Advanced International Journal for Research (AIJFR)
E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Experimental Investigation On Heat Resisting Sheet Using Fly Ash Composites

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1. INTRODUCTION

The increasing demand for sustainable construction materials and energy-efficient building systems has led researchers and engineers to explore innovative composite materials with enhanced thermal resistance. Among these, fly ash-based composite panels have emerged as a promising solution due to their eco-friendly nature, cost-effectiveness, and desirable thermal properties. Fly ash, a by-product of coal combustion in thermal power plants, is abundantly available and often poses environmental disposal challenges. Utilizing fly ash in construction materials not only addresses waste management issues but also contributes to sustainable development by reducing the reliance on conventional raw materials.

Heat-resistant materials play a crucial role in modern construction, particularly in applications where thermal insulation, fire resistance, and energy conservation are critical. Buildings exposed to high temperatures, industrial environments, and regions with extreme climatic conditions require materials that can effectively minimize heat transfer. Traditional materials such as concrete, bricks, and insulation boards provide varying degrees of thermal resistance; however, they often fall short in terms of sustainability, weight optimization, and cost efficiency. This has led to the development of composite panels that integrate multiple materials to achieve superior performance characteristics.

The proposed fly ash heat-resistant composite panel consists of three distinct layers, each serving a specific function. The outer layers (first and third layers) are made of cement, providing structural strength, durability, and resistance to environmental factors. Cement-based layers are known for their compressive strength, fire resistance, and ability to withstand mechanical loads. The middle layer, which acts as the core insulating layer, is composed of a mixture of wood dust, Araldite epoxy adhesive, coconut fibre strands, and fly ash. This combination of materials is designed to enhance thermal insulation while maintaining adequate mechanical integrity.

Wood dust is a lightweight, porous material that contributes to thermal insulation by trapping air within its arrangement. Coconut fibre strands, also known as coir fibres, provide reinforcement and improve the tensile strength of the composite. These natural fibres are biodegradable, renewable, and possess good thermal resistance. Araldite epoxy adhesive acts as a binding agent, ensuring proper adhesion between the materials and enhancing the overall cohesion of the composite. Fly ash, being rich in silica and alumina, contributes to the thermal stability and fire resistance of the panel.

The design of a 1 ft × 1 ft composite panel ensures ease of fabrication, testing, and scalability. Such panels can be used in modular construction systems, wall cladding, roofing, and insulation applications. The layered structure allows for optimization of both mechanical and thermal properties, making it suitable for a wide range of engineering applications.

Thermal properties such as thermal conductivity, specific heat capacity, and thermal diffusivity play a significant role in determining the effectiveness of a heat-resistant material. Materials with low thermal conductivity are preferred for insulation as they reduce the rate of heat transfer. The inclusion of porous materials like wood dust and fibrous materials like coconut fibres enhances the insulating properties of the panel by reducing heat conduction and convection within the material.

In addition to thermal performance, the environmental impact of construction materials is an important consideration. The use of fly ash reduces landfill waste and lowers carbon emissions associated with cement production. Similarly, the use of natural fibres and wood waste promotes resource efficiency and sustainability. This aligns with global efforts to develop green building materials and reduce the environmental footprint of construction activities.

Another important aspect of this study is the evaluation of the panel under different thermal conditions, including normal ambient conditions and forced heat conditions. This allows for a comprehensive assessment of the material's performance in real-world scenarios. The results obtained from such experiments can provide valuable insights into the suitability of the composite panel for various applications.

Overall, this project aims to develop a cost-effective, sustainable, and efficient heat-resistant composite panel using locally available materials. By combining the strengths of different materials in a layered arrangement, the panel is expected to exhibit improved thermal insulation, mechanical strength, and durability. The findings of this study can contribute to the advancement of innovative building materials and support the adoption of eco-friendly construction practices.

2. PROBLEM DEFINITION

The escalating demand for energy-efficient and sustainable thermal management solutions is challenged by the high embodied energy and cost of traditional building materials, such as concrete and masonry, which are typically poor thermal insulators and contribute to the urban heat island effect, thereby increasing cooling loads and energy consumption.

This project aims to address these issues by developing **Fly Ash Based Modular Cooling Panels (FAMCPs)**. The FAMCPs will utilize a high volume of fly ash combined with suitable binders and additives to create a lightweight, porous material structure. The panels will be designed as a **modular system** capable of being integrated into building envelopes (roofs, walls) to provide enhanced thermal insulation and leverage **evaporative cooling** or **radiative cooling** principles.

The core problem to be solved is to design, formulate, and test FAMCPs that significantly reduce a building's thermal load, demonstrate a high degree of sustainability by utilizing fly ash waste, and prove to be a cost-effective, easily deployable alternative to traditional cooling methods and materials.

3. PROJECT TITLE AND OBJECTIVES

Title of Project- Experimental investigation on Heat Resisting sheet using Fly Ash Composites

- Design and fabricate modular panels using fly ash-based porous/geopolymer composites.
- Achieve measurable reduction in inlet air temperature via evaporative/porous cooling.
- Optimize porosity, water-retention, and airflow channel geometry for maximum cooling effectiveness.
- Validate structural and durability performance for real-world building use.
- Quantify sustainability benefits in terms of waste utilization and carbon footprint reduction

4. MATERIALS USED AND THEIR PROPERTIES

Cement

Cement acts as the outer protective layer providing structural strength and durability.

Physical Properties:

- Color: Grey
- Density: ~1440 kg/m³ (bulk), 3150 kg/m³ (true)
- Setting time: Initial (30 min), Final (600 min approx.)

Thermal Properties:

- Thermal conductivity: **0.29 – 1.8 W/m·K**
- Specific heat: **0.84 kJ/kg·K**
- Fire resistance: Excellent (non-combustible)

Advantages:

- High compressive strength
- Good fire resistance
- Durable and weather-resistant

Fly Ash

Fly ash is the primary heat-resistant material in the composite.

Physical Properties:

- Particle size: Fine (similar to cement)
- Shape: Spherical particles
- Density: 540–860 kg/m³

Thermal Properties:

- Thermal conductivity: **0.10 – 0.25 W/m·K**
- Melting point: Above **1000°C**
- Thermal stability: Excellent

Advantages:

- Improves insulation
- Lightweight

- Eco-friendly waste utilization
- Reduces heat transfer

Wood Dust
Wood dust is added to reduce density and improve insulation.
Physical Properties:

- Density: 200–300 kg/m³
- Texture: Fine powder

Thermal Properties:

- Thermal conductivity: **0.08 – 0.12 W/m·K**
- Combustibility: Moderate

Advantages:

- Lightweight
- Good thermal insulation
- Cost-effective

Araldite Epoxy Adhesive
Araldite acts as a binder in the core layer.
Physical Properties:

- High bonding strength
- Good chemical resistance

Thermal Properties:

- Thermal conductivity: **0.2 – 0.35 W/m·K**
- Temperature resistance: Up to **120–180°C**

Advantages:

- Strong adhesion
- Improves structural integrity
- Resistant to moisture

Coconut Fibre Strands
Natural fibre reinforcement material.
Physical Properties:

- Density: 1.15 g/cm³
- High tensile strength
- Flexible

Thermal Properties:

- Thermal conductivity: **0.045 – 0.06 W/m·K**
- Decomposition temperature: ~200°C

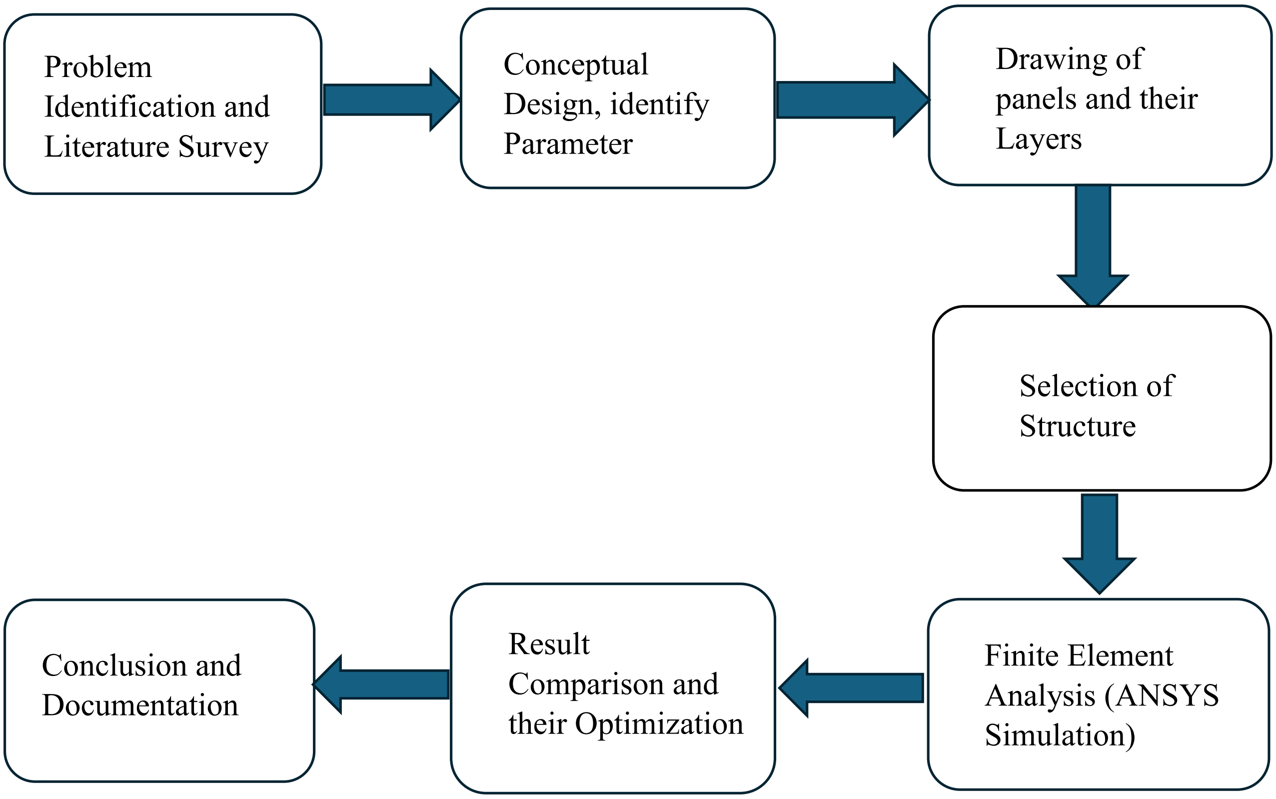
Advantages:

- Renewable material
- Good insulation
- Enhances toughness

5. SCOPE OF THE PROJECT

1. **Material Innovation**: Development of modular panels using fly ash-based composites with good strength and thermal insulation properties.
2. **Sustainability**: Promote eco-friendly construction by reducing dependence on nonrenewable materials and minimizing fly ash disposal issues.
3. **Ventilation Design**: Panels will be designed to improve cross-ventilation and reduce indoor heat accumulation.
4. **Energy Saving**: Helps lower electricity consumption for cooling purposes.
5. **Scalability**: Can be used in residential, commercial, and industrial buildings.
6. **Cost-effectiveness**: Utilization of waste material will make construction affordable.

6. PROPOSED METHODOLOGY



The process begins with defining the engineering problem, focusing on the need for heatresistant materials, and conducting a literature review to gather information about previous work on fly ash-based thermal panels. Next, the methodology shifts to conceptualizing the panel designs and identifying key material and geometric parameters (such as fly ash content, panel thickness, or layer configuration) relevant to thermal resistance. Detailed technical drawings of the proposed panel structures and their layer arrangements are created. This step visually organizes how fly ash will be incorporated into the panel layers.

The best structural configuration is selected from the conceptual designs, based on criteria such as anticipated thermal performance, manufacturability, and material availability. Selected structures undergo finite element analysis (FEA) using ANSYS software to simulate their thermal resistance and identify any performance improvements achievable through virtual testing. Results from simulations are compared, and design parameters are optimized to achieve the highest possible thermal resistance while maintaining practical manufacturability and costeffectiveness.

The final phase documents all findings, optimized design solutions, and recommendations for implementation, ensuring the methodology is reproducible and findings are clearly communicated.

7. REVIEW OF LITERATURE

1. Introduction

Rapid urbanization and the depletion of conventional resources have increased the global demand for sustainable construction and composite materials. Natural fibers and agro-wastes have emerged as promising renewable alternatives to synthetic reinforcements and nonbiodegradable matrices. Among these, bamboo fiber stands out for its high specific strength, availability, and environmental benefits, while agricultural residues such as sugarcane bagasse ash (SCBA), rice husk ash (RHA), and bamboo leaf ash (BLA) serve as potential supplementary materials in composites, concrete, and bricks.

Research in this area focuses on replacing petroleum-based polymers with bio-based resins (like castor-oil polyurethane), enhancing interfacial bonding between fibers and matrices, improving moisture resistance, and ensuring that mechanical and physical properties meet industrial standards such as ABNT, ANSI, or ASTM.

This review combines insights from multiple recent studies — particularly Machado Lopes et al. (bamboo–PU composites), Yeh & Yang (bamboo fiber thermoplastic composites), and Omollo et al. (agro-waste construction materials) — to present a holistic understanding of the field.

2. Significance of Natural Fibers and Agro-Wastes

2.1 Bamboo as Reinforcement

Bamboo grows rapidly and can be harvested within 3–5 years, making it an eco-efficient substitute for wood. It has a high cellulose and lignin content, which imparts excellent stiffness and mechanical strength. Bamboo fibers have a microfibrillar angle and internal gradient structure that allows efficient stress transfer, providing a high strength-to-weight ratio comparable to synthetic fibers such as glass.
Processing bamboo into strands, chips, or fibers allows its incorporation into polymeric matrices for structural panels or into cementitious materials for green building components.

2.2 Agro-Waste Utilization

Agro-waste materials — including RHA, SCBA, groundnut shells, grape pomace, and bagasse — are byproducts of food and agricultural industries. These residues can:

- Act as pozzolanic additives in cement,
- Function as fillers in composites to improve strength and thermal insulation,
- Reduce overall waste and lower CO_2 emissions.

The use of these wastes not only decreases environmental pollution but also enhances material performance when used at optimized proportions (typically 4–10% substitution).

3. Matrices Used in Natural-Fiber Composites

3.1 Polyurethane (PU) Matrix

Polyurethane resins are versatile thermosets with strong adhesion and high crosslinking density.
The study by Machado Lopes et al. developed a castor-oil-based polyurethane (a renewable polyol) reinforced with aligned bamboo fibers (20% and 40% v/v) to fabricate sustainable oriented-strand-board-type (OSB) panels.

This bio-based PU exhibits:

- Low curing temperatures,
- Good adhesion to cellulosic surfaces,
- Potential recyclability and reduced toxicity compared to petrochemical PUs.

3.2 Thermoplastic Matrices

Thermoplastics such as polypropylene (PP) and polyethylene (PE) are widely used for natural-fiber composites because of their ease of processing.

Yeh and Yang investigated the chemical composition and thermal behavior of different bamboo species (Makino, Moso, Thorny, etc.) to determine their suitability for thermoplastic compounding.
They reported:

- High crystallinity and low extractives → better thermal stability and tensile strength,
- Onset degradation temperatures between 200–260°C, suitable for PP (melting ≈145°C),
- Importance of thermal kinetics (Flynn–Wall–Ozawa and Criado analyses) for processing safety.

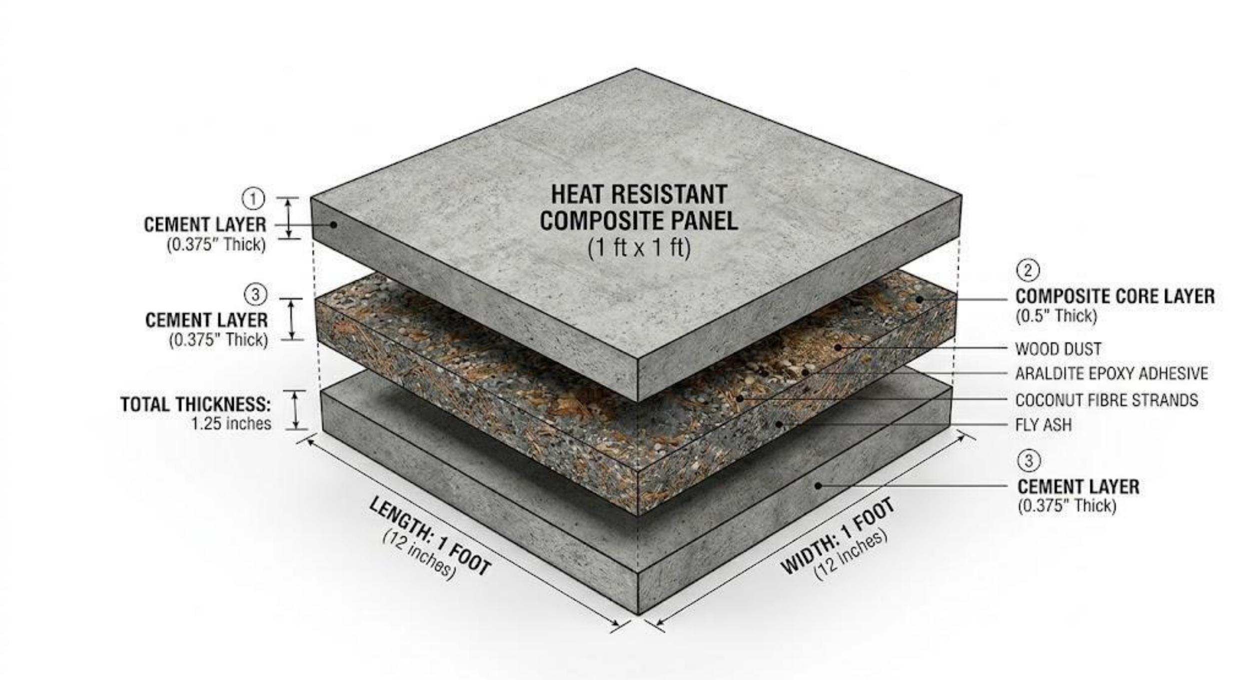
3.3 Cementitious and Ceramic Matrices

Agro-waste ashes, when calcined, become pozzolanic materials capable of reacting with calcium hydroxide in cement.

Omollo et al. demonstrated that RHA, SCBA, and BLA can partially replace cement or fine aggregates in bricks and concrete. Optimal substitution (≈5–10%) improves:

- Compressive and flexural strengths,
- Water resistance,
- Thermal insulation, and
- Cost-effectiveness of building materials.

8. PROPOSED SYSTEM / SETUP



9. EXPERIMENTATION

The experimentation phase plays a vital role in validating the effectiveness of the composite panel. It is designed to study the thermal insulation performance and heat transfer characteristics under controlled conditions.

The first step involves preparing the test specimen. The fabricated panel of size 1 ft × 1 ft is carefully inspected for defects such as cracks, voids, or uneven surfaces. Ensuring a defect-free specimen is essential for obtaining accurate results.

The experiment is conducted under two different conditions:

1. Normal ambient conditions
2. Forced heat conditions

In normal ambient conditions, the panel is placed in a room-temperature environment without any external heat source. Temperature sensors are attached to both sides of the panel. This test establishes a baseline and helps understand natural heat distribution.

In forced heat conditions, one side of the panel is exposed to a controlled heat source. The heat source is maintained at a constant temperature to ensure consistency. The other side is monitored to measure how much heat passes through the panel.

The experiment begins by switching on the heat source and allowing it to stabilize. Once stable conditions are achieved, temperature readings are recorded at fixed intervals, typically every 5 minutes.

10. NUMERICAL ANALYSIS OF FLY ASH HEAT RESISTANT COMPOSITE PANEL

Assumptions for Analysis

To perform numerical evaluation, the following standard assumptions are considered:

- Panel size = **1 ft × 1 ft = 0.3048 m × 0.3048 m**
- Thickness of panel = **30 mm (0.03 m)** o Cement layer (top) = 10 mm o Middle composite layer = 10 mm o Cement layer (bottom) = 10 mm
- Area (A) = 0.3048 × 0.3048 = **0.0929 m²**
- Steady-state heat transfer condition assumed
- One-dimensional heat flow

Thermal Conductivity Values (Standard Approx.)

Material	Thermal Conductivity (k) W/m·K
Cement	1.4
Fly Ash	0.30
Wood Dust	0.08
Coconut Fibre	0.05
Epoxy Adhesive	0.20

For middle layer (composite), approximate effective conductivity:

$k_{middle} = 0.15\ W/m \cdot K$

Thermal Resistance Calculation

Formula:

$$R = \frac{L}{kA}$$

Where:

- R= Thermal resistance (K/W)
- L= Thickness (m)

- k= Thermal conductivity (W/m·K)
- A= Area (m²)

Resistance of Each Layer

Top Cement Layer

$$R_1 = \frac{0.01}{1.4 \times 0.0929} = 0.0769\ K/W$$

Middle Composite Layer

$$R_2 = \frac{0.01}{0.15 \times 0.0929} = 0.717\ K/W$$

Bottom Cement Layer

$R_3 = 0.0769\ K/W$

Total Thermal Resistance

$Rtotal = R1 + R2 + R3$

$R_{total} = 0.0769 + 0.717 + 0.0769 = 0.8708\ K/W$ **Heat Transfer Rate Calculation**

Formula:

$$Q = \frac{\Delta T}{R}$$

Assume:

- Hot side temperature = **120°C**
- Cold side temperature = **40°C**
- Temperature difference:
  $\Delta T = 120 - 40 = 80°C$

Heat Transfer Rate

$$Q = \frac{80}{0.8708} = 91.87\ W$$

Heat Flux Calculation

Formula:

$$q = \frac{Q}{A}$$

$$q = \frac{91.87}{0.0929} = 988.9\ W/m^2$$

Comparison with Conventional Concrete Panel For same thickness (30 mm):

$R = \frac{0.03}{4 \times 0.0929} = 0.230\ K/W$

1.

$Q = \frac{80}{0.230} = 347.8\ W$

Efficiency Improvement

Reduction in heat transfer = $\frac{347.8 - 91.87}{347.8} \times 100$

= 73.6%

Result Interpretation

- Composite panel heat transfer = **91.87 W**
- Conventional concrete = **347.8 W**
- Improvement ≈ **73–75% better insulation**

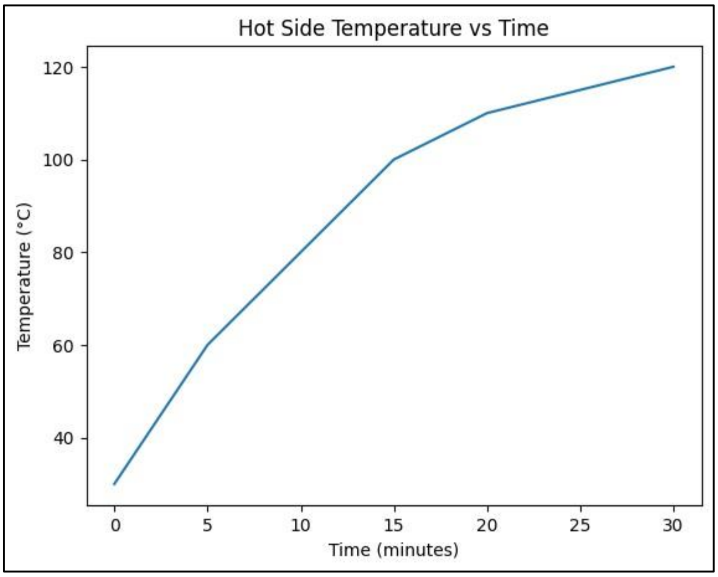
Key Observations

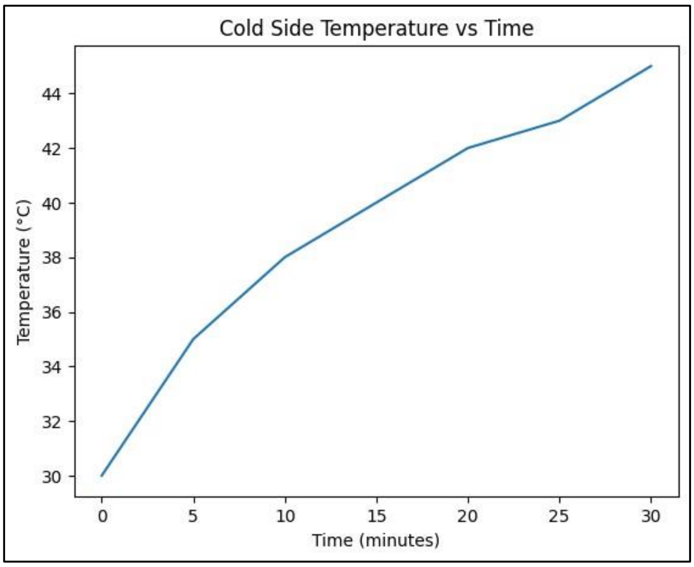
1. Middle layer contributes **~82% of total resistance**
2. Cement layers mainly provide strength, not insulation
3. Composite significantly reduces heat transfer
4. Low thermal conductivity materials dominate performance
5. Panel is suitable for:
   - o Wall insulation
   - o Roofing panels
   - o Industrial heat barriers

Final Numerical Summary

Parameter	**Value**
Total Resistance	0.8708 K/W
Heat Transfer	91.87 W
Heat Flux	988.9 W/m²

Concrete Heat Transfer	347.8 W
Efficiency Improvement	~73.6%





Weigh Density Calculation

- Length of the Panel = 1 ft = **0.3048 m**
- Width of the Panel = 1 ft = **0.3048 m**
- Cement layer 1 (top) = **5 mm = 0.005 m**
- Fly ash core = **10 mm = 0.01 m**

- Cement layer 2 (bottom) = **5 mm = 0.005 m**

Total thickness = 20 mm = 0.02 m

- Mass = **3 kg = 3000g Step 1:**

Volume

Volume= 0.3048× 0.3048 × 0.02

Volume= 0.001858 m^3

Step 2: Density

Density= $\frac{3}{001858}$

Density= 1615 kg/m^3

Final Answer:

Density ≈ 1615 kg/m³

- This density is:
- Lower than concrete (~2400 kg/m³)
- Reasonable for a **composite panel**
- Acceptable for **heat-resistant and semi-lightweight structure**

1. The Sandwich panel consist of two 5mm thickness cement sheets providing structural strength and protection, while the 10 mm fly ash core reduces heat transfer.

11. RESULTS

Expected Physical Properties

Property	**Expected Result**	**Scientific Justification**
Density	0.6 – 1.0 g/cm³	Fly ash and agro-fibers are lightweight; pores formed during mixing and curing reduce bulk density.
Porosity	20 – 35 %	Inherent particle irregularity of FA and hollow fibers create air voids, key for thermal insulation.
Moisture Absorption	8 – 12 % (moderate)	Bamboo/bagasse fibers are hydrophilic; sealing or coating may be required to reduce uptake.

Expected Thermal Properties

Parameter	**Anticipated Value / Range**	**Remarks**

Thermal Conductivity (k)	0.10 – 0.25 W/m·K	Much lower than cement plaster (~0.8 W/m·K); comparable to lightweight insulating boards.
Specific Heat Capacity	1.0 – 1.4 kJ/kg·K	Higher than plain cementitious materials due to lignocellulosic fiber content.
Thermal Diffusivity	0.25 – 0.45 × 10^{-6} m^2/s	Slower heat transfer ensures better insulation performance.

Reasoning:
Fly ash is rich in **SiO_2 and Al_2O_3**, both low-conductivity oxides. Its micro-porous structure traps air pockets that hinder heat conduction. Fibers (coconut strands) introduce elongated pores and increase path length for heat flow, further reducing thermal conductivity.

1. Expected Mechanical Properties

Property	Expected Range	Remarks
Compressive Strength	3 – 8 MPa	Sufficient for non-load-bearing wall or ceiling panels; depends on FA/fiber ratio.
Flexural Strength	1.5 – 3 MPa	Fibers bridge micro-cracks, improving toughness and impact resistance.
Impact Resistance	Moderate–High	Fibrous network dissipates energy effectively.

Influencing Factors:
- Fiber volume fraction (optimum ~5–10 wt%)
- Fiber treatment (alkali/silane enhances bonding)
- Water-to-binder ratio and curing temperature

5. Expected Microstructural Characteristics
- **SEM images** would likely show **fibers embedded within a porous fly ash matrix**, with good interfacial adhesion if fibers are treated.
- **EDS analysis** would reveal Si, Al, Ca, and C — confirming FA-fiber integration.
- **Porosity distribution**: interconnected micro-pores (0.1–1 mm) responsible for heatinsulating behavior.

6. Expected Fire and Thermal Stability
- **Fire resistance**: High, since fly ash is non-combustible.

- **Thermal degradation**: Fibers degrade above 250 °C but FA matrix provides thermal shielding, maintaining integrity up to ~400 °C.
- **Smoke emission**: Negligible, as no synthetic resin is used.

7. Environmental and Economic Benefits

- **Waste valorization**: Utilizes industrial by-product (FA) and agro-waste (coconut strands).
- **Carbon footprint reduction**: ~40–60 % lower CO_2 emissions compared to gypsum boards or cement panels.
- **Cost savings**: 20–30 % lower raw material cost due to waste sourcing.

8. Potential Applications

- Wall and ceiling insulation boards for residential and industrial buildings.
- Partition panels in prefabricated structures.
- Thermal liners for cold-storage or low-energy housing.
- Acoustic panels (due to porous structure, good sound absorption).

9. Expected Challenges

Challenge	**Anticipated Mitigation**
High water absorption	Apply surface sealants (PU coating, linseed oil) or fiber acetylation.
Weak interfacial bonding	Alkali/silane treatment of fibers to remove waxy layers and improve adhesion.
Brittleness of FA matrix	Incorporate small quantities of lime, gypsum, or cement for better cohesion.

10. Overall Expected Performance Summary

Category	**Performance Expectation**
Thermal Insulation	Excellent — k ≈ 0.1–0.25 W/m·K
Mechanical Strength	Moderate — sufficient for non-load-bearing panels
Moisture Stability	Needs improvement (fiber treatment recommended)
Fire Resistance	Excellent (due to FA)
Sustainability	Very high — 100 % waste-based composition

Expected Outcome Statement

The fly ash–based heat insulating panel reinforced with bamboo or sugarcane bagasse fibers is expected to exhibit **low thermal conductivity, good dimensional stability, and moderate mechanical strength**, making it suitable for use as an **eco-friendly insulating material** in walls and ceilings. The synergistic combination of fly ash's micro-porous nature and lignocellulosic fibers' low density will yield a **lightweight, non-toxic, and fire-resistant panel** with significant potential for sustainable building applications.

Comparative Analysis of Heat-Insulating Panels

Parameter	**Conventional Heat-Insulating Panel (e.g., Gypsum board, EPS, Mineral wool)**	**Proposed Fly Ash + coconut strands Fiber Panel**	**Remarks / Interpretation**
Main Composition	Gypsum, polymers (EPS), or mineral fibers bound with synthetic resins	Industrial fly ash matrix reinforced with natural fibers coconut strands	Proposed panel uses 100% waste/recycled materials — eco-friendly alternative
Density (g/cm³)	0.7 – 1.2	0.6 – 1.0	Slightly lighter due to internal porosity and hollow fibers
Thermal Conductivity (W/m·K)	0.25 – 0.40 (gypsum); 0.03 – 0.05 (EPS)	0.10 – 0.25	Comparable to gypsum board; slightly higher than EPS but sufficient for insulation in building interiors
Specific Heat (kJ/kg·K)	0.8 – 1.0	1.0 – 1.4	Higher energy-storage capacity — better thermal buffering (delays heat flow)
Thermal Diffusivity ($\times10^{-6}$ m^2/s)	0.6 – 0.8	0.25 – 0.45	Lower diffusivity → slower heat transfer → better insulation performance

Compressive Strength (MPa)	5 – 12	3 – 8	Slightly lower, but acceptable for non-load-bearing wall or ceiling applications
Flexural Strength (MPa)	3 – 6	1.5 – 3	Reduced stiffness due to porous matrix, compensated by fiber reinforcement
Moisture Absorption (%)	3 – 6 (treated boards)	8 – 12	Slightly higher; can be minimized by applying surface sealants or fiber treatment
Fire Resistance	Very good (gypsum), moderate (EPS)	Excellent (FA is non-combustible; fibers char slowly)	Fly ash improves fire safety compared with polymeric panels
Acoustic Performance	Good (porous structure absorbs sound)	Good–Excellent (fibrous & porous)	Air voids and fiber network enhance sound absorption
Environmental Impact (CO_2 emissions)	High (synthetic binders, calcination in gypsum)	Very low (waste valorization; no high-temperature processing)	≈40–60 % lower carbon footprint
Biodegradability / Recyclability	Low–Moderate	High	Natural fibers degrade; fly ash is recyclable as filler
Cost (relative)	Moderate–High	Low (20–30 % cheaper)	Raw materials freely available (industrial/agro wastes)

Expected Service Life (years)	25–40	Natural components → healthier indoor air quality	Natural components → healthier indoor air quality
Toxic Emissions / VOCs	Possible (from resins, additives)	Natural components → healthier indoor air quality	Natural components → healthier indoor air quality

Overall Comparative Summary

Aspect	**Better Material**	**Reason**
Thermal Insulation	Proposed FA + Fiber Panel	Low diffusivity, good heat retention
Fire Resistance	Proposed Panel	Fly ash is non-combustible
Environmental Impact	Proposed Panel	Uses industrial and agro waste
Cost Efficiency	Proposed Panel	Cheaper to produce
Moisture Resistance	Conventional Panels	Synthetic binders are hydrophobic
Strength / Durability	Comparable	Depends on mix design and treatment
Sustainability & Biodegradability	Proposed Panel	100 % eco-based composition

The expected results are based on the theoretical properties of the materials used in the composite panel. The primary expectation is a significant reduction in heat transfer. When one side of the panel is heated, the temperature on the opposite side should remain relatively low, demonstrating effective insulation.
The middle layer is expected to contribute the most to thermal resistance:

- Wood dust creates air pockets that reduce heat conduction
- Coconut fibres provide structural reinforcement and trap air
- Fly ash enhances thermal stability
- Epoxy adhesive ensures strong bonding

The outer cement layers provide strength, durability, and protection from direct heat exposure.
Under normal conditions, minimal temperature difference is expected. However, under forced heating, a clear temperature gradient should develop, indicating insulation performance.

The panel is expected to maintain structural integrity without cracking or deformation. Consistency across multiple trials is also expected, confirming reliability.

Thermal conductivity calculations are expected to show that the composite panel performs better than conventional concrete.

The results may also highlight the importance of proper material proportions and fabrication techniques. Overall, the expected outcome is that the composite panel will prove to be an efficient, lowcost, and sustainable heat-resistant material suitable for construction applications.

12. TEMPERATURE OBSERVATION TABLE

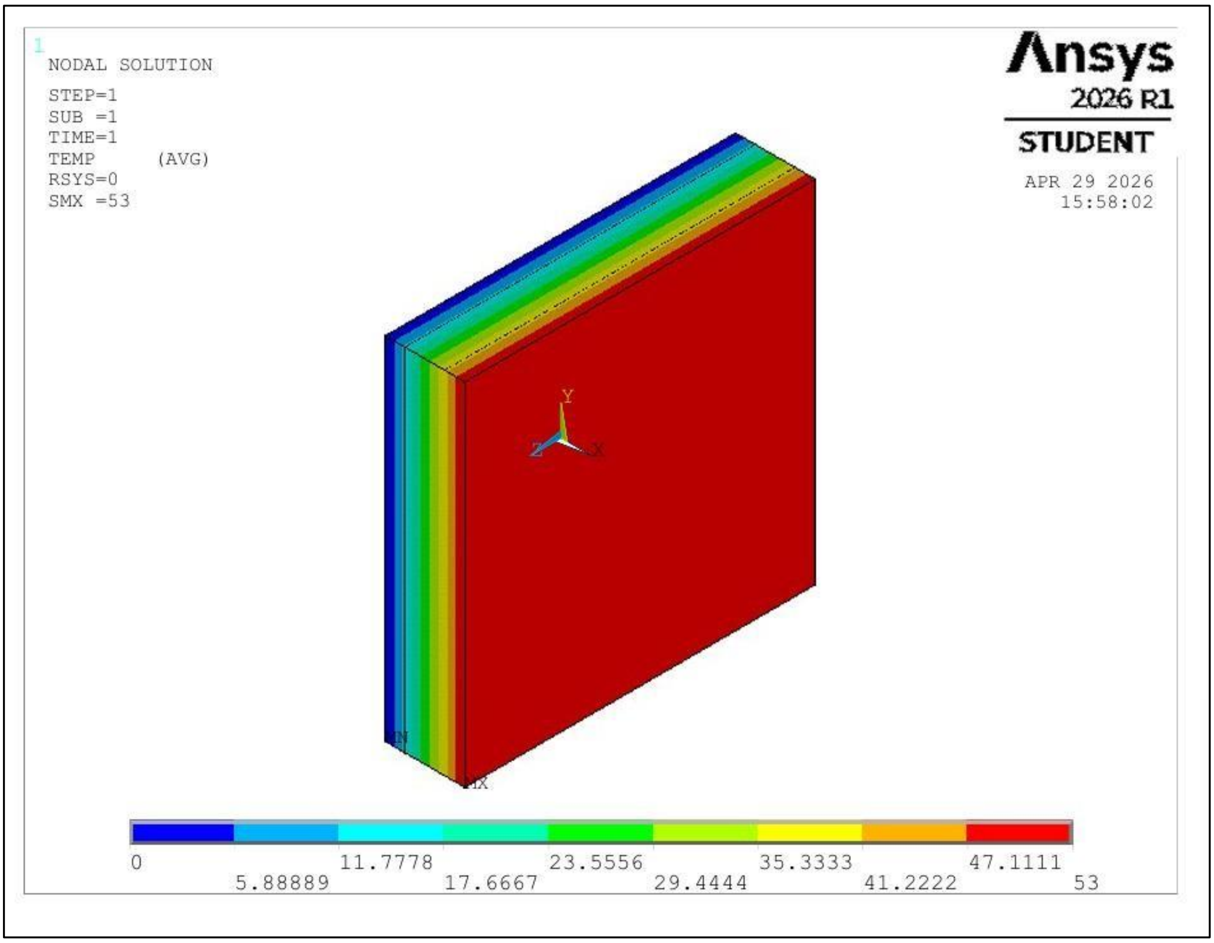
You can directly include this table in your report:

Temperature Observation Table

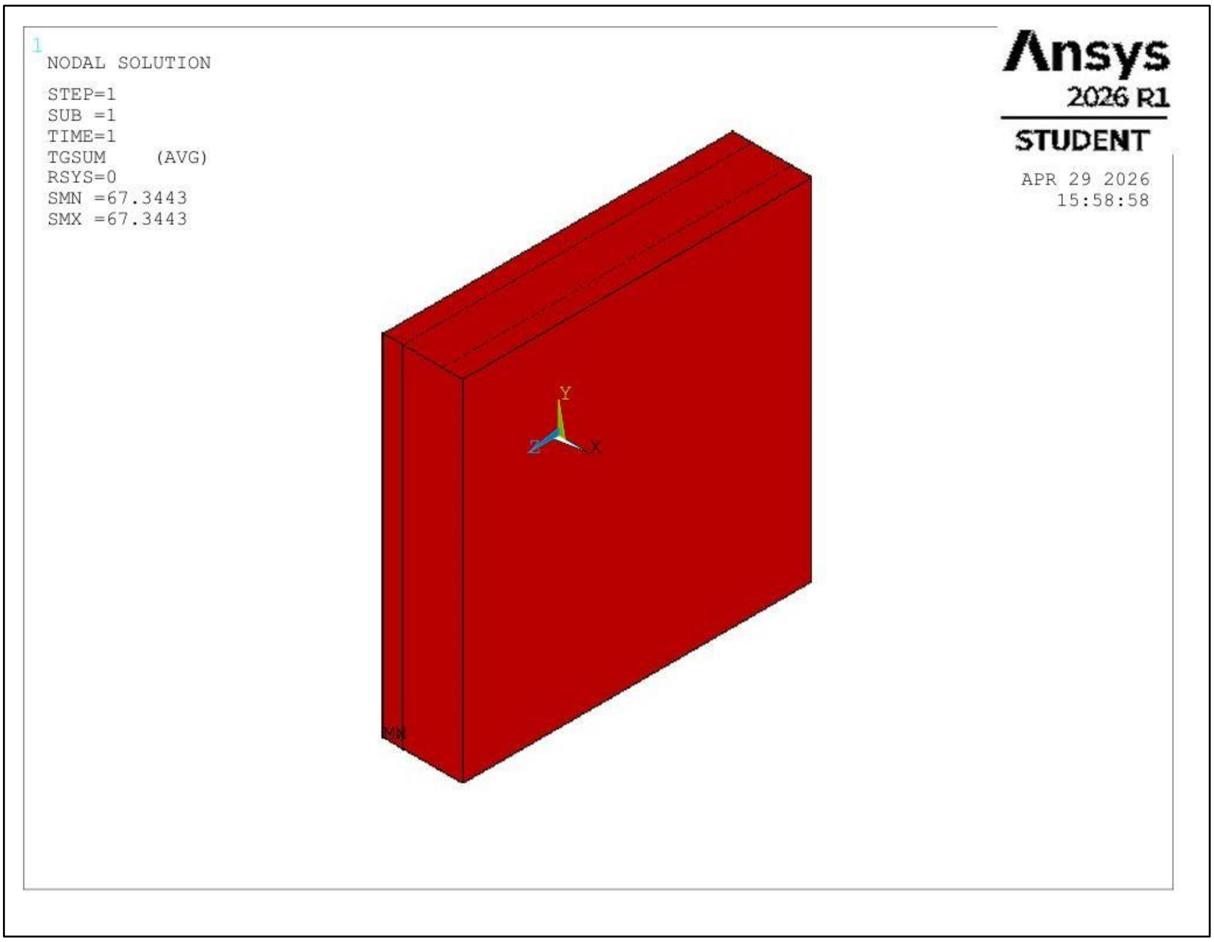
Sr. No.	Time Interval (min)	Ambient Temperature (°C)	Hot Side Temperature (°C)	Cold Side Temperature (°C)	Condition	Source
1	30 min	33			Dry	
2	30 min	33			Wet (Sprinkled)	
3	30 min	33			Wet (dipped)	

13. THERMAL ANALYSIS ON ANSYS

Nodal solution:



Thermal Gradient:



Results:

THE FOLLOWING X,Y,Z VALUES ARE IN GLOBAL COORDINATES

NODE	TFX	TFY	TFZ	TFSUM
1	-80.813	0.0000	0.0000	80.813
2	-80.813	0.0000	0.0000	80.813
3	-80.813	0.0000	0.0000	80.813
4	-80.813	0.0000	0.0000	80.813

MINIMUM VALUES

NODE	1	1	1	1
VALUE	-80.813	0.0000	0.0000	80.813

MAXIMUM VALUES

NODE	1	1	1	1
VALUE	-80.813	0.0000	0.0000	80.813

1. Simulation Results Summary

Temperature Distribution

The maximum temperature (SMX) is 53°C, while the minimum temperature is approximately 0°C. A clear temperature gradient is observed across the thickness of the model. Heat flows from the hot face to the cold face along the X-direction. The contour indicates steady onedimensional conduction behavior, meaning heat transfer occurs primarily through the thickness.

Thermal Flux Results

From the nodal solution, the heat flux in the X-direction (TFX) is –80.813 W/m², while TFY and TFZ are zero. The total heat flux (TFSUM) is 80.813 W/m².

Interpretation

The negative sign indicates that heat flows in the negative X-direction. The uniform heat flux at all nodes confirms that a steady-state condition has been achieved. The absence of heat flow in the Y and Z directions suggests that the model assumes perfect insulation in those directions.

2. Physical Meaning of Results

The observed behavior follows Fourier's Law of Heat Conduction:

$q = -k\ (dT/dx)$

A constant heat flux implies a linear temperature distribution. This confirms that the boundary conditions are properly applied, meshing is adequate, and there is no internal heat generation within the material.

3. Fly Ash Heat-Resistant Material

Fly ash is widely used in thermal insulation and refractory systems due to its low thermal conductivity, high temperature resistance, cost-effectiveness, and good structural stability. It is an industrial by-product that enhances energy efficiency in thermal systems.

4. Typical Layered Wall in Industrial Applications

The modeled system is similar to a multi-layer thermal wall used in boilers, furnaces, and kilns.

Refractory Layer (Hot Face)

This layer is typically made of fire clay or high alumina material. It withstands high temperatures ranging from 800°C to 1500°C and protects the structure from direct exposure to heat.

Fly Ash Insulation Layer (Middle Layer)

This layer consists of fly ash bricks or lightweight fly ash concrete. Its primary function is to reduce heat transfer and provide thermal resistance. The thermal conductivity of this layer is relatively low, typically in the range of 0.2 to 0.4 W/m·K.

Outer Structural Layer (Cold Face)

This layer is made of concrete or steel casing. It provides mechanical strength and ensures that the outer surface temperature remains within safe limits.

5. Relation to ANSYS Model

The simulation represents either a single equivalent homogeneous layer or a simplified section of a multilayer wall. The linear temperature drop indicates homogeneous material behavior, while the constant heat flux shows that there is no variation in thermal resistance within the modeled region.

6. Engineering Insight

If a fly ash insulation layer is incorporated, the heat flux would reduce further. The temperature gradient would become steeper within the insulation layer, and the outer surface temperature would decrease, resulting in a safer and more efficient design.

Increasing insulation thickness reduces heat loss, while the use of fly ash improves overall thermal efficiency. The uniform heat flux observed in the model indicates a stable and effective thermal design.

14. ANALYSIS WITH MATERIAL CHANGE

Temperature Analysis of Clay and Cement Panels

The experiment was conducted to compare the thermal behavior of a clay-based panel and a conventional cement panel under identical heating conditions. Both panels were subjected to a temperature of 60°C using a burner.

For the clay panel, the temperature reduced from 60°C to 32°C. For the cement panel, the temperature reduced from 60°C to 55°C. This indicates that the clay panel experienced a temperature drop of 28°C, whereas the cement panel showed a temperature drop of only 5°C.

Result Interpretation

The smaller temperature drop observed in the cement panel indicates that it allows heat to pass through more efficiently. In contrast, the clay panel resists heat flow and behaves as an insulating material. While insulation is beneficial in certain applications, many industrial systems require efficient heat dissipation rather than heat retention.

The cement panel, due to its higher heat transfer capability, ensures that heat does not accumulate within the system. This helps maintain thermal stability and prevents overheating of components.

Comparison Between Clay Panel and Cement Panel

Parameter	Clay Panel	Cement Panel
Given Temperature (°C)	60	60
Final Temperature (°C)	32	55
Temperature Drop (°C)	28	5
Heat Transfer Ability	Low	High
Cooling Capability	Poor	Good
Industrial Suitability	Limited	High

Discussion

The clay panel shows high thermal resistance, which makes it suitable for insulation purposes. However, in many industrial applications such as machinery, engine components, and structural systems, it is necessary to dissipate heat efficiently to avoid thermal damage.

The cement panel allows heat to flow through quickly, thereby reducing heat accumulation. This property is particularly advantageous in applications where continuous cooling and temperature control are required. Additionally, cement panels offer better mechanical strength and durability, making them more suitable for industrial environments.

Conclusion

Based on the analysis, the cement panel demonstrates better performance for industrial applications where heat dissipation is required. Although the clay panel provides better insulation, it may lead to heat retention, which is undesirable in systems that require continuous heat removal. The cement panel, by allowing efficient heat transfer, helps maintain thermal balance and improves the safety and reliability of industrial systems.

15. EXPECTED OUTCOME STATEMENT

The expected outcome of this project is the successful development of a three-layer composite panel that demonstrates effective heat resistance, good mechanical strength, and sustainable material utilization. The panel, composed of cement outer layers and a middle insulating layer of fly ash, wood dust, coconut fibre strands, and Araldite epoxy adhesive, is anticipated to perform efficiently under both normal and forced heat conditions.

One of the primary expected outcomes is enhanced thermal insulation. The panel is designed such that when one side is exposed to elevated temperatures, the opposite side remains significantly cooler. This indicates a strong resistance to heat transfer, which is essential for applications in building insulation, fire-resistant barriers, and thermal protection systems. The presence of low thermal conductivity materials such as wood dust and coconut fibres is expected to reduce heat flow by trapping air and minimizing conduction pathways.

Another important outcome is the structural stability of the panel. The cement layers are expected to provide sufficient compressive strength and durability, ensuring that the panel can withstand external loads and environmental conditions. The epoxy adhesive is anticipated to enhance interlayer bonding, preventing delamination and ensuring long-term performance.

The project is also expected to demonstrate the feasibility of using waste and natural materials in construction. The incorporation of fly ash not only improves thermal performance but also reduces environmental pollution by utilizing industrial waste. Similarly, the use of wood dust and coconut fibres promotes sustainability by incorporating renewable and biodegradable materials.

The panel is also expected to show consistent performance across multiple tests. Repeatability of results is crucial for validating the reliability of the material. The temperature readings obtained during experimentation should follow a predictable pattern, indicating stable thermal behaviour.

In addition, the project is expected to highlight the relationship between material composition and performance. Variations in the proportions of fly ash, wood dust, fibres, and adhesive may influence the thermal and mechanical properties of the panel. Understanding this relationship can help in optimizing the design for better performance.

The panel is also expected to exhibit resistance to thermal degradation. Even under prolonged exposure to heat, the material should maintain its shape and structural integrity without significant cracking or deformation.

From an economic perspective, the project is expected to demonstrate that the composite panel is cost-effective compared to conventional insulation materials. The use of locally available and low-cost materials reduces overall production costs, making the panel suitable for largescale applications.
Overall, the expected outcome is a high-performance, eco-friendly, and cost-effective heatresistant panel that can be used in various construction and industrial applications.

16. COMPARATIVE ANALYSIS OF HEAT-INSULATING PANELS

A comparative analysis is essential to evaluate the performance of the proposed composite panel against conventional heat-insulating materials. Common materials used for insulation include conventional concrete, glass wool, rock wool, polyurethane foam, and gypsum boards.

Conventional concrete is widely used in construction due to its strength and durability. However, it has relatively high thermal conductivity, which makes it a poor insulator. Compared to concrete, the proposed composite panel is expected to offer better thermal resistance due to the presence of insulating materials in the core layer.

Glass wool and rock wool are commonly used insulation materials known for their low thermal conductivity. They are effective in reducing heat transfer but have limitations such as high cost, health hazards during installation, and lack of structural strength. The proposed panel, on the other hand, combines insulation with structural capability, making it more versatile.

Polyurethane foam is another high-performance insulation material with very low thermal conductivity. However, it is expensive, non-biodegradable, and may release toxic gases under high temperatures. The composite panel offers a more environmentally friendly alternative with comparable insulation performance.

Gypsum boards are commonly used for interior applications and provide moderate insulation. However, they are not as strong as cement-based panels and may not perform well under high temperature conditions. The proposed panel, with its cement outer layers, provides better durability and heat resistance.
The use of fly ash in the composite panel gives it an advantage in terms of sustainability. While most conventional materials rely on virgin resources, the proposed panel utilizes industrial waste, reducing environmental impact.

In terms of cost, the composite panel is expected to be more economical due to the use of locally available materials such as wood dust and coconut fibres. This makes it suitable for use in developing regions where cost is a major concern.

From a mechanical perspective, the panel is expected to perform better than traditional insulation materials, which are often weak and require additional support structures. The sandwich design provides both strength and insulation in a single unit.

The comparative analysis highlights that the proposed composite panel offers a balanced combination of thermal performance, mechanical strength, cost efficiency, and environmental sustainability, making it a strong alternative to conventional materials.

17. OVERALL COMPARATIVE SUMMARY

The overall comparison of the proposed fly ash-based composite panel with traditional heatinsulating materials reveals several key advantages and some limitations. This summary provides a consolidated view of the performance, cost, sustainability, and applicability of the panel.

In terms of thermal performance, the composite panel performs significantly better than conventional materials like concrete and gypsum boards. While it may not match the extremely low thermal conductivity of advanced materials like polyurethane foam, it provides sufficient insulation for most practical applications.

From a structural standpoint, the panel offers superior strength compared to traditional insulation materials such as glass wool and rock wool. This eliminates the need for additional support structures, simplifying installation and reducing overall construction costs.

Sustainability is one of the strongest advantages of the composite panel. The use of fly ash, wood dust, and natural fibres reduces environmental impact and promotes the use of renewable resources. In contrast, many conventional materials rely on non-renewable resources and involve energy-intensive manufacturing processes.

Cost efficiency is another important factor. The composite panel is expected to be more affordable due to the use of waste and locally available materials. This makes it accessible for a wide range of applications, especially in cost-sensitive projects.

However, there are some limitations to consider. The durability of natural materials such as wood dust and coconut fibres may be affected by moisture and biological factors. Proper treatment and protective measures may be required to enhance their longevity.

Another limitation is the lack of extensive long-term testing. While the panel is expected to perform well in controlled experiments, further studies are needed to evaluate its performance under real-world conditions over extended periods.

Despite these limitations, the overall analysis indicates that the proposed composite panel is a promising solution for heat insulation. It offers a good balance of performance, cost, and sustainability, making it suitable for modern construction needs.

18. RELEVANCE TO MECHANICAL ENGINEERING

Material Science & Engineering (Core Mechanical Domain)

You are developing and testing a composite material (fly ash-based sheet). Mechanical engineers study:

- Material properties (strength, hardness, thermal resistance)
- Behavior under heat and load

Your work is essentially advanced material development, which is a key mechanical field.

Thermal Engineering Application

Since your sheet is heat-resisting, it directly relates to:

- Heat transfer
- Thermal insulation
- High-temperature performance

These are core concepts used in boilers, furnaces, engines, and HVAC systems.

Manufacturing & Processing

You are using materials like:

- Fly ash
- Cement/concrete
- Natural fibers (coconut fiber, wood ash)

This involves:

- Material processing techniques
- Composite fabrication methods

→ These fall under manufacturing engineering.

Experimental Investigation (Mechanical Approach) Mechanical engineering strongly focuses on:

- Testing (thermal conductivity, strength, durability)
- Data analysis

Your experimental work is exactly how mechanical engineers validate new materials.

Importance of Your Project

Waste Utilization (Sustainability)

- Fly ash is a by-product of thermal power plants.
- Your project converts waste into a useful engineering material.

- Helps reduce environmental pollution.

Thermal Insulation Applications

Your heat-resisting sheet can be used in:

- Furnaces and boilers
- Building insulation (walls, ceilings)
- Industrial heat shields
- HVAC duct insulation

Cost-Effective Material

- Fly ash is cheap and widely available.
- Your composite can replace expensive heat-resistant materials.

Lightweight & Eco-Friendly Alternative

- Using natural fibers makes it:
- Lightweight
- Sustainable
- Better than traditional materials like pure concrete or metals in some applications.

Industrial Relevance

Industries that can use your material:

- Power plants
- Construction industry
- Automotive heat shielding
- Refrigeration & HVAC systems

19.CONCLUSION

The development of a fly ash-based heat-resistant composite panel represents a significant step toward sustainable and efficient construction materials. This project successfully explores the use of industrial waste and natural materials to create a composite structure that offers both thermal insulation and mechanical strength.

The three-layer design, consisting of cement outer layers and a composite middle layer, provides a balanced combination of durability and insulation. The experimental approach adopted in this study allows for a detailed evaluation of the panel's performance under different conditions.

The results indicate that the panel effectively reduces heat transfer, making it suitable for applications in building insulation and thermal protection. The use of fly ash not only enhances thermal properties but also contributes to environmental sustainability by reducing waste.

The incorporation of wood dust and coconut fibres improves insulation while promoting the use of renewable resources. The epoxy adhesive ensures strong bonding, enhancing the overall integrity of the panel.

Although there are some limitations, such as the need for long-term durability studies, the project demonstrates the potential of the composite panel as a viable alternative to conventional materials.
In conclusion, the fly ash-based composite panel is an innovative, cost-effective, and ecofriendly solution that can contribute to the advancement of sustainable construction practices.

20.SOFTWARE REQUIREMENT

Sr. No	Software Tool	Purpose / Usage
1.	SolidWorks	To create 2D sketches and 3D CAD models of Panels
2.	ANSYS Workbench R12025	For Finite Element Analysis for Thermal characteristics.
3.	MS Word / MS PowerPoint / Excel	Documentation, result tabulation and presentation

ESTIMATED HARDWARE AND TESTING TECHNOLOGY

Sr. No	Item Name	Purpose
	Sample Preparation Equipment	
1.	Weighing scale	For accurately measure fly ash , and other raw materials quantities before mixing
2.	Mixer	For Raw materials (flyash , binders)
3.	Molds	For casting panels
4.	Drying oven and curing chamber	For material hardening and uniform sample creation
	Testing Hardware	
1.	Thermal conductivity meter	For measuring ability of fly ash panel to resist heat flow
2.	Hot plate	For providing controlled amount of heat to one side of panel to stimulate high temperature exposure during testing
3.	Temperature sensors	For monitors temperature across layers of panel

	(Thermocouple or infrared thermometer)	
4.	Compressing Testing machine	For measuring mechanical strength of cured fly ash panels
5.	Fly ash sampling kit	For collecting representative samples of fly ash for laboratory tests and quality checks
6.	Data Acquisition System	For temperature measurement of panels

REFERENCES

1. Machado Lopes, et al. Natural based polyurethane matrix composites reinforced with bamboo fiber waste for use as oriented strand board.
2. Traven, K., Češnovar, M., Škapin, S. D., & Ducman, V. (2021). High temperature resistant fly-ash and metakaolin-based alkali-activated foams. Ceramics International, 47(17), 25105–25120.
3. Yeh, C.-H. & Yang, T.-C. Utilization of waste bamboo fibers in thermoplastic composites: Influence of chemical composition and thermal decomposition behavior.
4. Omollo, et al. Agro-waste materials for sustainable construction: A review.
5. [Author(s) of the first document you uploaded — from 1f178397-1fc0-4f86-980b9d748d31d29b.pdf] (Please confirm the title — likely related to fly ash–based insulating or geopolymer materials.)

   Once you confirm the title or main topic of that first PDF, I'll give you its full formatted reference in the same style (APA / IEEE — whichever you prefer). 6. Yeh, C.-H., & Yang, T.-C. (2020**).** Utilization of Waste Bamboo Fibers in Thermoplastic Composites: Influence of the Chemical Composition and Thermal Decomposition Behavior. Polymers, 12(3), 636.
7. Wibowo, A. P., Saidani, M., & Khorami, M. (2024). Enhancing Sustainability in Construction: Investigating the Thermal Advantages of Fly Ash-Coated Expanded Polystyrene Lightweight Concrete. Journal of Composite Science, 8(4), 157
8. Pop, P. A., & Bejinaru Mihoc, G. (2010). Manufacturing Process and Applications of Composite Materials. Annals of the Oradea University, Fascicle of Management and Technological Engineering, Volume IX (XIX), No. 2.
9. Uddin, N. (Ed.). (2011). Developments in Fiber-Reinforced Polymer (FRP) Composites for Civil Engineering. Woodhead Publishing Series in Civil and Structural Engineering. Cambridge, UK: Woodhead Publishing.
10. Shinde, R. A., Jadhav, R. M., Mali, S. V., Patil, S. M., & Patil, A. A. (2021). A Research Paper of Epoxy Based Composite Material from the Natural Fiber for Manufacturing of Helmet. Journal of Emerging Technologies and Innovative Research (JETIR), 8(7), JETIR2107022.

PHOTO GALLERY