

FABRICATION OF TEST RIG FOR EVALUATING THERMAL PROPERTIES OF GEOPOLYMER SANDWICH COMPOSITE

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

By

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC 112B Status by UGC | Approved by AICTE

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APRIL– 2022



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of SARIDHAN K (38860013) and MOHAMED NEHAL MK (38860010) who carried out the project entitled **"FABRICATION OF TEST RIG FOR EVALUATING THERMAL PROPERTIES OF GEOPOLYMER SANDWICH COMPOSITE"** under my supervision from December 2021 to March 2021

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Internal Guide

Dr. V.K.BUPESH RAJA , M.E, Ph. d., (Prof. Head of dept Automobile)

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Submitted for Viva voce Examination held on_____

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DECLARATION

ISARIDHAN K, Hereby declare that the Project Report entitled **FABRICATION OF TEST RIG FOR EVALUATING THERMAL PROPERTIES OF GEOPOLYMER SANDWICH COMPOSITE** done by me under the guidance of Dr V.K.Bupesh Raja at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in **MECHANICAL ENGINEERING**.

DATE:

PLACE: CHENNAI

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. V.K.Bupesh Raja, M.E., Ph.D.**, Head of the Department, Dept. of Automobile Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. V.K.BUPESH RAJA, M.E., Ph.D.**, for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Automobile Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

This review paper aims to present fundamental aspects of geopolymer developments and science to emphasize their suitability for high-temperature exposure. Beginning with a comparison of thermal properties of OPC and geopolymer, the analysis then investigates the character and occurrence of aggregates and supplementary phase. Characteristics essential for evaluating geopolymer thermal properties are thermal expansion, thermal conductivity, strength retention, explosive spalling along with microstructural characteristics such as phase stability, weight changes, (dehydration /rehydration), morphology changes, and thermochemical properties were analyzed much in detail. This project aims to develop geopolymer composite and study their suitability for high –temperature exposure. Further a test rig for evaluating the thermal properties of the geopolymer sandwich composite shall be fabricated.

KEYWORDS: Geopolymer, thermal properties, high temperature exposure.

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CHAPTER 1

1.1 INTRODUCTION

Composite materials are widely used in all types industries. The requirements depend on the type of application. Ceramic composites are popular in applications where materials are expected to encounter high temperatures; such as engine components, exhaust systems and fire barriers. The low density as compared to metals makes them attractive in applications where weight is a critical design parameter. Most of the ceramic composites are fabricated using heat treatment and often the operating temperatures are lower than the temperatures used for the fabrication of the component. For the research reported in this paper a modified version of an inorganic resin known as Geopolymer was used. Typical Geopolymer can sustain temperatures up to 800°C. This composition was evaluated for a number of applications that require fire-resistance, such as the interior of an aircraft.

This low-cost, inorganic polymer is derived from naturally occurring geological materials, namely silica and alumina, hence the name Geopolymer. Geopolymer is a two-part system consisting of a silicate

liquid and a silica powder and cures at a reasonably low temperature of 150°C. Hardeners can be added to achieve room temperature curing (22°C). The matrix has been used to fabricate standard laminate composite plates with carbon, glass, and silicon carbide fibres, sandwich structures using syntactic foam, and strengthening of brick, masonry, and reinforced concrete elements. The composite materials based on renewable raw materials from agriculture and biomass are more and more used, because these products significantly compensate for the use of fossil fuels and reduce the greenhouse gas emissions in comparison with the petrol-based traditional materials. However, including natural fibres in polymers comes with several challenges, such as excessive absorption of water and low thermal properties, which must be overcome in order to manufacture materials with properties comparable with the traditional composite materials.

The synthetic resins have the disadvantage of a restriction of processing due to the high viscosity at melting, phenomenon which occurs at injection moulding, and the final product is hard to be recycled. This disadvantage can be removed by using a vegetal oil resin-based thermo rigid-biological matrix, which, being biodegradable, does not require a polymerization process. Biopolymers are obtained from renewable resources and, during recent years, they have acquired a higher

importance compared with petrol-based polymers. Among the most used vegetal resins are Sandarac, Copal and Dammar. These natural resins are insoluble in water, but are mildly soluble in oil, alcohol, turpentine and partially in petrol.

1.2 GEO POLYMER

The population growth, together with new global standards of modern construction requiring more demanding infrastructures. Statistical trends estimate an increase in global cement production from 4.3 billion metric tons in 2015 to 6.1 billion metric tons in 2050. This rate is even higher in developing countries such as China with a production of about half of the global cement in 2019. This high production of ordinary Portland cement (OPC) is challenged by demolishing reserves of limestone, a huge amount of CO₂ emission, around 7% of global CO₂ emissions, and an energy consuming process with the average primary energy intensity of about 4.8 GJ/t. Geopolymers, also named “alkali-activated binders”, have been introduced as a promising alternative to OPC with less environmental impacts. They are producing by mixing waste or natural aluminosilicate sources, such as fly ash (FA), volcanic

ashes (VA), and metakaolin (MK), with alkali activators such as sodium hydroxide and sodium silicate.

After mixing, the alkali activator dissolves the aluminosilicate precursors, and aluminate and silicate monomers are released, which later undergo polycondensation reaction. As a result, a cementitious gel is produced with potentially low CO₂ footprint, high early strength, and high thermal resistance. The term 'geopolymer' was coined within the Nineteen Seventies by Joseph Davidovits and applied to a category of solid materials synthesized through the process of chemical interaction of an aluminosilicate powder utilizing alkali solution. Geopolymer was originally engineered as fire-resisting various to organic thermo-set polymers following a series of fires in Europe, and merchandise supported this first work have since found application as coatings for fireplace protection for cruise ships as a resin in high-temperature carbon-fiber composites, in thermal insulation along with protection of wood structures, as a high temperature-resistant adhesive, as a monolithic refractory composite and in varied different niche applications. Then the foremost application for geopolymer binders has since shifted to uses in construction. This paper critiques the characteristics of geopolymer to thermal evolution and compares these to cement being currently used as OPC.

Geopolymers were proven to have massive capability to be used in elevated temperature applications, which is the reason numerous specialist have contemplated their conduct during excessive temperature exposure. Geopolymer due to their inorganic structure displays magnificent thermal stability, much in overabundance in accordance to conventional concrete. These qualities permit geopolymer and its composites in consideration for the high-temperature thermal application.

1.3FACTORS INFLUENCING THERMAL BEHAVIOR OF GEOPOLYMERS

Often thermal expansion of concrete, no matter if Portland or even cement that is certainly geopolymer, is completely outclassed by means of thermal expansion as part of the aggregates because they often constitute 65% to 80% about the actual volume.

As a whole, cement paste as part of the concrete shrinks while the aggregates enlarge as part of the course of substantial temperature exposure. Thedifferential enlargement associated with the aggregates plus the paste comes with repercussions when it

comes to the mechanical strength immediately after high-temperature subjection. Factors influencing geopolymer's thermal expansion are aggregate

type, binder type, and water-cement ratio. Of all these types of aggregate seems to have a notable impact. Aggregates appropriate for the use as parts of geopolymer concrete are similar as found as part of OPC. Research investigation on thermal expansion involving metakaolin geopolymer mortars incorporating granite aggregates and fine quartz by Subaer and van Riessen makes it clear that thermal shrinkage is reduced due to incorporation of fine aggregates into the mortar to substantially beneath 1%, one-half compared to that of paste. As a matter of fact, observed which the phase difference within typically the quartz aggregate established peaked value associated with a temperature range which is considered to be dimensionally stable.

CHAPTER 2

2.1 LITERATURE SURVEY

- YasirSofi and Iftekar Gull intended to study the properties of fly ash based Geopolymer concrete. M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) by varying alkaline liquid to fly ash ratio from 0.3 to 0.45. The compressive strength, tensile strength and

flexural strength tests were conducted on geopolymer concrete and parameters that affect it are analyzed and proved experimentally. The durability properties like permeability and acid attack are also studied. From the test results, it was concluded that geopolymer concrete possesses good compressive strength and offers good durability characteristics. With the increase of alkaline liquid to fly ash ratio strength decreases and alkaline liquid to fly ash ratio less than 0.3 is very stiff.

- P. K. Jamdade and U. R. Kawade studied the strength of Geopolymer concrete by using oven curing. In this study Geopolymer concrete is prepared by mixing sodium silicate and sodium hydroxide with processed fly ash. The concrete is cured at different condition and different temperatures i.e; 600 C, 900 C and 1200 C so as to increase the strength of concrete. It was observed that higher curing temperature resulted in larger compressive strength of Geopolymer concrete, even though an increase in the curing temperature beyond 600 C did not

increase the compressive strength substantially. Also longer curing time improved the polymerization process resulting in higher compressive strength of Geopolymer concrete.

- Arya Aravind and Mathews M Paul carried out research on mechanical properties of Geopolymer concrete reinforced with steel fiber. This study focuses on the compressive strength and
- split tensile strength of geopolymer concrete reinforced with steel fiber. Experiments were performed using the Box–Behnken experimental design. Box–Behnken experimental design is a type of response surface methodology. Response surface methodology is an empirical optimization technique for evaluating the relationship between the experimental outputs and factors called X1 , X2 , and X3 . For obtaining the results for Box Behnken design, analysis of variance has been calculated to analyze the accessibility of the model and was carried in Microsoft Office Excel 2007. It can be concluded that compressive strength of geopolymer concrete is gradually increased with prolonged curing period also with the increase of sodium silicate to sodium hydroxide liquid ratio by mass. Split tensile strength of geopolymer concrete increased as percentage of steel fiber increased. Another important observation was obtained that curing under normal sunlight yielded strength of 16 N/mm² .

- Kamlesh. C. Shah conducted research on strength parameters and durability of fly ash based Geopolymer concrete. In this study, two concrete mixes are to be worked out; GPC Mix-1 fly ash concrete and OPC Mix-2 Concrete mix having OPC equivalent to amount of cementitious material used in GPC Mix-1. Different parameters were used such as alkaline liquid to fly ash ratio of 0.40 ,0.45 and 0.50, ratio of NaOH to Na₂ SiO₃ 2.0 and 2.5, molarities of NaOH; 10M ,12M, 14M and 16M. Compressive
 - strength test, split tensile test, pull out test and durability test were performed under ambient temperature curing conditions i.e; 600 C, 900 C and 1200 C. Higher average compressive strength, tensile strength and pull out strength of 52.25, 4.10 and 10.25N/mm² were observed for concrete GPC Mix-1 as compared to that of concrete OPC Mix-2. The test results showed that oven cured fly ash based geopolymer concrete have an excellent resistance to sulfate attack, salt attack and acid attack as compared to ambient curing.
- Benny Joseph and George Mathew carried out the influence of aggregate content on the engineering properties of Geopolymer concrete. Influence of other parameters such as curing temperature, period of curing, ratio of sodium silicate to sodium hydroxide, ratio of alkali to fly ash and molarities of sodium

hydroxide were also discussed. Based on the study carried out, it can be concluded that a geopolymer concrete with proper proportioning of total aggregate content and ratio of fine aggregate to total aggregate, along with the optimum values of other parameters, have better engineering properties than the corresponding properties of ordinary cement concrete. Compared to ordinary cement concrete, 14.4% enhancement in modulus of elasticity and 19.2% enhancement in Poisson's ratio could be achieved in geopolymer concrete.

- Aminul Islam Laskar and RajanBhattacharjee investigated the variation of workability of fly ash based Geopolymer concrete with the variation of lignin based plasticizer and poly-carboxylic ether based superplasticizer. It has been observed that there exists a critical value of molar strength of sodium hydroxide beyond which superplasticizer and plasticizer have adverse effect on workability of fly ash based geopolymer concrete. There is an increase in slump below the critical molar strength of sodium hydroxide. Lignin based first generation plasticizer shows better performance in terms of workability over third generation superplasticizer below the critical value of molar strength. It was also observed that there is a good correlation between the rheological parameters and slump for fly ash based geopolymer concrete incorporating plasticizer and superplasticizer.

- Steenie Edward Wallah used low-calcium fly ash as its source material, alkaline activators and aggregates normally used for Ordinary Portland cement concrete. Four series of test specimens
- with different compressive strength were prepared to study the drying shrinkage of this concrete. Results obtained were compared with the calculated results of drying shrinkage as predicted by Gilbert Method which is normally used for Ordinary Portland cement concrete. Results showed that the heat cured fly ash-based geopolymer concrete undergoes very low drying shrinkage. The drying shrinkage strain at one year as calculated using Gilbert Method was much higher, about five to seven times, compared to the measured drying shrinkage strain.

2.2 MATERIALS

2.2.1 SAND



The most common component of sand is silicon dioxide in the form of quartz. The Earth's landmasses are made up of rocks and minerals, including quartz, feldspar and mica. Weathering processes — such as wind, rain and freezing/thawing cycles — break down these rocks and minerals into smaller grains. Sand is a granular material composed of finely divided rock and mineral particles. Sand has various

compositions but is defined by its grain size. Sand grains are smaller than gravel and coarser than silt.

Sand can also refer to a textural class of soil or soil type; i.e., a soil containing more than 85 percent sand-sized particles by mass. The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland

continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz.

Calcium carbonate is the second most common type of sand, for example, aragonite, which has mostly been created, over the past 500 million years, by various forms of life, like coral and shellfish. For example, it is the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean. Somewhat more rarely, sand may be composed of calcium sulfate, such as gypsum and selenite, as is found in places like White Sands National Park and Salt Plains National Wildlife Refuge in the U.S.

Sand is a non-renewable resource over human timescales, and sand suitable for making concrete is in high demand. Desert sand, although plentiful, is not suitable for concrete. 50 billion tons of beach sand and fossil sand is used each year for construction.

2.2.2 FLY ASH



Fly ash, flue ash, coal ash, or pulverised fuel ash (in the UK) – plurale tantum: coal combustion residuals (CCRs) – is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler's combustion chamber (commonly called a firebox) is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment

before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash.

Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial

amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. The minor constituents of fly ash depend upon the specific coal bed composition but may include one or more of the following

elements or compounds found in trace concentrations (up to hundreds ppm): gallium, arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with very small concentrations of dioxins and PAH compounds.^{[1][2]} It also has unburnt carbon.

In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In the United States, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

In the case that fly (or bottom) ash is not produced from coal, for example when solid waste is incinerated in a waste-to-energy facility to produce electricity, the ash may contain higher levels of contaminants than coal ash. In that case the ash produced is often classified as hazardous waste.

2.2.3 COMPOSITE SHEET



A sandwich panel is any structure made of three layers: a low-density core (PIR, mineral wool, XPS), and a thin skin-layer bonded to each side. Sandwich panels are used in applications where a combination of high structural rigidity and low weight is required.

The structural functionality of a sandwich panel is similar to the classic I-beam, where two face sheets primarily resist the in-plane and

lateral bending loads (similar to flanges of an I- beam), while the core material mainly resists the shear loads (similar to the web of an I- beam). The idea is to use a light/soft but thick layer for the core and strong but thin layers for face sheets.

This results in increasing the overall thickness of the panel, which often improves the structural attributes, like bending stiffness, and maintain or even reduce the weight.

Sandwich panels are an example of a sandwich structured composite: the strength and lightness of this technology makes it popular and widespread. Its versatility means that the panels have many applications and come in many forms: the core and skin materials can vary widely and the core may be a honeycomb or a solid filling. Enclosed panels are termed cassettes.

2.2.4 JUTE



Jute is one of the most affordable natural fibers, and second only to cotton in the amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute fiber falls into the bastfiber category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc.. The industrial term for jute fiber is *raw jute*. The fibres are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the "golden fiber" for its color and high cash value. Jute is maybe the most sensible normal fibers, and second to cotton in the whole made and arrangement of businesses. Jute fiber are made basically out of the plant materials cellulose and lignin. It falls into the bastfiber characterization (fiber assembled from bast, the phloem of the plant, on occasion called the "skin") close by kenaf, current hemp, flax (material), ramie, etc The

advanced term for jute fiber is rough jute. The fiber are grayish to brown, and 1–4 meters (3–13 feet) long. Jute is moreover called the splendid fiber for its tone and high cash regard. Creation is amassed generally in Bangladesh, similarly as India's domains of Assam, Bihar, and West Bengal. India is the world's greatest producer of jute, anyway imported around 162,000 tons of rough fiber and 175,000 tons.

PROCESS







CHAPTER 3

AIM & SCOPE

3.1 AIM

This project aims to develop geopolymer composite and study their suitability for high –temperature exposure. Further a test rig for evaluating the thermal properties of the geopolymer sandwich composite shall be fabricated.

3.2 SCOPE & OBJECTIVES

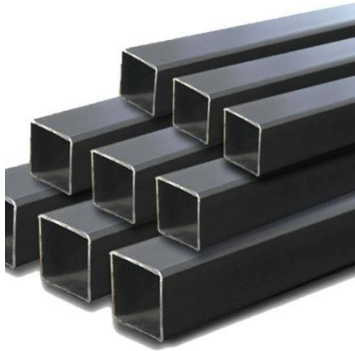
- Preparation of geopolymer composite.
- Fabrication of thermal testing kit.
- Thermal testing for geopolymer composite using thermal testing kit.
- To advance the measurements and properties of the geopolymer.
- To create a geopolymer sandwich composite can be utilized for protecting purposes on top of the autos.
- To acquire a simple to utilize item that doesn't hurt climate or the customers using it

CHAPTER 4

COMPONENTS

- HELIUM SHEET
- LEAD SCREW
- MS SQUARE TUBE
- 2000W HEATER
- HEAT DETECTOR
- HEAT REGULATOR
- MS PLATE (5 MM)
- HEAT TEMPERATURE OBSERVOR

4.1 SQUARE TUBE

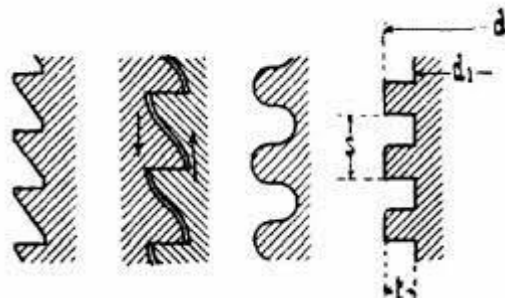


Rectangular and square HSS are also commonly called tube steel or box section. Circular HSS are sometimes mistakenly called steel pipe, although true steel pipe is actually dimensioned and classed differently from HSS. Square tubes are generally used for maintenance and structural purposes. Some examples of applications would be building

construction, railings, and sign posts. They are measured by their outside dimensions and their wall thickness.

Square Steel Tube is a welded structural grade tubing that is available in either type A513 or A500 Grade B, depending on its size and wall thickness. Either grade is ideal for all structural applications, general fabrication, manufacturing and repairs.

4.2 LEAD SCREW



A leadscrew (or lead screw), also known as a power screw or translation screw, is a screw used as a linkage in a machine, to translate turning motion into linear motion. Because of the large area of sliding contact between their male and female members, screw threads have larger frictional energy losses compared to other linkages.

They are not typically used to carry high power, but more for intermittent use in low power actuator and positioner mechanisms.

Leadscrews are commonly used in linear actuators, machine slides (such as in machine tools), vises, presses, and jacks. Leadscrews are a common component in electric linear actuators.

Leadscrews are manufactured in the same way as other thread forms (they may be rolled, cut, or ground).

A lead screw is sometimes used with a split nut (also called half nut) which allows the nut to be disengaged from the threads and moved axially, independently of the screw's rotation, when needed (such as in single-point threading on a manual lathe). A split nut can also be used to compensate for wear by compressing the parts of the nut.

A hydrostatic leadscrew overcomes many of the disadvantages of a normal leadscrew, having high positional accuracy, very low friction, and very low wear, but requires continuous supply of high pressure fluid and high precision manufacture leading to significantly greater cost than most other linear motion linkages.

4.3 2000W HEATER

Electric heating is a process in which electrical energy is converted to heat energy. Common applications include space heating, cooking, water heating and industrial processes. An electric heater is an electrical device that converts an electric current into heat. The heating element inside every electric heater is an

electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy.

Most modern electric heating devices use nichrome wire as the active element; the heating element, depicted on the right, uses nichrome wire supported by ceramic insulators. Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, that draws heat energy from a source such as the ground or outside air and directs that heat into the space to be warmed. Some systems can be reversed so that the interior space is cooled and the warm air is discharged outside or into the ground.

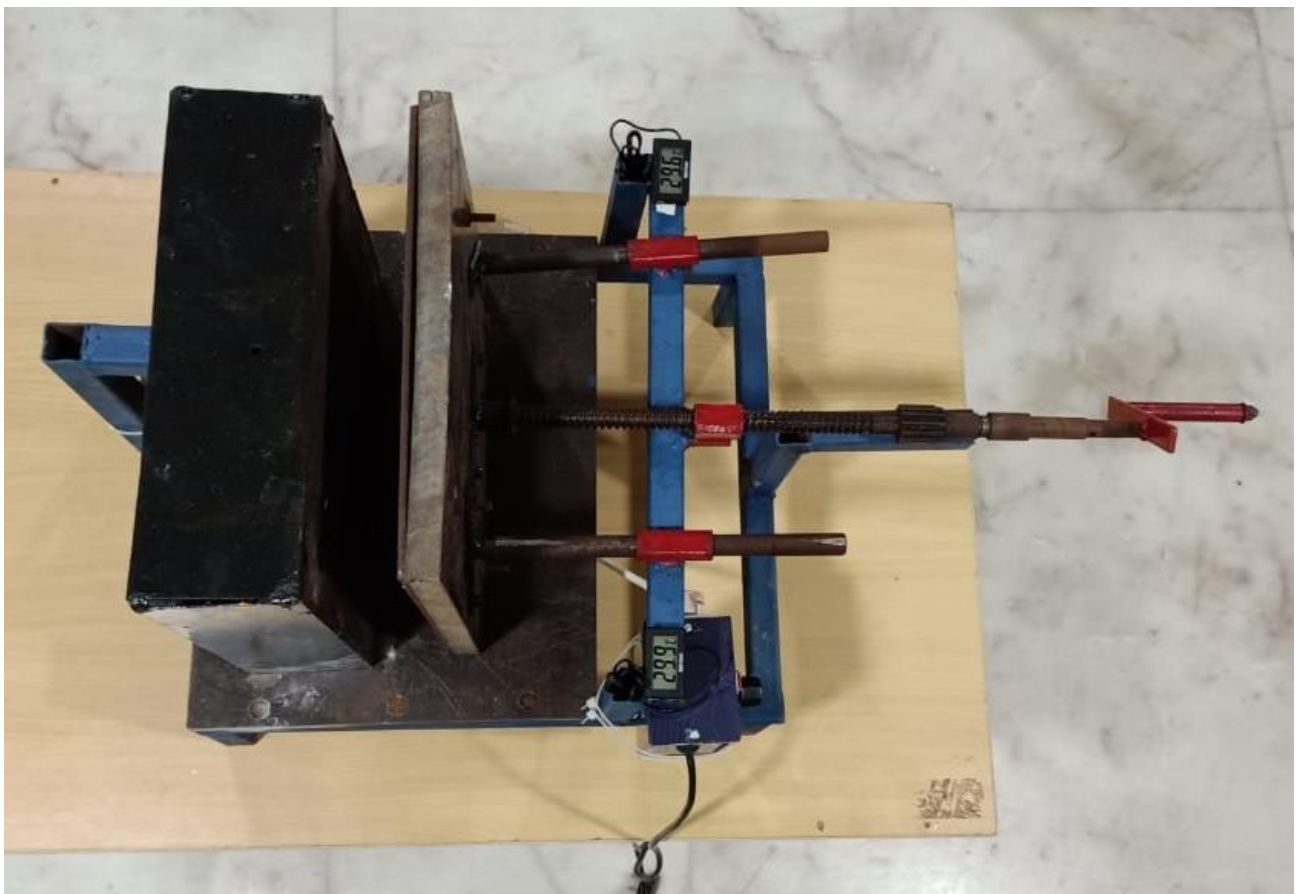
4.4 HEAT REGULATOR & DETECTOR





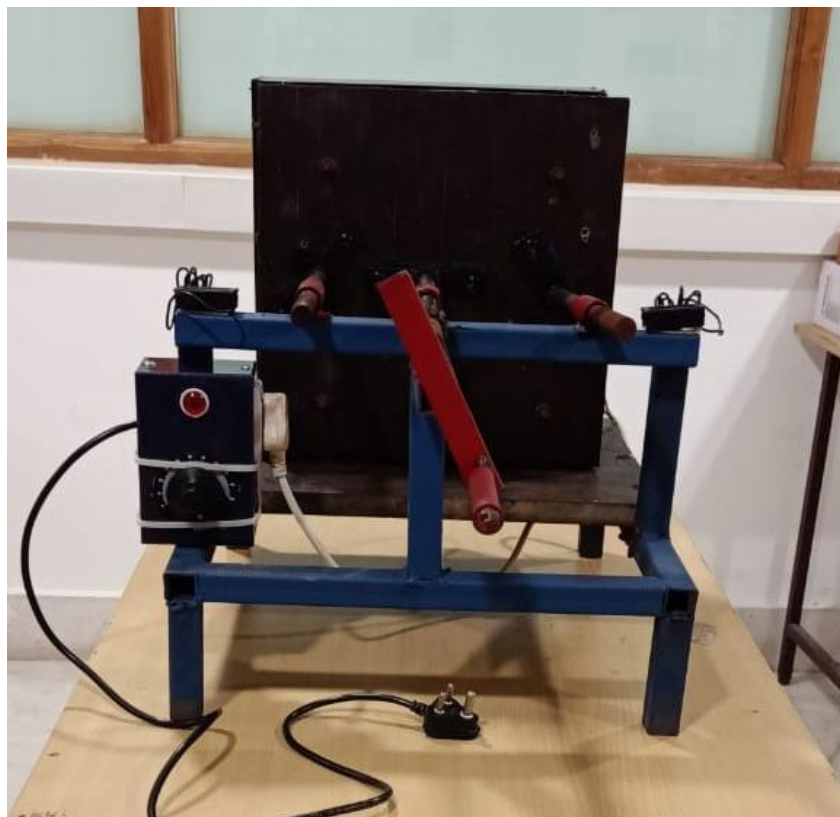
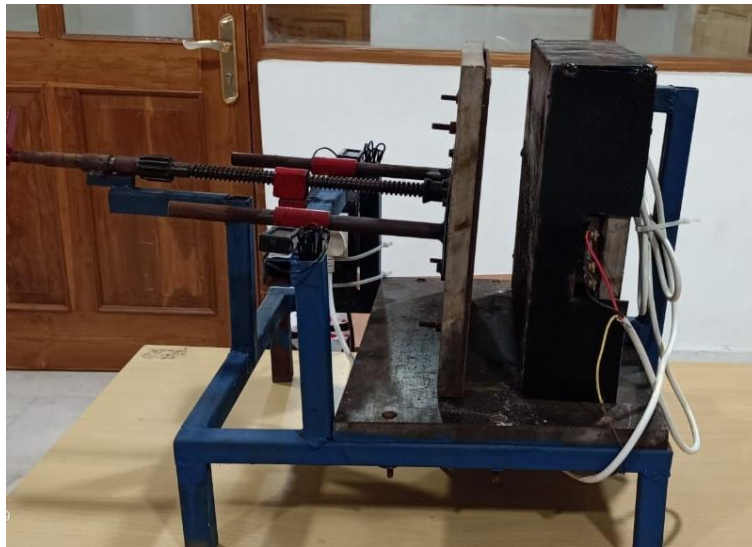
CHAPTER 5

5.1 PROJECT IMAGES

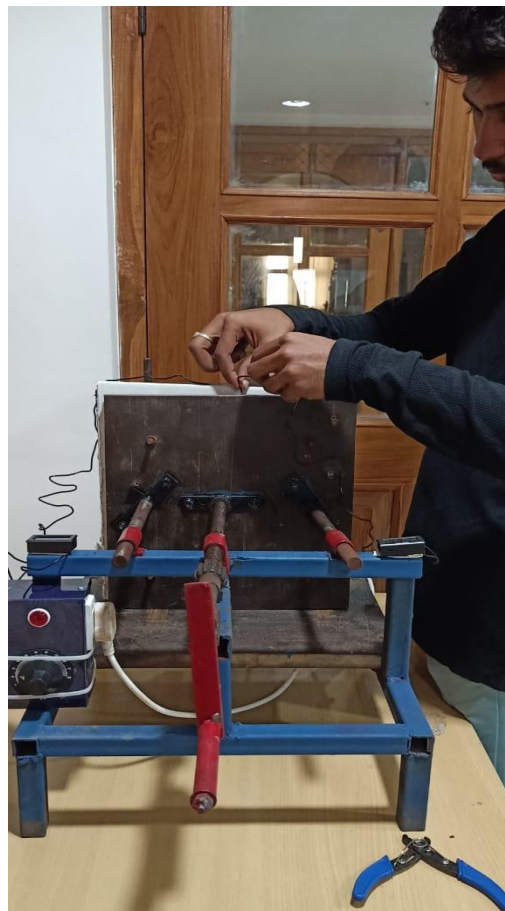
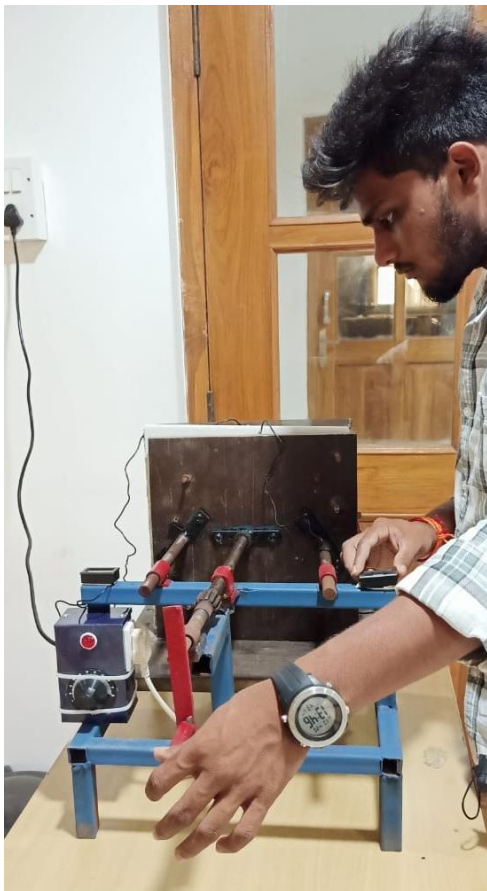


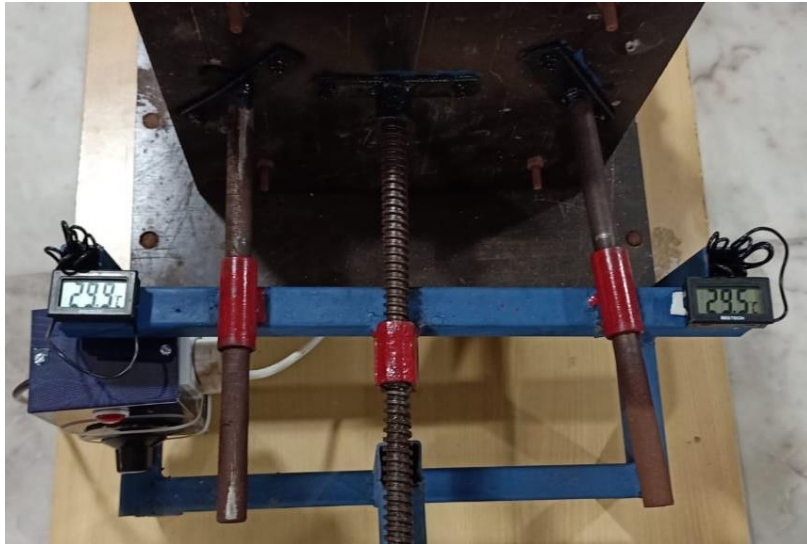
TOP VIEW

SIDE VIEW



5.2 WORKING IMAGES





CHAPTER 6

CONCLUSION

Geopolymer due to their inorganic structure displays magnificent thermal stability, much in overabundance in accordance to conventional concrete. These qualities permit geopolymer and its composites in consideration for the high-temperature thermal application. Further research should be conducted to gain a deeper insight into commercializing geopolymers innovations and to develop sustainable products that are low in terms of embodied energy, low carbon footprint, cheap production costs, and safe to

handle on-site. In addition, researchers should focus on fabricating geopolymer concrete

by using short fibres as reinforcement and incorporation of nanoparticles to assess the long-term thermal performance of geopolymer concrete.

REFERENCES

- 1) Talling, B. (2002) Geopolymers give fire safety to cruise ships. Geopolymers 2002. Turn Potential into Profit, Melbourne, Australia, Lukey, G. C. (Ed.), CD-ROM Proceedings.
- 2) Lyon, R. E., Balaguru, P. N., Foden, A., Sorathia, U., Davidovits, J. and Davidovics, M. (1997)

- 3) doi:10.1002/(SICI)1099-1018(199703)21:2<67::AID-FAM596>3.0.CO;2-N. Giancaspro, J., Balaguru, P. N. and Lyon, R. E. (2006) Use of inorganic polymer to improve the fire response of balsa sandwich structures. *Journal of Materials in Civil Engineering*, 18, 390–397. doi:10.1061/(ASCE)0899-1561(2006)18:3(390).
- 4) Bell, J. L., Gordon, M. and Kriven, W. M. (2005) Use of geopolymetric cements as a refractory adhesive for metal and ceramic joins. *Ceramic Engineering and Science Proceedings*, 26, 407–413.
- 6) Krivenko, P. V. and Kovalchuk, G. Y. (2007) Directed synthesis of alkaline aluminosilicate minerals in a geocement matrix. *Journal of Materials Science*, 42, 2944–2952. doi10.1007/s10853-006-0528-3.

- 7) G. Manjunatha, Radhakrishna, K. Venugopal, S.V. Maruthi, Strength characteristics of open air cured geopolymer concrete, Transactions of the indian ceramic society 73(2) (2014) 149-156.
- 8) S.S. Kumar, K. Pazhani, K. Ravisankar, Fracture behaviour of fibre reinforced geopolymer concrete, CURRENT SCIENCE 113(1) (2017) 116-122.
- 9) M. Albitar, P. Visintin, M.M. Ali, M. Drechsler, Assessing behaviour of fresh and hardened geopolymer concrete mixed with class-F fly ash, KSCE Journal of Civil Engineering 19(5) (2015) 1445-1455.
- 10) D. Hardjito, B.V. Rangan, Development and properties of low-calcium fly ash-based geopolymer concrete, (2005).

- 11) Z. Pan, J.G. Sanjayan, B.V. Rangan, Fracture properties of geopolymer paste and concrete, Magazine of concrete research 63(10) (2011) 763-771.
- 12) G.S. Ryu, Y.B. Lee, K.T. Koh, Y.S. Chung, The mechanical properties of fly ash-based geopolymer concrete with alkaline activators, Construction and Building Materials 47 (2013) 409- 418.
- 13) M. Farooq, A. Bhutta, N. Banthia, Tensile performance of eco-friendly ductile geopolymer composites (EDGC) incorporating different micro-fibers, Cement and Concrete Composites 103 (2019) 183-192.
- 14) Bhutta, P.H.R. Borges, C. Zanotti, M. Farooq, N. Banthia, Flexural behavior of geopolymer composites reinforced with

steel and polypropylene macro fibers, *Cement and Concrete Composites* 80 (2017) 31-40.

- 15) Fire-resistant aluminosilicate composites. *Fire and Materials*, 21, 67–73.