

THERMAL STUDIES ON GEOPOLYMER COMPOSITE

Submitted in partial fulfilment of the requirements for the award of Bachelor of
Engineering degree in Mechanical Engineering

By

SUJAN.S (39150707)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600 199**

APRIL – 2023



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DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of SUJAN.S (30150707) who carried out the project entitled "THERMAL STUDIES OF GEOPOLYMER COMPOSITE" under my supervision from December 2022 to May 2023.

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DECLARATION

I, SUJAN.S, hereby declare that the Project Report entitled “THERMAL STUDIES OF GEOPOLYMER COMPOSITE” done by me under the guidance of Dr. V. K. BUPESH RAJA, M.E., Ph.D., at Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.



DATE: 10-05-2023

PLACE: CHENNAI

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ABSTRACT

The word Geopolymer originates from inorganic compounds typically ceramic, aluminosilicate forming long range and covalent bonds. It is a light weight material used in structures of construction, automobile and aerospace applications. It is widely used as it has greater strength, stiffness and light in weight.

The primary benefits of geopolymer include its high strength, low shrinkage, and excellent heat and chemical resistance. In this review article the geopolymer composites are discussed in detail, as it is a material being fabricated from industrial waste such as steel slag, fly ash and fibers. Hence this Geopolymer composite is an eco-friendly and cost efficient material.

This paper discusses experimentally determined thermal and mechanical characteristics of a geopolymer composite. Many investigators have strived to develop a geopolymer composite which possesses high thermal resistance, mechanical stability and less in weight, which shall be exposed to high temperatures and different types of loads.

Hence the geopolymer composite material made from industrial waste reduces the land pollution created by these waste which are dumped in landfills. The geopolymer composite material can be used in civil construction purposes as an alternate to Portland cement.

Key Words: Geopolymer composite, thermal, mechanical, alkali, industrial waste, fly ash, steel slag

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
Si	Silicon
Al	Aluminium
AAFA	Alkali Activation of Fly Ash
OPC	Ordinary Portland cement
°C	Degree Celsius
EMI	Electromagnetic Interferences
EMI SE	EMI Shielding Effectiveness
m ³	Cubic Metre
Kg/m ³	Kilograms per cubic metre
gm	Grams
CO ₂	Carbon dioxide
SiO ₄	Silicon-Oxygen tetrahedron
AlO ₄	Aluminium-Oxygen tetrahedron
F	Fahrenheit
PCC	Portland cement concrete
NaOH	Sodium Hydroxide
Na ₂ SiO ₃	Sodium Silicate
F.A	Fine aggregate
SiO ₂	Silicon dioxide
pH	Potential of hydrogen

wt. %	Weight percentage
dB	Decibels
M	Mega Hertz
GBFS	Ground granulated furnace slag
GHz	Giga Hertz
HCFA	High carbon fly ash
LCFA	Low carbon fly ash
M	Moles
CLSM	Controlled low strength material
Kg	Kilogram
SEM	Scanning electron microscope
EDAX	Energy dispersive X-ray spectroscopy
μm	Micrometre

CHAPTER 1

INTRODUCTION

GEOPOLYMER

In order to achieve sustainable growth, the environment must be given special consideration throughout the entire construction process. The energy sector, particularly energy conservation, is one that is crucial for sustainable development today. These sectors are excellent suited for material engineering. The hunt for novel construction materials with remarkable thermal and tensile properties is on-going [1][2][3]. The qualities of materials that provide thermal insulation can considerably improve how well buildings work, reduce heat loss, use less energy, and, as a result, emit less CO_2 . Goals for environmental conservation are served by all of this. The use of Geopolymer as solutions for sustainable building materials is desired [4] [5].

Joseph Davidovits invented the term "Geopolymer" in the 1970s to describe a class of solid materials created by chemically reacting aluminosilicate particles in an alkaline solution [6].

Following a succession of fires in Europe, geopolymers were initially created as a fire resistant combination of organic thermoset polymers. Fiber composites, thermal insulation and wood building protection, high temperature adhesives, monolithic fire resistant composites and a wide variety of applications [7].

They have the potential to resist fire due to their inorganic structure, geopolymers exhibit incredible heat stability compared to traditional concrete, much more so. These factors allowed geopolymer and its composites to be used in high-temperature thermal applications [8].

The materials are also used to remediate industrial and nuclear wastes including heavy metals or radiation, making it particularly beneficial to environmental protection. Nevertheless, its wide variety of applications has been hampered by its poor mechanical properties and high-temperature stability.

Numerous researchers have examined the behaviour of geopolymers under high-temperature exposure and high stresses since it has been demonstrated that they have a significant potential for usage in high-temperature and high mechanical applications [9]. The thermal characteristics of building materials can be a crucial factor and an effective instrument for achieving desired functionality. The uses for thermal transfer are numerous and involve both low and high temperatures as well as operating temperatures that call for either highly insulating or strongly conducting behaviour [10][11].

Construction methods and materials with low carbon footprints are in demand due to rising CO_2 levels and global temperatures. Ordinary Portland cement (OPC) is now the most extensively used structural material. Owing of the high calcination temperature required for 1 OPC, a large quantity of energy is required. Per ton of OPC produced, approximately 1 ton of CO_2 is emitted [12].

The properties of a hardened geopolymer are heavily determined by its initial input materials. There is a sizable quantity of industrial waste that could be used as precursors. Due to the existence of certain contaminants, some of these raw materials are rarely marketable or even useless unwanted substances like iron, magnesium, etc., as well as potentially dangerous heavy metals. Utilizing garbage that is high in iron is one example. The significance of iron content for its high temperature functionality of a fly ash based geopolymer. Iron oxides immediately impacted the thermal characteristics when present by modifying the phase composition, affecting the thermal expansion, and altering the division following heating [13].

This is one of the best alternate to the regular Portland cement being used these days for civil application, as this is an eco-friendly material which is being brought from industrial waste it reduces land pollution where these waste would be dumped in landfill. It reduces air pollution as the Portland cement creates high amounts of air pollution while processing the gypsum and lime stone [13].

Since geopolymer materials do not require fire, they may often complete initial curing in one day and utilise less energy than conventional refractories.

The production process has been simplified. Refractory geopolymer ceramics have potential uses such as refractory boiler panels, mould cores, flame retardant concrete, runway surface treatment, and so on. These applications need high heat resistance and strength. Nevertheless, conventional geopolymer materials have low mechanical strength and heat resistance [14]. Fiber reinforcing is thought to be an effective procedure for improving both mechanical and thermal resistance. As a reinforcing stage, the amount of fibres is chosen to improve the characteristics of geopolymers incorporating natural fibres such as cotton, wood, and hemp [15].

High-temperature synthesis of geopolymer composites using Silicon Carbide whiskers covered with the composite demonstrated increased high temperature strength up to 900 °C. Geopolymer composites offer enhanced tolerance to high temperatures up to 800°C. Mechanical characteristics degrade over 1000°C [16].

MATERIALS

Fly Ash

Fly ash is a byproduct that naturally occurs when coal is burned, and it shares similarities with volcanic ash. In the past, volcanic ash concrete was used to build structures such as the Coliseum, the Pantheon, and ancient Roman aqueducts, which still stand today. When coal is burned in power plants, temperatures exceed 2800 degrees Fahrenheit, and fly ash is produced as a non-combustible mineral along with bottom ash. Bottom ash is a lightweight aggregate material that typically settles at the bottom of the boiler, while fly ash is created in coal-fired, electric, and steam power plants. Coal is usually shredded and forced into the combustion chamber of the boiler by air, where it rapidly fires and produces heat generation and molten mineral residue. Every year, approximately 20 million metric tons (22 million tons) of fly ash are used for various technical purposes such as Portland Cement Concrete (PCC), grouts, soil and road foundation stabilization, structural fills, and asphalt filler.

The use of fly ash, particularly in concrete, provides significant environmental benefits, including:

- (1) Improved concrete resilience and extended lifespan of concrete roads and structures.
- (2) Reduced energy consumption, greenhouse gas emissions, and negative air pollutants when fly ash substitutes made cement.
- (3) A substantial decrease in the amount of coal combustion products disposed of in landfills.
- (4) Conservation of natural resources and materials



Fig: 1.2: Fly Ash

Characteristics of Fly Ash

When fly ash is used as a substitute for or supplement to manufactured cement, it can provide substantial environmental advantages. For instance, it can extend the lifespan of concrete roads and structures by enhancing their durability, while also resulting in a net reduction in energy use, greenhouse gas emissions, and other harmful air pollutants. Moreover, using fly ash reduces the amount of coal combustion products that end up in landfills, and it can conserve other natural resources and materials.

Physical Characteristics of Fly Ash

Fly ash is a fine-grained substance made up mostly of spherical, glassy particles. Some ashes also contain uneven or angular particles. Fly ash is bottom ash collected from fuel gases through the use of an appropriate technology such as cyclone separation or electrostatic precipitation.

Chemical composition of Fly Ash

The chemical composition of fly ash can vary depending on the coal source being used and the operational conditions of the boilers. As a result, its quality may differ from one source to another and even within the same source. Although fly ash exhibits cement-like properties, it requires a longer curing time than cement and should not be mixed with water.

In geopolymer technology, fly ash acts as a binding material, while an alkaline activator is used to initiate the process of geopolymerization. During this process, the fly ash and alkaline activator react to form an aluminosilicate gel. The alkaline solution employed in this study involves a mixture of sodium hydroxide (NaOH) and sodium silicate (Na₂SiO₃).

Steel Slag

Steel slag Steel slag is a secondary resource obtained during the manufacturing process of steel. It is formed by the melting of iron ore along with limestone and coke in a blast furnace. Once cooled, it solidifies into a hard and dense material that has several applications, including road construction, cement production, and soil stabilization. Steel slag is renowned for its excellent strength and durability, as well as its positive impact on the performance and sustainability of various engineering materials. It has potential uses in several applications, including as a substitute for natural aggregates in concrete, as a construction material in road and infrastructure projects, and as a soil conditioner. The use of steel slag in construction and infrastructure projects can offer a range of environmental and economic benefits, including reduced greenhouse gas emissions, energy conservation, and decreased reliance on natural resources. Additionally, the use of steel slag in road construction can improve the durability and performance of the road, while its use as a soil conditioner can enhance the fertility and productivity of agricultural land. Steel slag intended for use as aggregate must be stored outside for many months in order to be exposed to moisture through natural precipitation or water spraying. The goal of such storage is to enable possibly damaging hydration and accompanying expansion to occur before the material is used in bulk applications. The amount of time necessary for sufficient exposure to the elements varies greatly. It might take as long as 18 months to hydrate these expansive oxides.



Fig: 1.3: Steel slag

Properties of Steel Slag

- The shape of steel slag aggregates is highly angular, and their surface texture is rough. These aggregates also have a high bulk specific gravity and a low ability to absorb water.
- The elemental composition of steel slag is typically converted into simple oxides using x-ray fluorescence analysis.
- The pH of steel slag is generally on the alkaline side, typically ranging from 8 to 10. However, it's important to note that there are instances when the pH of the slag's leachate can reach levels as high as 11. This can pose a potential risk to aluminum or galvanized steel pipes that are directly exposed to the slag, as the high pH levels can cause damage to the pipes.
- Steel slag that has been processed is well-suited for use as an aggregate due to its mechanical properties. These properties include good abrasion resistance, soundness characteristics, and high bearing strength.
- Steel slag possesses the mechanical properties required for its use as an aggregate, including excellent abrasion resistance, soundness characteristics, and high bearing strength. Additionally, its ability to retain heat may be advantageous in hot mix asphalt repair operations during colder weather.

River Sand

Sand is a material which naturally occurs in granular material composed of minerals and rocks that are finely divided. Its particle size is larger than silt but smaller than gravel. Sand is classified as a soil type or textural class when it contains more than 85% of sand-sized particles. The composition of sand varies depending on the location and geological sources, but silica (in the form of silicon dioxide, SiO_2) is the most common component of sand found in non-tropical coastal areas and inland continental regions.

The second most common type of sand is made up of calcium carbonate, such as aragonite, which has formed over billions of years as a result of various life forms, including coral and shellfish. In fact, this type of sand is frequently found in areas where coral reefs have dominated the ecosystem for millions of years. Sand is considered a non-renewable natural resource that has been experiencing high demand in recent times.

It is a popular construction material due to its abundance and accessibility, as it is often readily available near riverbeds. River sand typically has a relatively uniform particle size distribution and a low clay content, which makes it ideal for use in concrete and mortar mixes. Its properties also include good compaction, high compressive strength, and good drainage properties. Additionally, river sand is often used as a landscaping material due to its attractive appearance and ability to provide a stable base for planting



Fig: 1.4 River Sand

Sodium Hydroxide

Sodium hydroxide, also known as caustic soda or lye, is a highly corrosive substance that has the ability to neutralize acids and produce sodium salts. At room temperature, it is a white, odourless solid that can absorb moisture from the surrounding air. When mixed with water or an acid, it releases heat that is strong enough to ignite flammable materials. Typically, it is used in solid form or as a solution with a 50% concentration. Sodium hydroxide is used in the production of various products, including soaps, rayon, paper, explosives, dyestuffs, and petroleum products. It is also used in the processing of cotton fabrics, cleaning metals, oxide coating, electroplating, electrolytic extraction, laundering and bleaching, and is commonly found in commercial drain and oven cleaners.



Fig: 1.5: Sodium Hydroxide Pellets

Properties of Sodium Hydroxide

The NaOH module is responsible for determining the physical characteristics of sodium hydroxide (caustic soda) solutions, specifically in a temperature range of 20°C to 100°C, and with concentrations ranging from 0 to 50 wt. % NaOH. In our first experimental phase of preparing geopolymer samples, we utilize sodium hydroxide and sodium silicate solutions, along with sand, rather than water as in Portland cement. For the current study, we use a mixture of NaOH and Na₂SO₃ in a 1:2 ratio.

Sodium Silicate

Sodium silicate, also known as "water glass" or "liquid glass", is a popular substance with a broad range of industrial and commercial uses. It is primarily composed of an oxygen-silicon polymer backbone that has water trapped in its molecular matrix pores. Depending on the intended use, sodium silicate products can be produced in solid or thick liquid form. For example, water glass is frequently used as a sealant for metal components. Despite the well-established manufacturing process for sodium silicate, ongoing research is focused on discovering new applications due to its excellent heat-conductive properties. This versatile inorganic chemical is created by combining sand and soda ash (sodium carbonate) at high temperatures in varying proportions, resulting in a range of products with unique chemical properties that are valuable in various industrial and commercial settings.

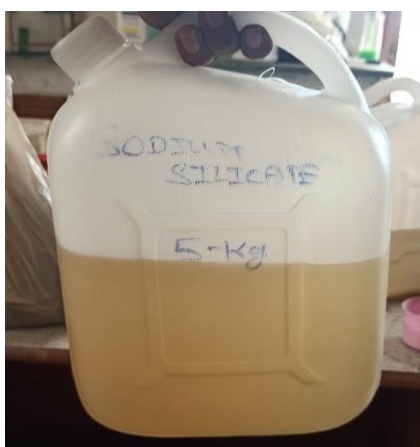


Fig: 1.6: Sodium Silicate

1.2.5.1 Properties of Sodium Silicate

Sodium silicates are unique alkaline salts that offer a broad range of beneficial properties that are not present in other compounds, and they are commonly used in numerous industries due to their low cost. These compounds are employed as adhesives, detergents, cleaning ingredients, cement, binders, coatings, coagulant aids, anti-corrosives, and zeolites, among other applications. The various properties and functional characteristics of silicates can be utilized to address a range of issues that arise in different industrial and chemical processes in a cost-effective

manner. Silicates with higher silica polymer content (i.e., a ratio of 2.8 to 3.2) are utilized as adhesives or binders, as they remove water and solidify from a liquid to a solid. Sodium silicate adhesives offer benefits such as expansion, adjustable indices over a wide range, and the formation of a rigid layer that creates a strong, permanent seal that is resistant to tearing and has mild resistance to heat and water.

In my study, I used air curing to solidify the geopolymer samples over a 28-day curing period. We observed that compression strength of the samples increased with longer curing times.

Composite sheet

Composite sheets, also known as sandwich panels, are a popular construction material used in a variety of applications where a combination of high structural rigidity and low weight is required. These panels consist of three layers - a low-density core made of materials like PIR, mineral wool, or XPS, and a thin skin-layer bonded to each side. The working principle behind sandwich panels is similar to that of an I-beam structure, where two face sheets resist in-plane and lateral bending loads (like flanges of an I-beam), while the core material resists shear loads (like the web of an I-beam).

The primary advantage of sandwich panels is their ability to provide high structural performance while maintaining low weight. This is achieved by using a thick, lightweight core material that is strong enough to resist shear loads and thin, strong face sheets that resist bending loads. The overall thickness of the panel is increased, which improves its structural attributes like bending stiffness while maintaining or reducing weight. Sandwich panels are used in a wide range of applications, and can come in different configurations with various core and skin materials. They may also come as cassettes if they are enclosed. The versatility of sandwich panels, as well as their strength and lightness, has made them a popular choice in construction, transportation, and other industries.



Fig: 1.7: Composite sheet

Properties of composite sheet

The outstanding insulation properties of sandwich panels, or composite sheets, make them highly desirable in construction. The insulation core of the panels provides low thermal conductivity, which results in better insulation. As a result, they are widely used in building renovation, including roofs and facades, as well as in the construction of industrial buildings.

Furthermore, the manufacturing and installation of sandwich panels are relatively fast, as they can be quickly screwed onto the structure, with visible or concealed screws depending on the desired finish. Compared to other systems, the construction time is one of the shortest.

One of the main advantages of composite sheets as a construction material is the wide variety of shapes and finishes available in the market, which makes them suitable for different types of buildings. The finishes range from rustic to modern, and there are also panels with imitation wood or tile patterns, among others.

JUTE

Jute is a low-cost natural fiber that is widely used in various applications, making it the second most popular fabric after cotton in terms of production and versatility.

Jute fibres are largely made up of the plant components cellulose and lignin. Jute fibre is classified as a fibre. The fibre is extracted from the plant's phloem, sometimes known as the "skin," along with knead, industrial hemp, flax, ramie, and other fibres. Raw jute is the industrial word for jute fibre. The fibres range in colour from off-white to brown and are 1-4 metres (3-13 feet) length. Because of its colour and great monetary worth, jute is also known as the "golden fibre". Jute is a highly practical natural fibre, ranking only behind cotton in terms of worldwide production and range of applications. The fibres of jute consist mainly of cellulose and lignin, which are key components of plant structures. When it comes to fibre properties, jute is considered to be one of the best, second only to other fibres like kenaf, industrial hemp, flax, ramie, and more. Rough jute is an advanced name for jute fibre. Jute is additionally known as the magnificent fibre due to its colour and its monetary value.



Fig: 1.8: Jute

CHAPTER 2

LITERATURE SURVEY

A. Van Riessen, W. Rickard J, Sanjayan et al (2009): In this chapter, the thermal properties of metakaolin and fly ash geopolymers are examined and compared with conventional cements like OPC. Researchers have explored the behaviour of geopolymers under high temperature exposure because of their potential for use in high temperature applications. Geopolymers possess remarkable thermal stability due to their inorganic framework, surpassing that of traditional cements. As a result, they can be used for high temperature applications like furnace linings, thermal insulation, and wall panels.

Salmabanu Luhar, Sandeep Chaudhary, Ismail Luhar et al (2018): In this experiment, At high temperatures, both the control and rubberized geopolymer concrete produced N-A-S-H (alumina silicate). In addition, zeolite was formed as a secondary reaction product in both types of concrete, which further transformed into hydrosodalite ($\text{Na}_4\text{Al}_3\text{Si}_3\text{O}_{12}\text{OH}$) at high temperatures. Eventually, zeolite underwent recrystallization, resulting in nepheline (NaAlSiO_4) and albite (NaAlSiO_8) that resemble a hydrous alumina silicate after being exposed to 600°C and 800°C.

R. Hardjito, D. Wallah, Steenie. E et al (2005): Geopolymer and alkali activated binders are promising Portland cement concrete alternatives. Although considerable global study, choosing suitable raw materials and calculating their ratios for attaining desired qualities stays a trial and error procedure. As a result, the variables that follow were investigated to provide guidance for the selection of raw materials and their proportions for producing geopolymer concrete with the desired properties: (a) the effect of curing process and activator dosages on the strength of fly ash mortar; (b) the influence of physical and chemical properties of different fly ash sources; and (c) the effect of partially replacing fly ash with ggbs.

Partha Sarathi Deb, Pradip Nath, Prabir Kumar Sarker et al (2015): In this study, the researchers found that adding more ground granulated blast furnace slag (GGBFS) to fly ash geopolymer concrete increased its compressive strength. The mixture with a SS/SH ratio of 1.5 and 20% slag had the highest compressive strength, ranging from 40 to 54 MPa after 28 days. They also found that shrinkage decreased as the percentage of slag increased and the SS/SH ratio decreased. The mixture with the lowest shrinkage was R1.5S20, with a shrinkage range of 482 to 722 microstrain at 180 days. The shrinkage values for the 56-day period were below the specification for normal OPC concretes. However, the measured 28-day shrinkage values were higher than the calculated design values for all mixtures except for OPC and R1.5S20. By increasing the slag content and reducing the SS/SH ratio during room temperature curing, the shrinkage of the geopolymer concrete could be reduced to within the calculated design values.

Gustavo Lopes, Vicente Paes, João Dos Santos and Lais Alves et al (2019): The study found that adding jute fibers to geopolymer composites resulted in an increase in compressive strength compared to non-fiber composites. Specifically, the compressive strength of the fiber composites was 21.6 MPa, while the non-fiber composites had a compressive strength of only 15.8 MPa. The addition of fibers also improved the ductility and toughness of the material, allowing it to better resist deformation and load after cracking. The material with fibers had a strain capacity of 0.51%, compared to 0.31% for the non-fiber material. However, there was an issue with the fiber concentration in one of the specimens (CP-2F14D), which negatively affected its maximum resistance. Overall, the fiber and matrix had good compatibility, as the material was able to support the applied forces and maintain its shape while gaining strength and deformation capacity.

CHAPTER 3

AIM AND SCOPE

AIM

The aim of this project is to create a thermally and mechanically stable geopolymer composite which is made of Composite sheet, Jute and industrial waste such as fly ash and steel slag and to compare with other insulating material such as gypsum.

SCOPE

- To fabricate a geopolymer that can be effectively utilized for shielding against heat.
- To create a best alternative insulating material
- To offer a cheaper product by utilizing low cost and readily available industrial by-products those are eco-friendly as well.

CHAPTER 4

METHODOLOGY AND EXPERIMENTAL SET-UP

WORK MATERIALS

The data below clearly signifies the work materials that were required for the process. The main work materials utilized in the process were fly ash, steel slag, river sand and composite sheet for making geopolymer samples. The experimental setup for thermal studies has been prepared.

COLLECTION OF MATERIALS

- Fly Ash
- Steel Slag
- River Sand
- Sodium Hydroxide
- Sodium Silicate
- Composite sheet
- Jute

METHADODOLOGY

- Preparation of geopolymer slurry by mixing the steel slag, fly ash, M sand, sodium silicate, sodium hydroxide.
- In a square mould box the composite sheet is placed after which the slurry is poured over the composite sheet.
- In the next layer jute is placed and the slurry is poured, this process is done alternatively till a certain thickness is attained.
- Allowing the composite to cure due to the reaction of alumino silicates in the slag and ash with the alkaline.
- Removing the hardened geopolymer from the square mould box and allowing the air to dry even more over sides.
- Thermal testing of geopolymer composite with the help of thermal test rig.
- Subjecting the geopolymer panel to water absorption.
- Evaluation of the test results.



Fig 4.1:- Geopolymer mixture



Fig 4.2:- fabricated Geopolymer panel



Fig 4.3:- Cured Geopolymer panel

EXPERIMENTAL SETUP

Thermal conductivity test



1

2

3

4

5

6

- 1 - Movable Jaw
- 2 - Fixed Jaw and heating element
- 3 - Temperature sensors
- 4 - Digital Voltmeter and Ammeter
- 5 - Current Transformer
- 6 - Variable Transformer

Fig 4.4:- Experimental setup of thermal test rig

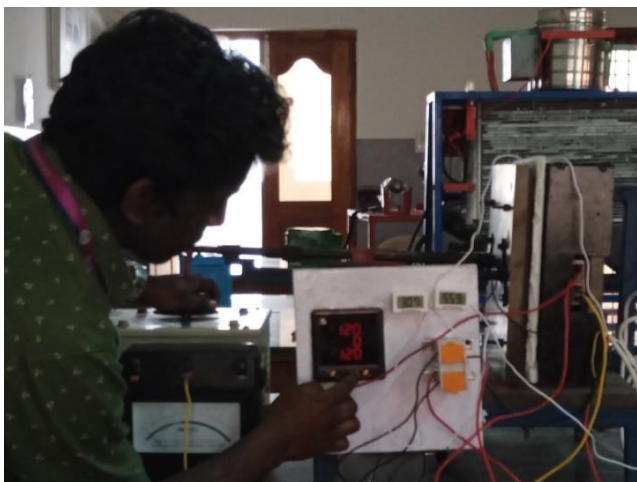


Fig 4.5:- Testing of Gypsum Board

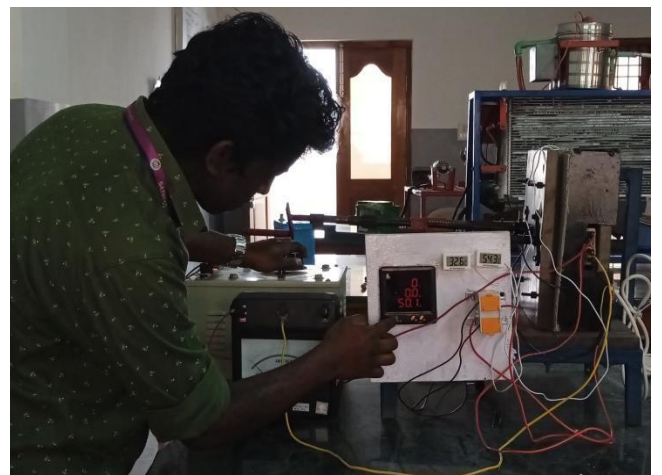


Fig 4.6:- Testing of Geopolymer panel

Water Absorption test



Fig 4.7:- Testing sample of Geopolymer panel

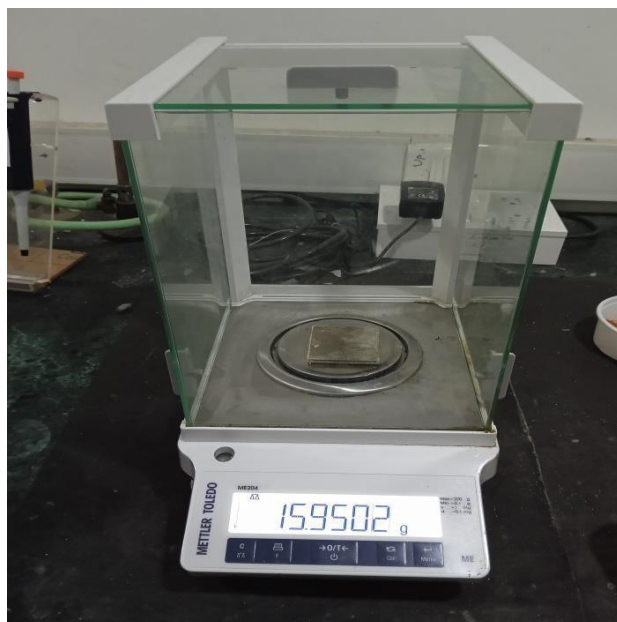


Fig 4.8:- Weighing of sample before water absorption test

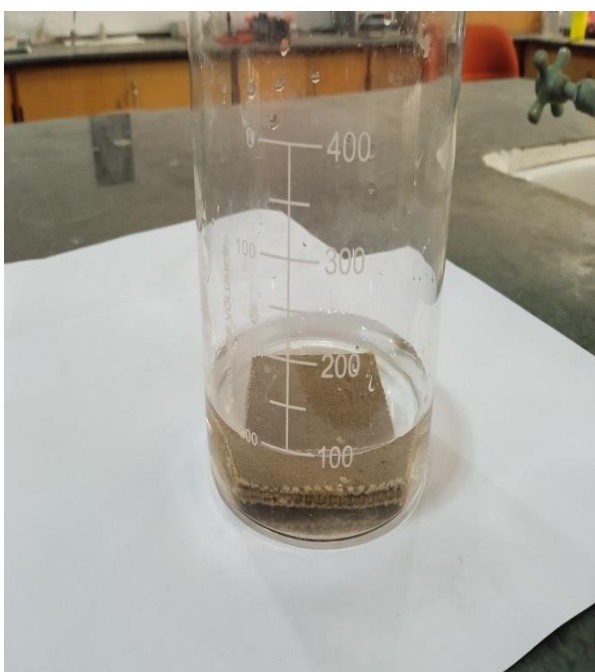


Fig 4.9:- Testing of water absorption in the sample with distilled water

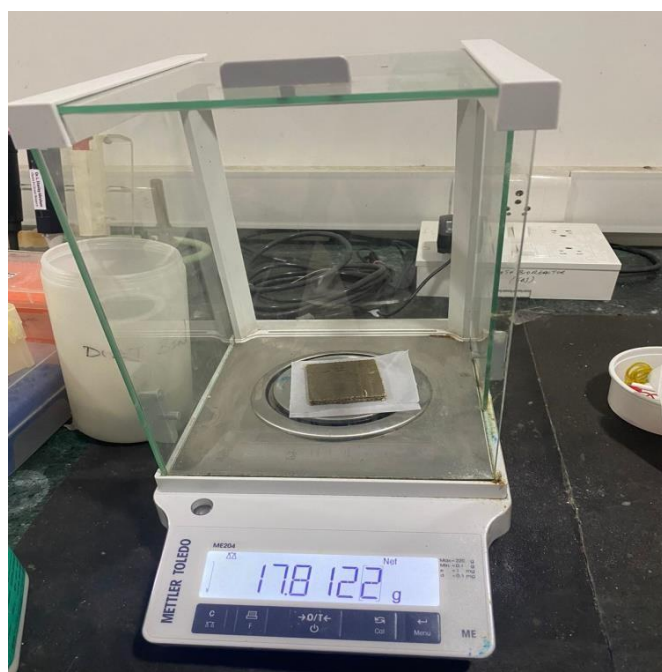


Fig 4.10:- Weighing of A after water absorption test

CHAPTER 5

RESULTS AND DISCUSSION

Thermal Conductivity Studies on Geopolymer Sandwich Composite

S.NO	Input supply		T1 (°C)	T2 (°C)	Q (watts)	K (W/mk)
	Volt (V)	Current (A)				
1.	120	0.8	51	79.6	96	0.186

Table 5.1:- thermal conductivity of geopolymer panel

Calculation

Length of Geopolymer panel = 300mm = 0.3m

Thickness of Geopolymer panel = 5mm = 0.005

Area of the Geopolymer panel = 0.3*0.3 = 0.09m

$$Q = V \cdot A = 120 \cdot 0.8 = 96$$

$$Q = \frac{K \cdot a \cdot \Delta T}{t}$$

$\Delta T = T_2 - T_1 = 79.6 - 51 = 28.6 \text{ } ^\circ\text{C}$

$$K = \frac{Q \cdot t}{a \cdot \Delta T}$$

$$K = \frac{96 \cdot 0.005}{0.09 \cdot 28.6}$$

$$K_{\text{Ge}} = 0.186 \text{ W/mK}$$

Thermal Conductivity Studies on Gypsum Sheet

S.No	Input supply		T1 (°C)	T2 (°C)	Q (watts)	K (W/mk)
	Volts (V)	Amps (a)				
1	120	0.8	49.1	92.5	96	0.206

Table 5.2:- thermal conductivity of gypsum board

Calculation

Length of Gypsum panel = 320mm = 0.32m

Thickness of Gypsum panel = 12mm = 0.012

Area of the Gypsum panel = 0.32*0.32 = 0.102m

$$Q = V \cdot A = 120 \cdot 0.8 = 96$$

$$Q = \frac{K \cdot a \cdot \Delta T}{t}$$

$\Delta T = T_2 - T_1 = 92.5 - 49.1 = 43.4 \text{ } ^\circ\text{C}$

$$K = \frac{Q \cdot t}{a \cdot \Delta T}$$

$$K = \frac{96 \cdot 0.012}{0.09 \cdot 43.4}$$

$$K_{\text{Gy}} = 0.206 \text{ W/mK}$$

Comparison Graph b/w Geopolymer panel and Gypsum panel

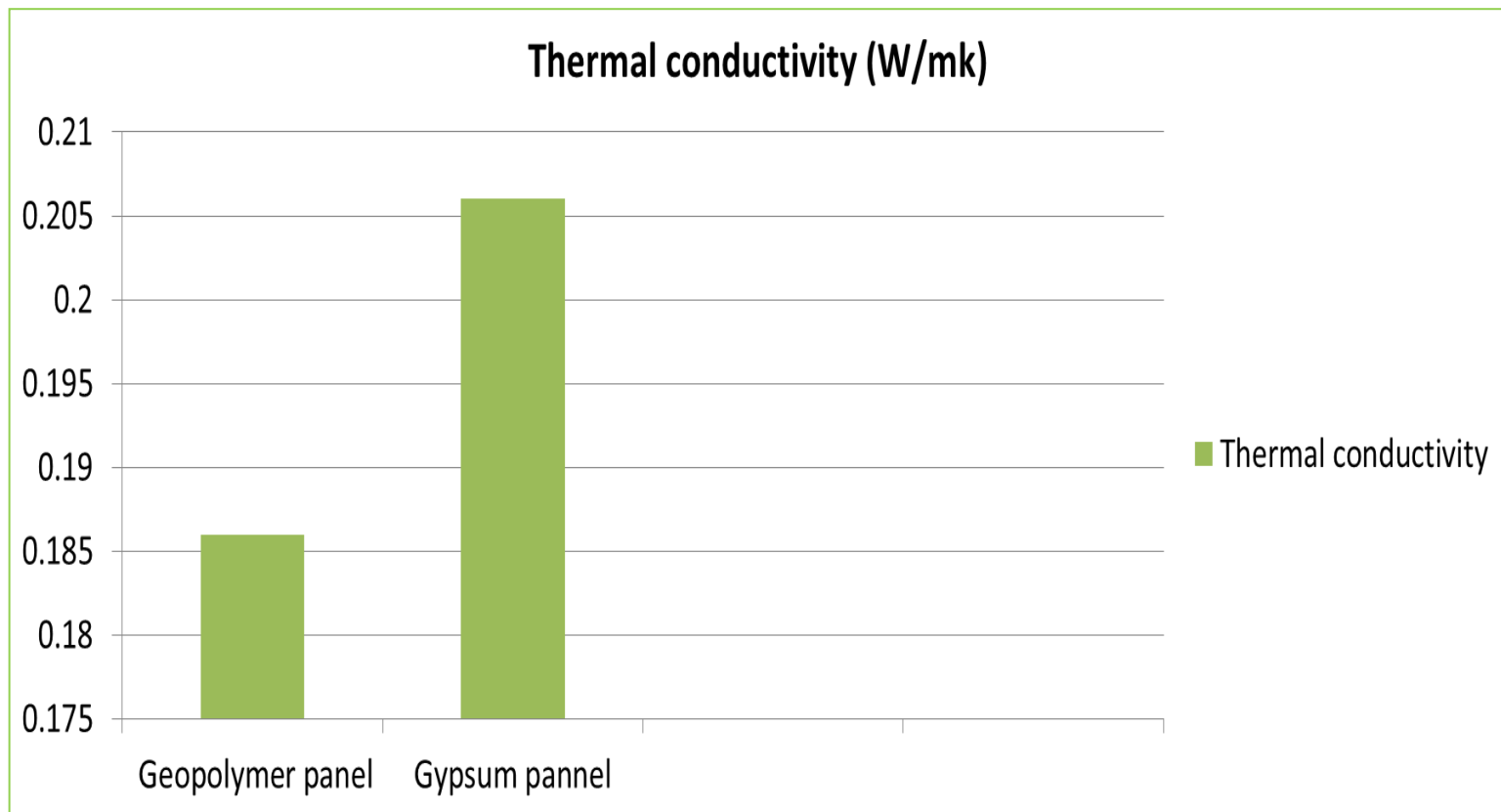


Fig 5.1- Comparison Graph b/w Geopolymer panel and Gypsum panel

Water absorption test of geopolymer sample

Size of sample = 50mm

Area of sample = $50 \times 50 = 250\text{mm}$

Time taken = 24 hours

Water absorption is expressed as increase in weight percentage.

Formula: Water Absorption (in %) = $[(\text{Wet weight} - \text{Dry weight}) / \text{Dry weight}] \times 100$

Water Absorption = $[(17.8122 - 15.9502) / 15.9502] \times 100$

Water Absorption = 11.66%

CHAPTER 6

CONCLUSION

- Therefore, the thermal conductivity of two different insulators is compared through the modified thermal test rig. Which represents that the geopolymer panel conducts lesser amount of heat ($k_{Ge} = 0.186 \text{ W/mK}$) compared to the gypsum board ($K_{Gy} = 0.206 \text{ W/mK}$).
- As a conclusion Gypsum panel ($k_{Gy} = 0.206 \text{ W/mK}$) is having a **10.75%** increase in thermal conductivity in contrast to Geopolymer panel ($K_{Ge} = 0.186 \text{ W/mK}$).
- So, as we conclude the geopolymer panel is a better insulator comparing to the gypsum panel.
- The Geopolymer sample is having an 11.66% increase weight after soaking in distilled water for 24 hours.
- Gypsum board is found to have water absorption about **45.65%** (based on references).

References

1. R.Hardjito, D.Wallah, Steenie.E, Sumajouw, Factors influencing the compressive strength of fly ash-based geopolymer concrete. Civil Engineering Dimension, 2005, Volume 6, pages 88-93.
2. Perera, S.Trautman, R.L, Geopolymer with the Potential use as Refractory Castables, AZojomo Journal of Materials online, 2006, Volume 2, pages 1-5.
3. Giancaspro, J.Balaguru, P.N. and Lyon R.E, Use of Inorganic Polymer to Improve the Fire Response of Balsa Sandwich Structures, Journal of Materials in Civil Engineering, 2006, Volume 18, pages 390-397
4. A.Van Riessen, W.RickardJ, Sanjayan, Thermal properties of geopolymers, Publishing Series in Civil and Structural Engineering 2009, volume12, Pages 315-342
5. William D. A. Rickard, Assessing the Suitability of Fly Ash Geopolymers for High Temperature Applications, Journals of materials in civil engineering 2012, Volume 573, Pages 250-262
6. J. L. Provis and J. S. J. Van Deventer, Introduction to geopolymers, no. 1940. Woodhead Publishing Limited, 2009.
7. Partha Sarathi Deb, Pradip Nath, Prabir Kumar Sarker, Drying Shrinkage of Slag Blended Fly Ash Geopolymer Concrete Cured at Room Temperature, Procedia engineering 2015, volume125, pages 594-600.
8. R.Padmapriya, V.K.Bupesh Raja, V.Ganesh Kumar, J.Baalamurugan, Study On Concrete By Replacing Coarse Aggregate With Steel Slag And Cement By Fly ash, International Journal of Earth Sciences and Engineering, Vol. 8, No.5, 2015.
9. R.Padmapriya, V.K.Bupesh Raja, V.Ganesh Kumar, J.Baalamurugan, 'Study on replacement of coarse aggregate by steel slag and fine aggregate by manufacturing sand in concrete', International Journal of ChemTech Research, Vol.8, No.4, pp. 1721-1729, 2015. ISSN: 0974-4290.
10. Padmapriya.R., Bupesh Raja.V.K, Ganesh Kumar.V, Baalamurugan.J, Study on replacement of coarse aggregate by steel slag and fine aggregate by manufacturing sand in concrete, International Journal of ChemTech Research, Vol. 8, No.4, pp.1721-1729, January 2015. ISSN: 0974-4290.

11. Salmabanu Luhar, Sandeep Chaudhary, Ismail Luhar, Thermal resistance of fly ash based rubberized geopolymer concrete, Journal of Building Engineering 2018, volume 19, pages 420-428.
12. J.Baalamurugan, V.Ganesh Kumar, K. Govindaraju, B. S. Naveen Prasad, V.K.Bupesh Raja and R.Padmapriya, 'Slag based nanomaterial in the removal of hexavalent chromium', International Journal of Nanoscience, Vol. 17, No. 01n02, 1760013, pp.1 – 6, 2018
13. V. K. Bupesh Raja*, M.Deepak Sairam, S.Krishna Raj, V.Hari Prasath, Akash Mishra, Ritam Das, R.Padmapriya, V.Ganesh Kumar, J.Baalamurugan, J.SenthilKumar, S.Jeyanthi, Manoj Gupta, Sound Absorption Studies on Geopolymer Composites, International Conference on Materials Engineering & Characterization, 2019
14. R.Padmapriya*, V.K.Bupesh Raja, V.Ganesh Kumar, J.Baalamurugan, Effect on properties of concrete in partial replacement of fine aggregate by steel slag and cement by metakaolin, Rasayan J. Chemistry, 12 (4), 1744 – 1751, 2019.
15. Baalamurugan J, V.Ganesh Kumar, V.Chandrasekaran, S.Balasundar, B.Venkatraman, R.Padmapriya, V.K.Bupesh Raja, Utilization of induction furnace steel slag in concrete as coarse aggregate for gamma radiation shielding, Journal of Hazardous Materials 2019, Vol. 369, pages 561-568
16. Lais Alves, Gustavo Lopes, Vicente Paes, João Dos Santos, Study of the Compression Resistance of a Geopolymer Based Composite with Added Jute Fiber, Crimson Publishers 2019, Volume 12, pages 1276-1280.
17. Bupesh Raja, Venkatagiri, Deepak Sairam, Hari Prasath, V. Ganesh Kumar, J. Baalamurugan and Mathew Alphonse, Cellulose - Geopolymer sandwich thermal shield for automobiles – A review, AIP Conference Proceedings 2020, 2311, 108885, 040020,
18. Agustini N. K. A, Triwiyono.A, Sulistyono.D, Suyitno, Effects of water to solid ratio on thermal conductivity of fly ash-based geopolymer paste, IOP Conference Series: Earth and Environmental Science 2020, volume 426, pages 100-112.

19. Shaswat Kumar Das, Syed Mohammed Mustakim, Adeyemi Adesina, Jyotirmoy Mishra, Thamer Salman, Alomayrie, Hasan Suliman Assaedi, Cyriaque Rodrigue Kazeg. Fresh, strength and microstructure properties of geopolymer concrete incorporating lime and silica fume as replacement of fly ash. *Journal of Building Engineering* 2020, Volume 50, pages 101-130.
20. Partha Sarathi Deb, Pradip Nath, Prabir Kumar, Sarker, The effects of ground granulated blast-furnace slag blending with fly ash and activator content on the workability and strength properties of geopolymer concrete cured at ambient temperature, *Materials & Design* 2021, volume 62, pages 32-39.
21. V. K. Bupesh Raja, S. Krishna Raj, M. Deepak Sairam, Anipeddi Venkata Ramana Sundar Kasyap, V. Ganesh Kumar, R. Padmapriya, J. Baalamurugan, Pushkaraj D. Sonawane, "Geopolymer Green Technology", Twenty-Eighth International Conference on Processing and Fabrication of Advanced Materials, *Materials Today Proceedings*, Elsevier Publications, February 2021, pages 1-6.
22. Piyush Gupta, Garima Nagpal, Namrata Gupta, Fly ash-based geopolymers: an emerging sustainable solution for heavy metal remediation from aqueous medium. *Beni-Suef University Journal of Basic and Applied Sciences* 2021, volume 10, pages 1-29.
23. K. Hemra, T. Kobayashi, P. Aungkavattana, and S. Jiemsirilers, Enhanced mechanical and thermal properties of fly ash-based geopolymer composites by wollastonite reinforcement, *Journal of metals, materials and minerals* 2021, vol. 31 pages 13-25.
24. Rashidah Mohamed Hamidi, Zakaria Man, Khairun Azizi Azizli, Concentration of NaOH and the Effect on the Properties of Fly Ash Based Geopolymer, *Procedia Engineering* 2021, volume 148, pages 189-193.
25. Manuela Bazzani Kretzera, Carneane Effting, Samoel Schwaab, Adilson Schackowa, Hybrid geopolymer-cement coating mortar optimized based on metakaolin, fly ash, and granulated blast furnace slag, *Cleaner Engineering and Technology* 2021, volume 4, pages 269-274.

