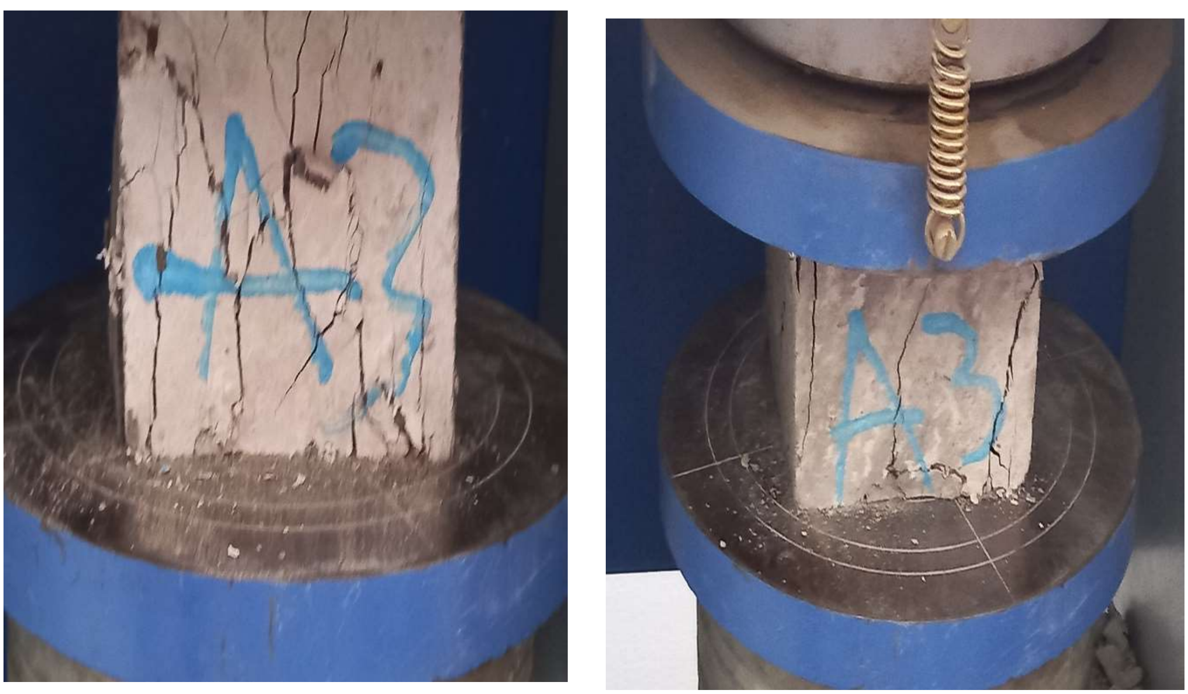

Figure 3.6 The compressive strength

Figure 3.7 failure

Figure 3.8 failure

3.7.2 Tensile Strength

Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking or deforming. It is a measure of a material's ability to resist tensile forces and is typically expressed in units of force per unit area, such as pounds per square inch (psi) or newtons per square meter (N/m^2). Tensile strength is an important property of many materials, including metals, plastics, ceramics, and composites, and is used to determine their suitability for various applications, such as construction, engineering, and manufacturing

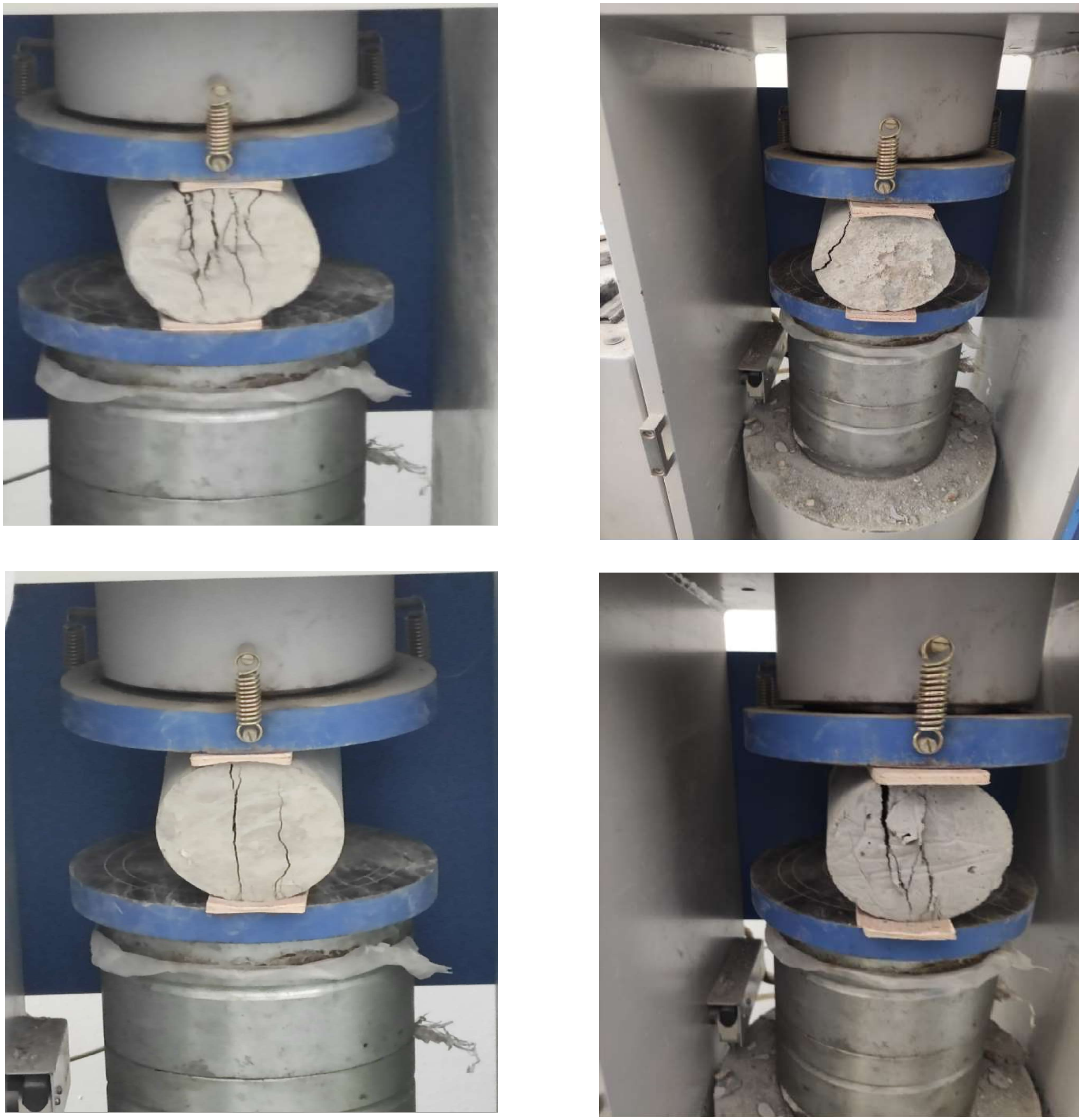

Figure 3.9 The tensile strength

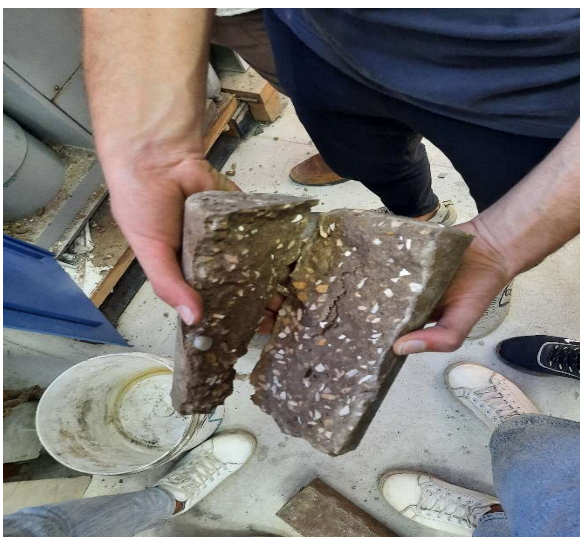

Figure 3.10 failure

3.7.3 Flexural Strength

Flexural strength, also known as bending strength or modulus of rupture, is the maximum stress that a material can withstand when subjected to a bending load or force. It is a measure of a material's ability to resist deformation or fracture when a force is applied perpendicular to its longitudinal axis. Flexural strength is typically expressed in units of force per unit area, such as pounds per square inch (psi) or megapascals (MPa).

Flexural strength is an important property of many materials used in structural applications, such as concrete, wood, metals, and composites. It is often used to determine the suitability of a material for a particular use, such as in beams, columns, or other load-bearing structures. The flexural strength of a material is influenced by various factors, including its composition, microstructure, and processing conditions.

Figure 3.11 flexural strength

3.7.4 Rebound Hammer

a rebound hammer is a device used to measure the surface hardness of concrete or other materials. It works by striking the surface with a spring-loaded hammer and then measuring the rebound velocity of the hammer. The rebound velocity is directly related to the surface hardness of the material, which can be used to estimate its compressive strength.

Rebound hammers are commonly used in construction and civil engineering to assess the quality of concrete structures, such as bridges, buildings, and pavements. They are portable, non-destructive, and easy to use, making them a popular choice for field testing. However, it's important to note that rebound hammer tests provide only an estimate of the compressive strength of the material, and more accurate testing methods, such as core sampling and compression testing, may be necessary for critical applications.

Figure 3.12 rebound hammer

3.7.5 Density Of Geopolymer Concrete

The density of geopolymer concrete can vary depending on the specific mix design, but generally, it falls within the range of 2,000 to 2,500 kilograms per cubic meter (kg/m³) or 125 to 156 pounds per cubic foot (lb/ft³). This is comparable to the density of conventional Portland cement concrete.

3.8 Content Of Mixture Geopolymer Concrete

Mix no.	Fly ash	sand	Coarse aggregate	Activator solution		molarity	water	Sikament
				Sodium silicate	Sodium hydroxide			
1	400	1000	700	120	60	8M	81	4
2	400	1000	700	120	60	10M	81	4
3	400	1000	700	120	60	12M	81	4

Table 3.1 content of mixture geopolymer concrete(kg/m^3)

- we used The same amount of fly ash, fine aggregates , coarse aggregates, water and sikament.
- the ratio of sodium hydroxide to sodium silicate 1:2
- change in the molarity concentration of sodium hydroxide

the ratio of Activator solution = 0.45


14.000


20.000


0.080


2.405

Figure 3.13 Content of mixture geopolymer concrete

Figure 3.14 Content of mixture geopolymer concrete

Chapter 4 : Results

4.1 Cube Compressive Strength Test

4.1.1 After 7 Days From Casting Concrete

Mix number	Cube number	Fracture load (KN)	Compressive strength
1	1	320.4	32.04
	2	315.7	31.57
	3	321	32.1
2	1	330.2	33.02
	2	350.2	35.02
	3	341.4	34.14
3	1	360.3	36.03
	2	352.6	35.26
	3	355.3	35.53

Table-4.1 cube compressive strength test after 7 days from casting concrete

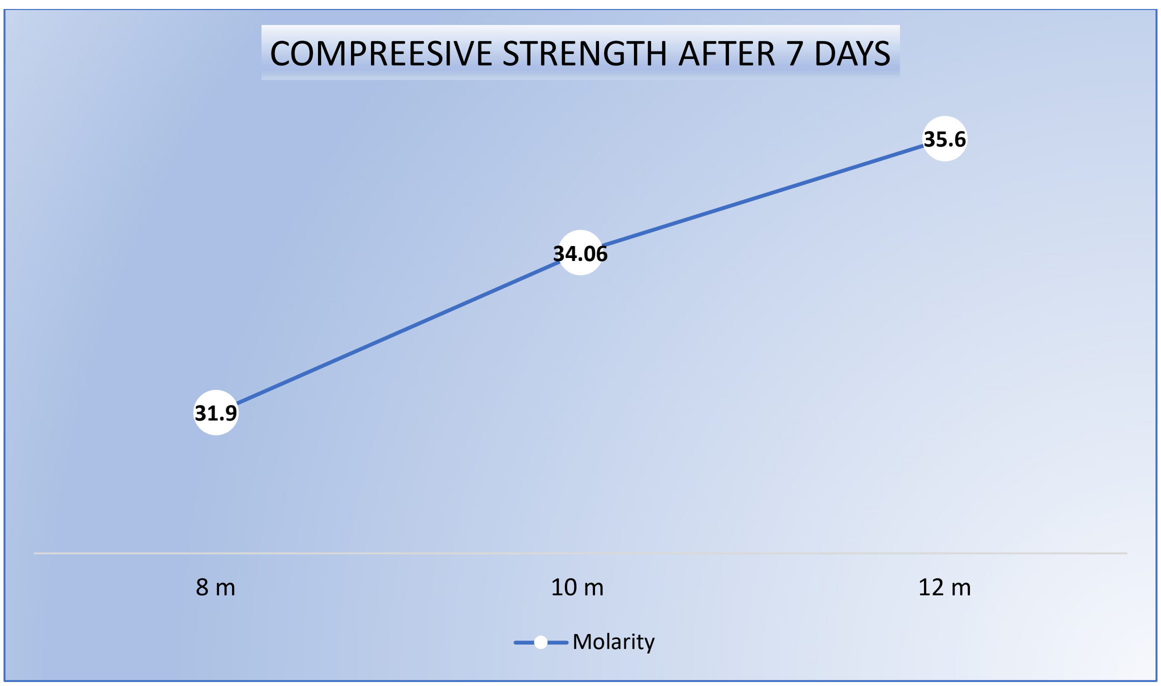

Figure 4.1 compressive strength test after 7 days (N/mm2)

4.1.2 After 28 Days From Casting Concrete

Mix number	Cube number	Fracture load (KN)	Compressive strength
1	1	401.6	40.16
	2	390.9	39.09
	3	421.8	42.18
2	1	434.9	43.49
	2	467.2	46.72
	3	471.6	47.16
3	1	517.2	51.72
	2	493.4	49.34
	3	557.1	55.71

Table-4.2 cube compressive strength test after 28 days from casting concrete

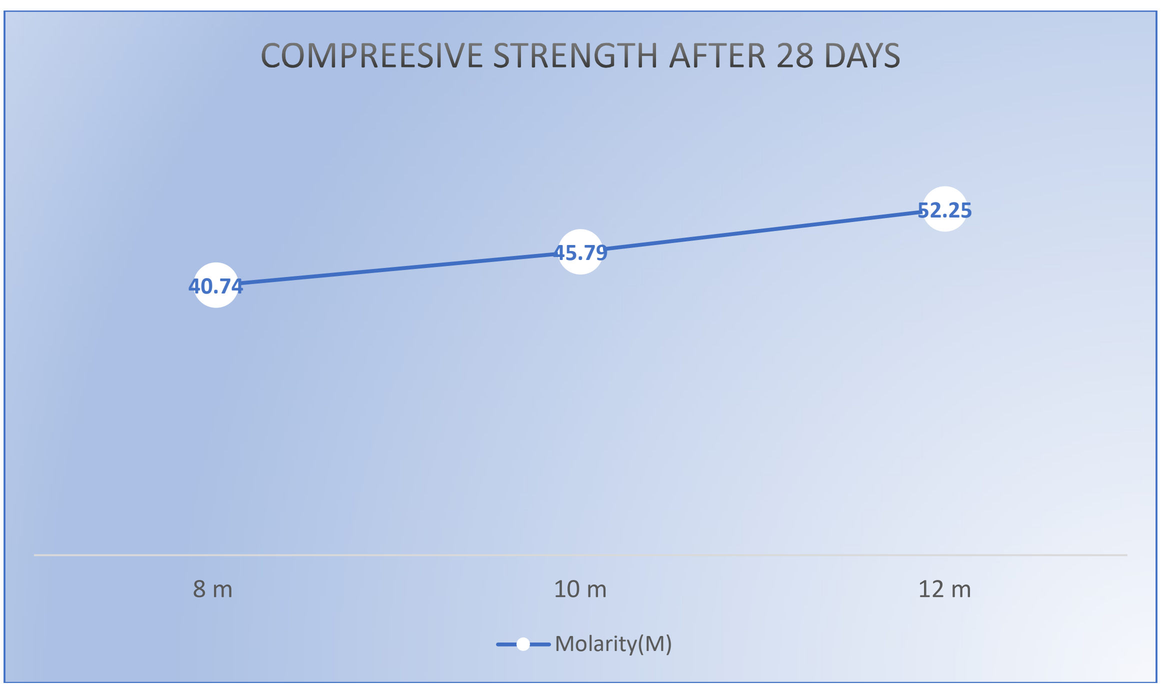

Figure 4.2 compressive strength test after 28 days (N/mm2)

4.2 Cylinder Tensile Strength Test

Mix number	Fracture load (KN)	Tensile strength (N/mm^2)
1	107.9	3.4
2	116.5	3.71
3	120.3	4.05

Table-4.3 cylinder tensile strength test after 28 days from casting concrete

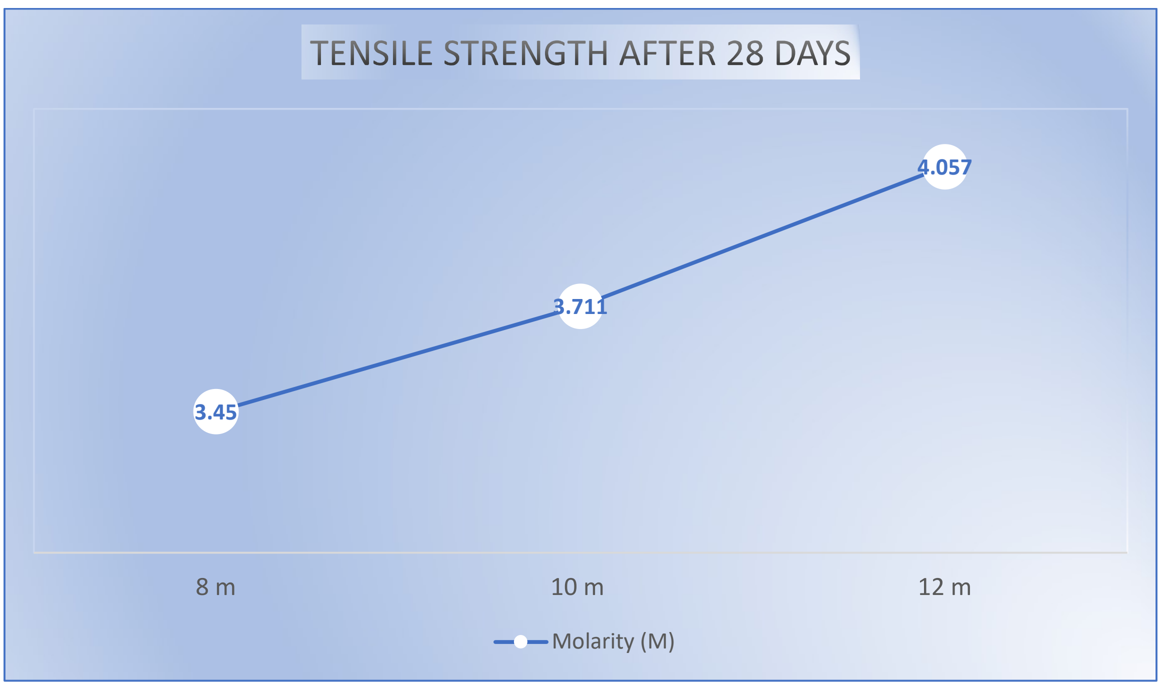

Figure 4.3 tensile strength test after 28 days (N/mm2)

4.3 Beam Flexural Strength Test

Mix number	Fracture load (KN)	Compressive strength
1	5.265	2.388
2	6.324	2.715
3	7.325	3.295

Table-4.4 beam flexural strength test after 28 days from casting concrete

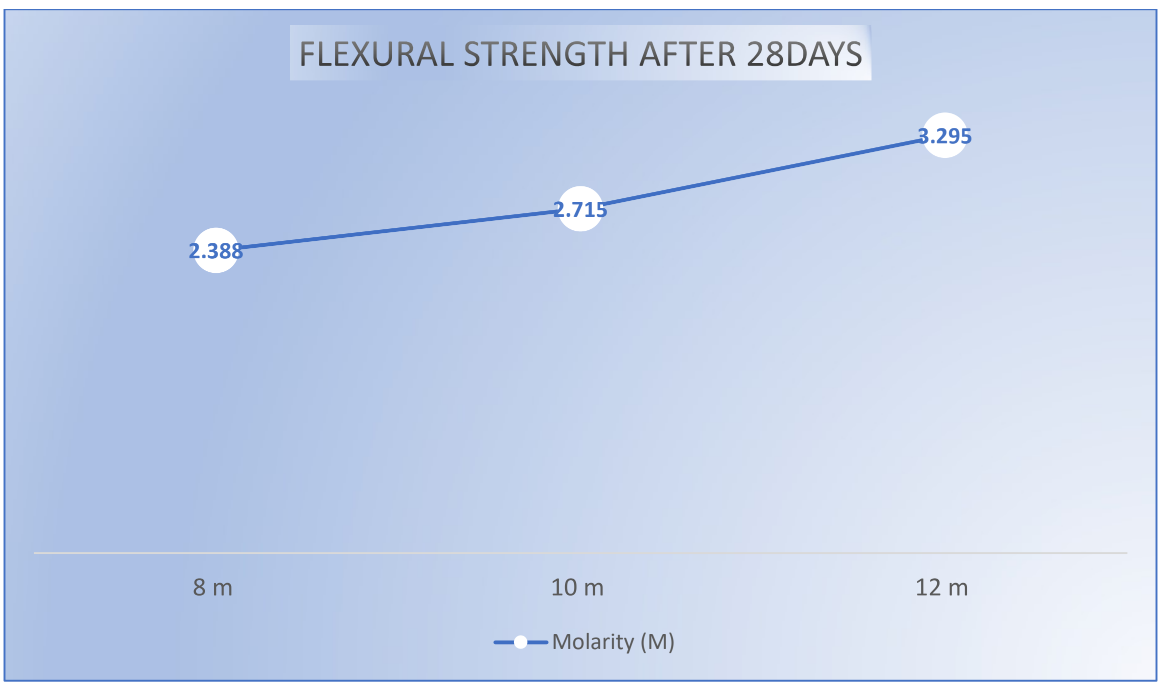

Figure 4.4 flexural strength test after 28 days (N/mm2)

4.4 Rebound Hammer Test
4.4.1 Rebound hammer Test After 7 Days

Mix number	Cube number	Rebound hammer
1	1	30-28-28-28-26-30
	2	27-24-28-26-30-25
	3	26-29-25-28-30-24
2	1	30-28-30-28-28-29
	2	28-27-29-30-28-30
	3	27-29-28-30-30-28
3	1	30-29-28-30-29-28
	2	30-32-28-29-28-27
	3	30-28-27-32-29-29

Table-4.5 rebound hammer test after 7 days

p4.4.2 Rebound hammer Test After 28 Days

Mix number	Cube number	Rebound hammer
1	1	30-28-33-32-28-30
	2	29-32-28-33-30-29
	3	30-29-25-28-30-34
2	1	30-28-30-30-32-29
	2	28-30-29-30-28-32
	3	30-29-28-32-30-28
3	1	30-29-28-30-29-32
	2	30-32-30-29-28-29
	3	30-28-29-32-32-29

Table-4.6 rebound hammer test after 28 days

4.5 Compare Between Other Team (Sodium Silicate To Sodium Hydroxide)

4.5.1 Cubes After 7 Days From Casting Concrete

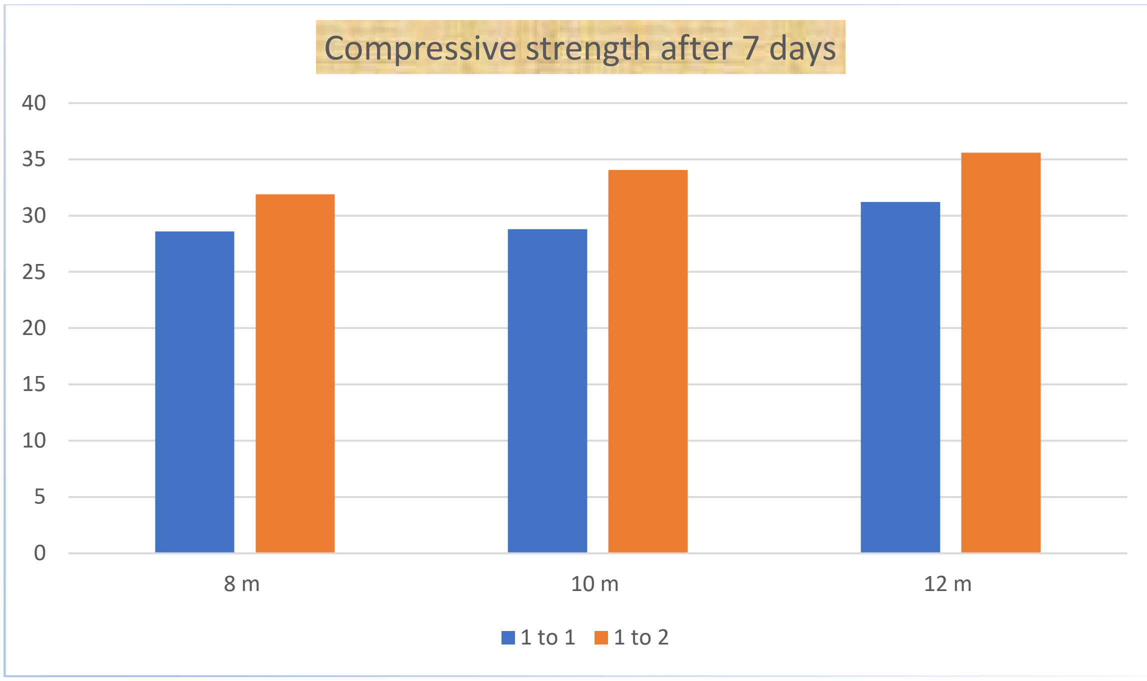

Figure 4.5 Compressive strength after 7 days (N/mm2)

4.5.2 Cubes After 28 Days From Casting Concrete

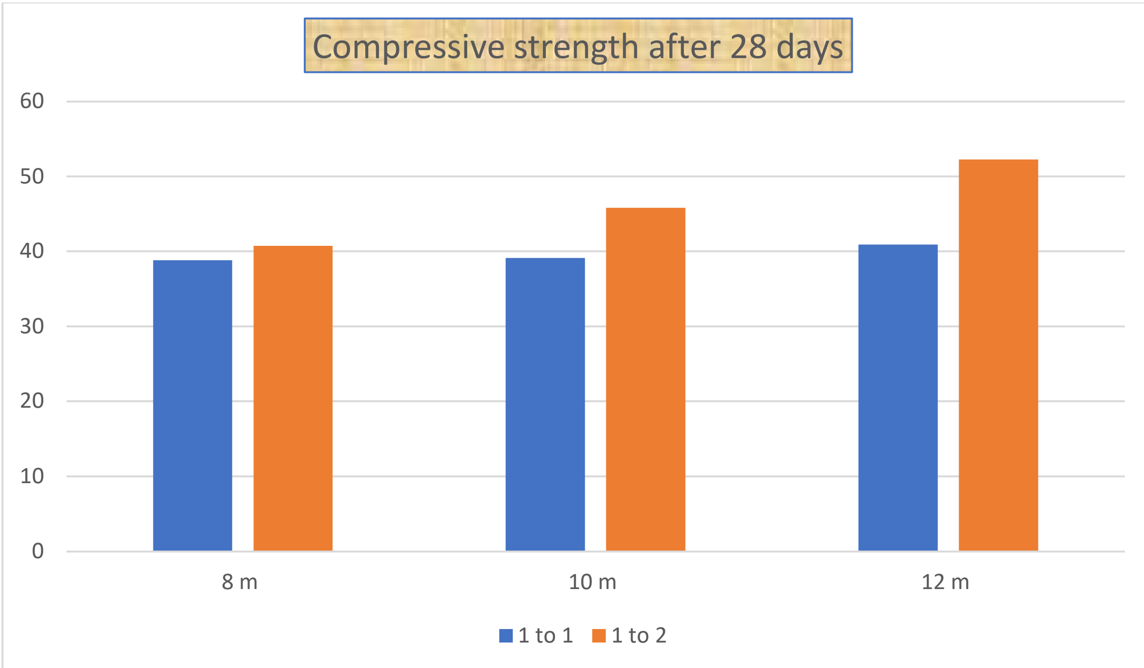

Figure 4.6 Compressive strength after 28 days (N/mm2)

4.5.3 Cylinder After 28 Days From Casting Concrete

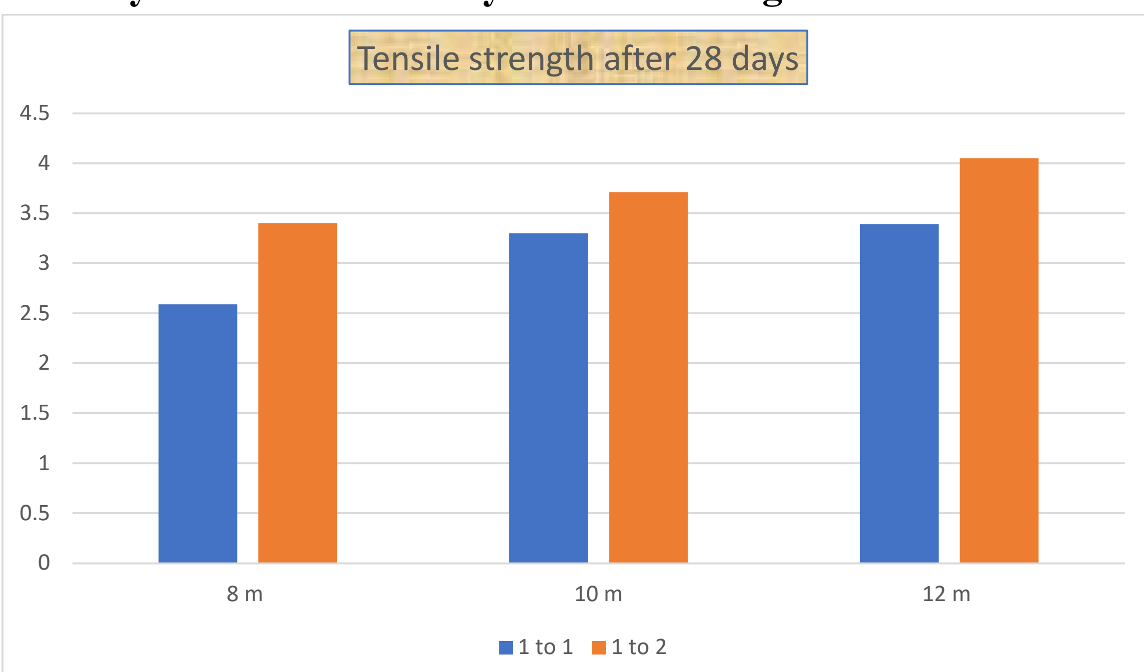

Figure 4.7 Cylinder after 28 days (N/mm2)

4.5.4 Beam After 28 Days From Casting Concrete

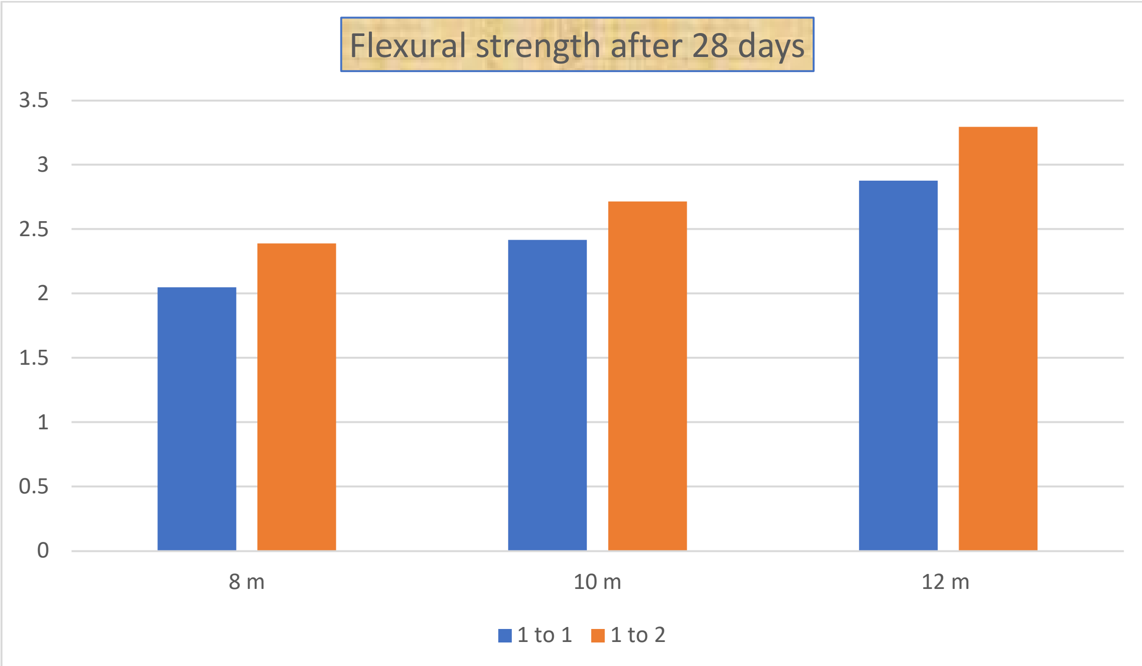

Figure 4.8 Beam after 28 days (N/mm2)

4.6 Conclusion

Geopolymer concrete is well known for its promising mechanical properties .therefore is a potential alternative construction material with comparable properties to OPC concrete. The constituents of Geopolymer Concrete shall be capable of being mixed with a relatively low alkali activating solution and must be curable in a reasonable time under ambient conditions**.**

- Geopolymer concrete can provide better cost, quality and durability than Portland cement

-The higher the ratio of sodium hydroxide to sodium silicate, the greater of compressive strength of geopolymer concrete

- we concluded that higher concentration of sodium hydroxide (molar) resulted higher compressive strength of geopolymer concrete

-The compressive strength of geopolymer concrete increases with increasing curing time. The increase in strength after 28 days is greater than after 7 days

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Appendix

1. Software Code

Tip Microsoft Word is a word processing program used for writing letters, memos, reports and paper presentations. Microsoft Excel is a spreadsheet program used for calculations, making charts and recording data about all sorts of business processes.

Uses for Microsoft Word

Microsoft Word is a word processing program designed to make it possible to create a variety of documents that will look the same between different computers and similar on the screen to how they appear on paper.

It's used by businesses and individuals to write personal and professional letters, reports for work and school and to take notes on conversations and in seminars and classes. Because it's so widely used, many businesses appreciate that it's possible to send documents created in Word to clients, employees and other business associates without worrying about whether or not they'll be able to open them.

The program allows for the use of a wide variety of fonts and styles in order to create a number of different types of documents, from informal lists of notes after a meeting to reports ready to ship out to a valued client or top executive.

Uses for Microsoft Excel

Microsoft Excel is a spreadsheet program. That means it's used to create grids of text, numbers and formulas specifying calculations. That's extremely valuable for many businesses, which use it to record expenditures and income, plan budgets, chart data and succinctly present fiscal results.

It can be programmed to pull in data from external sources such as stock market feeds, automatically running the data through formula such as financial models to update such information in real time. Like Microsoft Word, Excel has become a de facto standard in the business world, with Excel spreadsheets frequently emailed and otherwise shared to exchange data and perform various calculations.

Excel also contains fairly powerful programming capabilities for those who wish to use them that can be used to develop relatively sophisticated financial and scientific computation capabilities.

Alternatives to Word and Excel
Microsoft Word and Excel aren't the only word processing and spreadsheet programs
available. Google's G Suite office software collection is increasingly popular with many businesses, and it offers free versions to many users. Apple's iWork suite, including Pages and Numbers, competes with Word and Excel, is also used by Mac users as an alternative to Microsoft Office.
The open source LibreOffice toolkit also includes free alternatives to Word and Excel, called Writer and Calc

With PowerPoint on your PC, Mac, or mobile device, you can:
- Create presentations from scratch or a template.
- Add text, images, art, and videos.
- Select a professional design with PowerPoint Designer.
- Add transitions, animations, and cinematic motion.
- Save to OneDrive, to get to your presentations from your computer, tablet, or phone.
- Share your work and work with others, wherever they are.

2. Engineering Standards

1. Egyptian code ECP: 203 (2020): Egyptian code of practice for design and construction of reinforced concrete structures, Annual Book for testing of materials, part 3, Ministry of Housing and Urbanization, Housing and Building Research Center, Cairo, Egypt.

2. Egyptian standard specification ES requirements (4756-1/2005)

3. Relation With Environment

Environmentally friendly geopolymer concrete.

An experimental analysis of the properties of geopolymer concrete, for both the fresh and hardened case of concrete, is presented in the paper. Concrete mixtures differed according to the type and quantity of mineral additives (fly ash). It is proved that the addition of fly ash significantly improves the mechanical properties and durability of geopolymer concrete, and it is environmentally friendly due to the reduction of carbon dioxide emissions. Based on the test results obtained, appropriate recommendations for practical application are given.