

# Development and Testing of Insulating Material from Natural Fibers for Refrigerator

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## Abstract

The objective of the study “Development and Testing of Insulating Material from Natural Fibers for Refrigerator” was to develop a green and cost-effective insulation alternative to thermocol, or polyurethane foam, traditionally used for conventional insulation. The goal of the design was to use natural fibers such as coconut fibers, sisal fibers, and combine these fibers with some epoxy resin to develop composite insulation panels. Natural fibers are renewable, biodegradable and have low thermal resistance therefore they are a good application for refrigeration. The composites developed, were assessed for thermal conductivity, strength and durability, whilst compared to conventional materials. The results of the experimental study indicated that natural fiber composites are lower in thermal conductivity to insulate and reduce energy loss from refrigeration. The study illustrates that not only can natural fibers be used to develop sustainable insulation panels, but also they are of lower carbon footprint which is beneficial for the natural fiber industry. The study demonstrates that natural fiber composites can be an alternative green lightweight energy-efficient insulation with regards to thermal insulation applications.

**Keywords:** Natural Fibers, Coconut Fiber, Sisal Fiber, Epoxy Resin, Refrigerator.

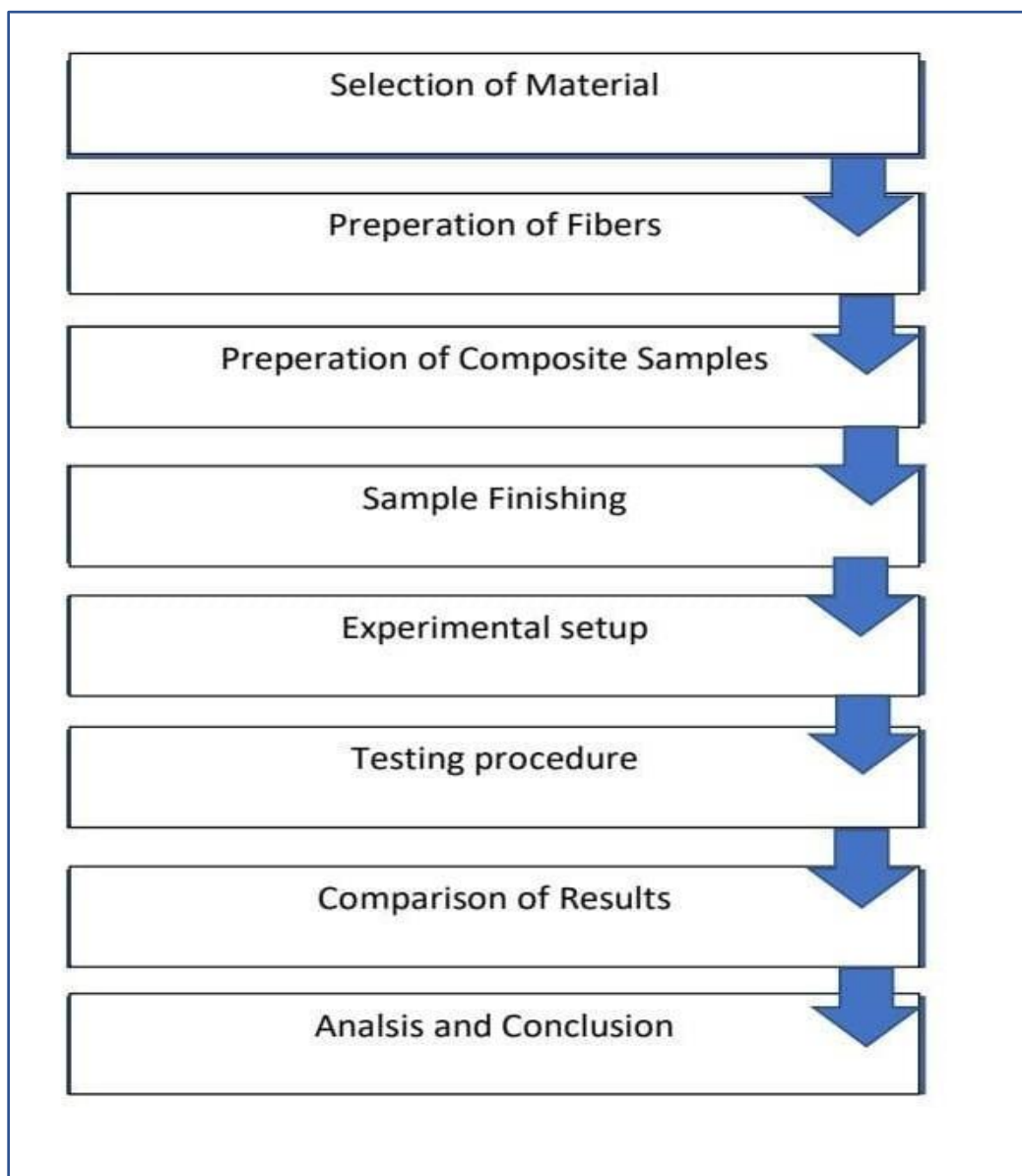
## 1. INTRODUCTION

- Refrigeration is among the most important technologies in modern life. It is used for food storage, medical storage, and in various industries. The insulating material used can greatly influence the efficiency of any refrigeration system, as the purpose of insulating materials to minimize heat transfer between the refrigerated space and the exterior. Typically, materials such as thermocol (expanded polystyrene) and polyurethane foam (PUF) have been widely adopted for insulation due to their relatively low thermal conductivity and ease of production. These materials can be non- biodegradable, non-renewable and unsafe to the environment which leads to difficulties in disposal and pollution. Given the need for sustainability and eco-friendly materials, this project considers the use of natural fibers as alternative material sources for insulating applications.
- Natural fibers such as coconut and sisal fiber are renewable, widely available, lightweight, and contain suitable thermal and mechanical properties. Natural fibers combined with a matrix such as epoxy resin produce a natural fiber-reinforced composite and improve both insulation performance and mechanical strength. Natural fibers typically have hollow, porous structures that encourage the entrapment of air that minimizes heat conduction, consequently improving insulation performance.
- The project aims to develop and evaluate composite panels made from various combinations of coconut fiber-epoxy and sisal fiber-epoxy. The samples that will be manufactured will be subjected to thermal conductivity tests and mechanical strength tests, as well as a comparison with regular insulative materials, e.g., thermocol. The intent is to determine whether these natural fiber composites can act as substitutes for insulation in refrigeration devices with no performance loss.
- Utilization of natural fibers for insulation aligns with waste product utilization and

sustainability. Coconut husk, as well as sisal leaves, are considered agricultural waste products and are frequently either wasted or burned, adding to environmental stresses. Developing good insulative materials out of them adds to value of agricultural waste and reduces overall carbon footprint. Furthermore, because the energy/running efficiency of a refrigerator is determined by its ability to maintain temperature with minimal energy consumption, improved insulation using renewable materials directly supports energy sustainability.

- To summarize, this project proposes to design, develop and test the performance of a natural fiber-based insulation material that is adequately priced, suitable for use, biodegradable and uses less energy. The project illustrates the usability of renewable resources in creating sustainable engineering solutions that fit our modern environmental and industrial needs.

## 2. METHODOLOGY



### 3. PROCESS

#### 3.1. Material Selection:

The material selection for this project was predicated on thermal, mechanical, environmental, and economic considerations tailored specifically for insulation uses in refrigerated systems. The intent was to create a material that is functional, sustainable, and economical in comparison to the represented thermocol product.

##### a) Coconut Fiber:

- Readily Available and Renewable: Readily obtainable from coconut husk byproducts, it is an eco-ethical material.
- Low Heat Conductivity: The hollow structure allows coir to provide good thermal insulation characteristics.
- Lightweight and Eco-ethical: Overall system weight is reduced, as well as the eco-footprint.
- Economical: Easily available for low cost in tropical countries such as India.
- Good Compatibility to Epoxy Resin: Medium to high bonding with the matrix to create an effective and stable composite.

##### b) Sisal Fiber:

- Good Strength and Stiffness: Gives the composite panel decent mechanical strength.
- Low Density: Helps to minimize the overall weight of the insulating panel.
- Good Thermal Resistance: Capable of withstanding temperature changes without losing its mechanical properties.
- Natural and Biodegradable: Environmentally sound alternative to synthetic fibers.
- Good Fiber-Matrix Adhesion: Ensures a stable and long-lasting composite when used with epoxy resin.

##### c) Epoxy Resin:

- Strong Adhesive: Creates a strong bond between the fibers and ensures a long-lasting composite design.
- Chemical and Moisture Resistant: Extends the life of the insulation panel.
- Good Dimensional Stability: Resists deformation and strength loss with fluctuations in temperature and load.
- Easy to Process: Simple mixing with curing at room temperature to allow simple fabrication.
- Moderate Thermal Conductivity: Allow for a controlled heat transfer whereby the insulation efficiency is improved when the thermoset is reinforced with fibers.

#### 3.2. Cleaning and Drying:

- Coconut and Sisal fibers are washed with the help of Hydrogen Peroxide and water by maintaining ph of 7.
- Then this cleaned fiber is dried in sunlight for 24 hours.



Fig. Cleaning of Fiber

Fig. Drying of Fiber

### 3.3. Plate Forming:

#### 3.3.1. Mould Making :

- Dimensions of Mold :  $l*b*t = 48*30*3$  (cm)
- Material of Mold : Wood

#### 3.3.2. Clamping Unit:

- Dimensions :  $47.5*29.5*5$
- Material : wood

#### 3.3.3. Plate Making:

- The epoxy resin (LY 556) and hardener (HY 951) are mixed in a specific ratio, typically 10:1 by weight. In the mixture, the epoxy resin serves as the matrix material that gives strength and rigidity to the mixture, while the hardener initiates the chemical curing process
- The epoxy resin is then mixed with the cleaned and dried fibers. The clean, dried fibers are added gradually to the mixed resin. The mixed resin and fibers are stirred appropriately to obtain a uniform dispersion of the fibers within the resin. Properly mixed resin and fibers ensures that the resin wet the fibers completely which is important for good bonding and load transfer in the composite.
- Using a spatula, the fiber–resin mixture is evenly poured into the mould and spread evenly. The filled mould is compressed, either by a hydraulic press or by simply placing a heavy flat plate on top, to expel trapped air and excess resin. This step ensures even thickness and smoothness of the surface.
- The mould is left undisturbed at room temperature for 24 hours for initial curing. Then, in order to achieve complete polymerization and improve mechanical strength and thermal stability, post-curing is performed in an oven at 60–80 °C for 2-3 hours.
- The plate is precisely removed from the mould at the end of the curing period. Trimming and remodelling are done on the edges and surfaces to achieve the desired dimensions and surface finish. The plate is now prepared for measuring thermal conductivity, mechanical properties and density.

## 4. EXPERIMENTAL SETUP

- The experimental design is intended to examine and compare the thermal insulation capacity of the developed natural fiber–epoxy composite materials with standard insulating materials (such as Thermocol). The experimental setup mainly consists of a home refrigerator, subzero temperature measurement device, data collection devices, and test section for insulating materials.

### 1. Refrigerator

- A home refrigerator was used as the principle apparatus for the test. The installed insulation

on one side of the refrigerator wall was replaced with the developed natural fiber composite plate (either coconut fiber–epoxy or sisal fiber–epoxy). This unique method allows for a direct comparison of temperature retention and cooling performance of the conventional and developed insulating materials under identical operating circumstances.

- The refrigerator is based on the Vapour Compression Refrigeration System (VCRS) principle. The compressor, condenser, expansion valve, and evaporator unit working together to maintain the inside compartment at the desired low temperature.

## 2. Subzero Temperature Sensor

- A sub-zero temperature sensor (digital type) was used to measure and record the temperature inside the refrigerator over time and continuously monitor the inside temperature. The digital temperature sensor measures temperature ranging from the low-end  $-50\text{ }^{\circ}\text{C}$  to a high-end of  $+110\text{ }^{\circ}\text{C}$  with accuracy at a range of defined levels throughout the specified temperature range. The sensor is fastened at different uniformity and operating condition locations in the refrigerator — close to the evaporator coil and at the inner surface of the insulation plate — to determine operating condition temperature variation.
- Temperature data values from the temperature sensor were recorded against time and displayed on the digital temperature measurement device, used for further analysis of measured performance data. The sub-zero temperature sensor is used to evaluate the cooling performance and the rate of heat leaks through different combinations of insulating materials according to the operating conditions seen.

## 3. Power Supply and Control

- The refrigerator operates on a 230 Volt AC supply while the temperature sensor measurement devices run on a low voltage AC source. This refrigerator is equipped with a control panel that allows the user to switch the refrigerator ON/OFF, record data, and adjust the sensor inputs.

## 4. Procedure for Testing

- The refrigerator is run with normal thermocol insulation, and temperature readings are taken at the subzero sensor in regular time intervals.
- The thermocol is then exchanged for the natural fiber–epoxy composite plate developed for this research.
- The same operating conditions are maintained and temperature changes are taken.



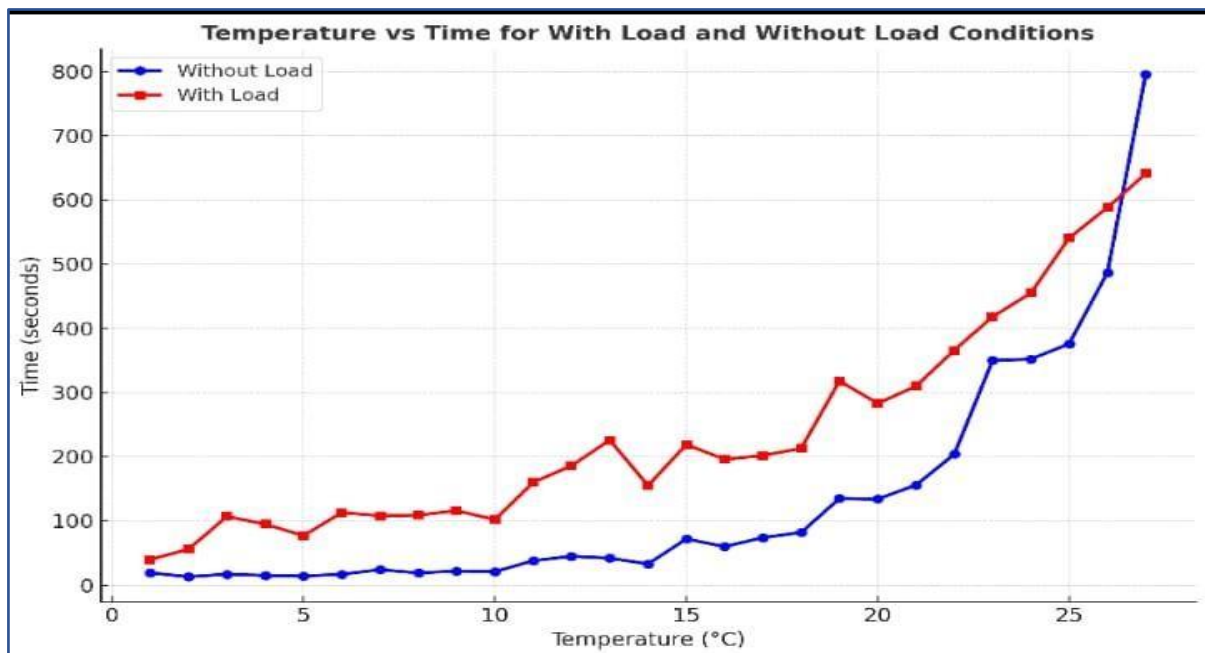
Fig.Experimental Setup

## 5. RESULT

### 1) Thermocol

Table 5.1 Existing Material Temp. Drop with Respect to Time

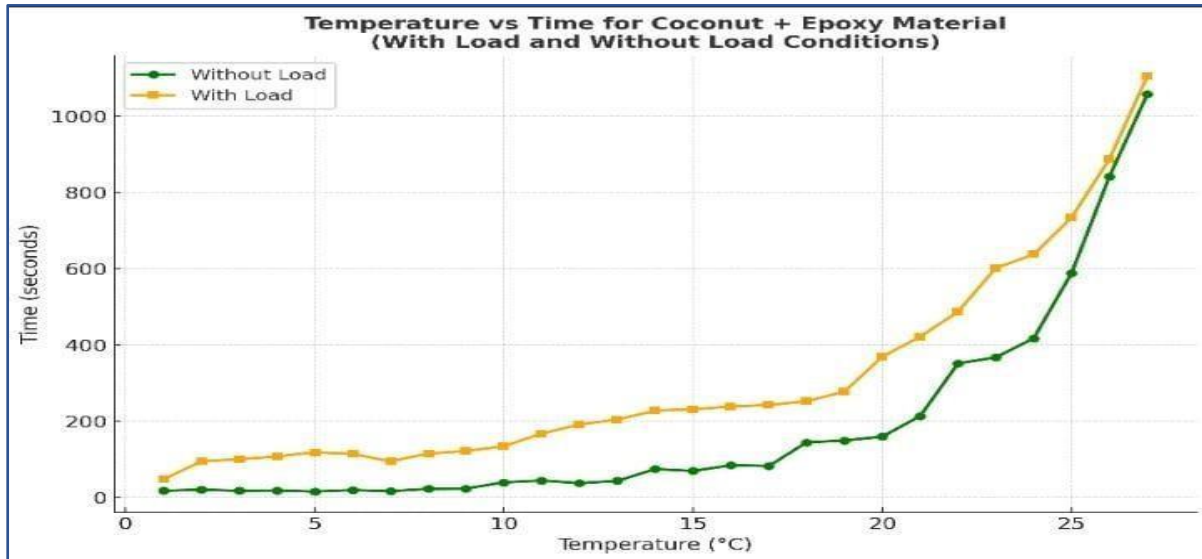
Temp.(°C)	Without load Time (sec)	With load Time (sec)
0 to 5	78	375
6 to 10	103	548
11 to 15	199	869
16 to 20	423	1048
21 to 25	1196	1832
26 to 28	1659	1770



### 2) Coconut Fiber + Epoxy Resin:

Table 5.2 Coconut Fiber + Epoxy Resin Temp. Drop with Respect to Time

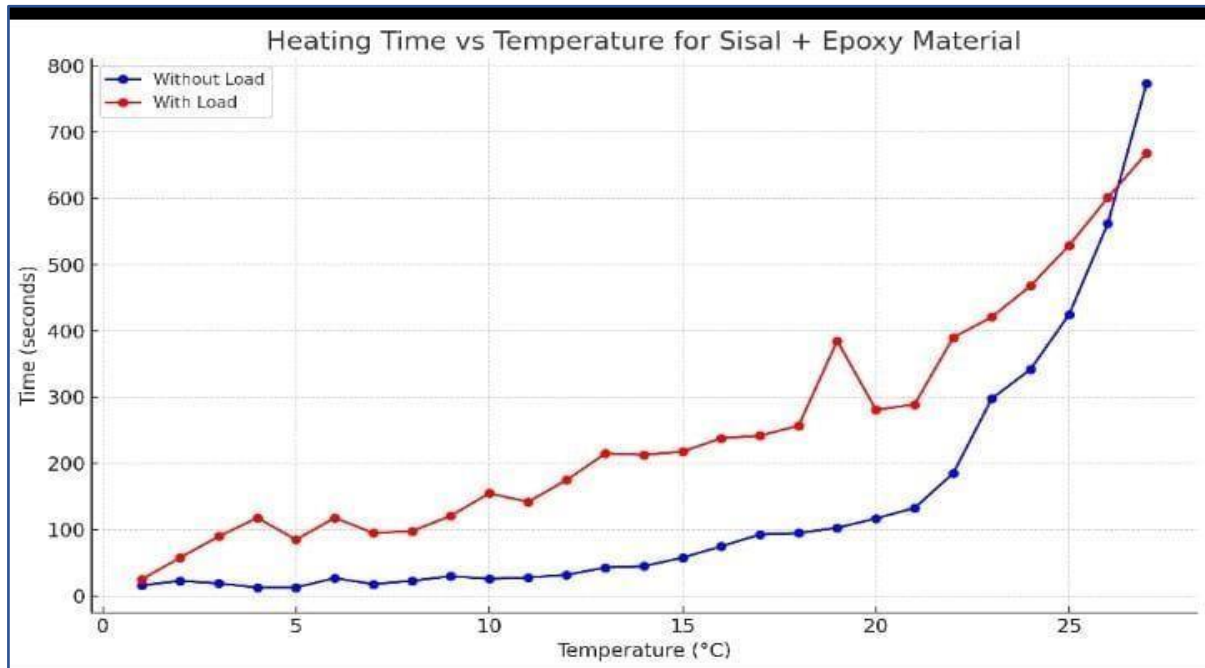
Temp.(°C)	Without load Time (sec)	With load Time (sec)
0 to 5	92	469
6 to 10	116	486
11 to 15	242	1016
16 to 20	533	1245
21 to 25	1512	2520
26 to 28	2489	2728



### 3) Sisal Fiber + Epoxy Resin :

Table 5.3 Sisal Fiber + Epoxy Resin Temp. Drop with Respect yo Time

Temp.(°C)	Without load Time (sec)	With load Time (sec)
0 to 5	96	376
6 to 10	121	587
11 to 15	182	974
16 to 20	404	1340
21 to 25	1075	1849
26 to 28	1724	1798



## 6. COST

Sr.No	Aspect	Cost
1.	Refrigerator	4000
2.	Coconut Fiber	270
3.	Sisal Fiber	550
4.	Epoxy Resin	2850
5.	Hardener	600
6.	Other Equipments	1500
7.	Total	9770

## 7. FUTURE SCOPE

### 1. Optimization of Fiber Composition:

Further research can be carried out to determine the optimum proportion of coconut and sisal fibers in the epoxy matrix to achieve the best balance between thermal insulation and mechanical strength.

### 2. Use of Hybrid Composites:

A combination of different natural fibers (such as banana, jute, or hemp) can be tested with epoxy resin to develop hybrid composites with improved thermal and structural properties.

### 3. Surface Treatment Enhancement:

Advanced chemical treatments can be applied to fibers to improve bonding with epoxy resin, thereby enhancing the composite's durability and thermal performance.

### 4. Testing Under Dynamic Conditions:

The material can be tested under varying environmental conditions such as humidity, vibration, and temperature cycles to evaluate long-term performance in real refrigerator systems.

### 5. Industrial Application and Prototyping:

The developed material can be used in actual refrigerator insulation panels to test energy savings, efficiency, and performance in comparison with commercial thermocol.

## 8. CONCLUSION

Natural fiber based insulating materials were fabricated and tested for their insulating properties, which demonstrated an alternative for conventional insulating materials used in refrigeration. The project introduced coconut fiber and sisal fiber reinforced with epoxy resin to create the insulation composite plates. The natural fiber composites had low thermal conductivity values, in relation to conventional insulating materials, like thermocol, and provided advantages in terms of biodegradability, sustainable, and low cost insulation (reducing building costs with insulation, such as refrigeration).

The refrigeration unit connected to the subzero temperature sensor verified that the natural fiber insulation provided the desired cooling performance with very little energy wasted / insulated effectively. This also aligns with the research that natural fiber composites are a sustainable insulating option for refrigeration applications concrete. The study showed progression in green technology development and thermal insulation field while lowering the

impacts of human impact / influence on the environment while promoting the use of agriculture waste materials.

## 9. REFERENCES

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