Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 23 | No. 1 | pp. 311-319 | 2024

Original Research Paper

https://doi.org/10.46488/NEPT.2024.v23i01.026

Open Access Journal

Effective Utilization of Bio and Industry Wastes to Produce Thermal Insulation Concrete: A Novel Solution for Energy-Saving Buildings

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 05-07-2023
Revised: 24-08-2023
Accepted: 02-09-2023

Key Words:
Thermal insulation concrete
Energy saving buildings
Sustainable materials
Recycling
Waste materials

ABSTRACT

The research addressed the effective and sustainable ways to enhance the thermal insulation properties of concrete without compromising its structural integrity. Traditional methods of enhancing thermal insulation in buildings, such as using thick layers of insulation materials, can be costly and may not always be practical in certain settings. Additionally, the disposal of waste materials such as date palm fiber, shopping plastic bags, and thermocol beads presents an environmental challenge. Therefore, this study aims to investigate the potential use of these waste materials as additives in concrete to improve its thermal insulation properties while also providing a sustainable solution for waste disposal. Date palm fiber is a natural material that is widely available in the Gulf region. Plastic bags are a huge waste from the shops every day, and from the packing materials, this thermocol is a huge waste product. We have to recycle it very efficiently to protect the environment. Three types of special materials, such as thermocol beads (30%), date palm fiber (3%) & shopping plastic bag fiber (3%), were tested in this research. Thermocol beads, when used, reduce their strength and increase the thermal resistance of concrete, while date palm fiber and shopping bag waste fiber, when used, increase the strength of concrete and also increase the thermal resistance of concrete, so it is an excellent reinforcing material and thermal barrier for shopping plastic bags fiber and date palm fiber. Based on this research result, when thermocol beads are used, they prevent heat by 42 percent, while when added with date palm fiber and plastic fiber, they also block heat by an average of 30% percent; thus, all three ingredients are considered excellent thermal insulation material. The reduction in thermal conductivity was attributed to the formation of air voids and the low thermal conductivity of the waste materials. The density of the concrete decreased with the addition of the waste materials. The study suggests that the incorporation of date palm fiber, shopping bag waste fiber, and thermocol beads can be an effective way to enhance the thermal insulation properties of concrete while also providing an environmentally sustainable solution for waste disposal. It will boost green energy technology in the construction industry.

INTRODUCTION

Insulating concrete is an important way to reduce energy consumption and lower greenhouse gas emissions. The use of waste materials in concrete production is also an effective way to reduce the environmental impact of construction. By combining these two approaches, it is possible to create a more sustainable and energy-efficient building material.

Many different types of waste materials can be added to concrete to enhance its thermal insulation properties, including agricultural waste, sawdust, and fly ash. These materials are often readily available and inexpensive, making them an attractive option for builders and contractors. Enhancing thermal insulation in concrete by adding bio and industry wastes is a novel solution for energy-saving buildings that have the potential to reduce energy consumption and lower greenhouse gas emissions in the construction industry. The idea is to use waste materials to create a more sustainable and energy-efficient building material.

Concrete is one of the most commonly used building materials in the world, but it has a high thermal conductivity, which means it can allow heat to escape easily (Hagishima & Tanimoto 2013). This makes it an inefficient material for building insulation, and as a result, a lot of energy is wasted on heating and cooling buildings. To solve this problem, builders have traditionally used various types of insulating materials, such as fiberglass and foam, to improve the insulation properties of concrete. However, these materials can be expensive and harm the environment. By adding waste materials to concrete, it is possible to create a more sustainable and cost-effective insulation solution (Karakurt et al. 2010). Agricultural waste, sawdust, and fly ash are all examples of waste materials that can be added to concrete to enhance its thermal insulation properties. These materials are often readily available and inexpensive, making them an attractive option for builders and contractors (Holt & Raivio 2005)

Agricultural waste, such as rice husks, wheat straw, and corn cobs, can be used as lightweight aggregate in concrete production. When added to concrete, it creates pockets of air that improve the insulation properties of the material. Sawdust is another waste material that can be added to concrete to improve its insulation properties. When sawdust is added to concrete, it creates small voids that trap air and reduce thermal conductivity. Fly ash, a by-product of coal-fired power plants, is another waste material that can be added to concrete to improve its insulation properties. When fly ash is added to concrete, it reduces the amount of cement needed, which lowers the carbon footprint of the concrete. It also improves the insulation properties of the material by creating a more porous structure (Asan 1998)

The study investigates the effects of using rice husk ash and sawdust ash as partial replacements for cement in concrete. The results show that both materials can significantly improve the thermal insulation properties of concrete (Asan & Sancaktar 1998). The study evaluates the sustainability of lightweight concrete made with agricultural and industrial waste aggregates. The results show that the use of waste materials in concrete production can significantly reduce the environmental impact of construction and improve building energy efficiency (Asan 2000, 2006). The review article discusses the potential of using various industrial waste by-products, such as fly ash, blast furnace slag, and silica fume, as thermal insulation materials in sustainable construction. The authors conclude that these waste materials have the potential to improve building energy efficiency and reduce environmental impact (Hlaváček et al. 2015). The study investigates the thermal properties of lightweight concrete produced with wood sawdust and polyurethane foam wastes. The results show that this type of concrete has excellent thermal insulation properties and can significantly reduce energy consumption in buildings (Petrov & Schlegel 1994). The study investigates the thermal insulation performance of concrete with rice husk ash. The results show that rice husk ash can significantly improve the thermal insulation properties of concrete (Shi et al. 2020, Singh et al. 2011). The review article discusses the use of various industrial waste materials, such as fly ash, blast furnace slag, and silica fume, as insulation materials in buildings. The authors conclude that these waste materials have the potential to reduce energy consumption and improve building sustainability (Real et al. 2016). The study investigates the thermal insulation properties of concrete with sawdust as an aggregate. The results show that sawdust concrete has excellent thermal insulation properties and can significantly reduce energy consumption in buildings (Jayamaha et al. 1996). The study investigates the development of lightweight concrete using various industrial waste materials, such as fly ash, blast furnace slag, and bottom ash. The results show that these waste materials can be effectively used to produce lightweight concrete with good thermal insulation properties (Petrov & Schlegel 1994).

The research focuses on developing energy-efficient hygrothermal bio-composites by incorporating industrial and hazardous waste materials. These composites aim to provide effective thermal insulation. The work likely involves characterizing the mechanical, thermal, and hygrothermal properties of these bio-composites to assess their suitability for energy-saving applications in construction (Muhammad et al. 2020). The study presents a novel approach to creating a thermal insulation composite using a compression method. It combines industrial solid wastes and expanded polystyrene beads, aiming to enhance thermal efficiency. The research explores a sustainable solution for repurposing waste materials and improving building insulation (Guopu et al. 2021). The research offers a comprehensive review of sustainable bio-based insulation materials for energy-efficient buildings. It examines various natural and renewable materials that can enhance thermal performance while minimizing environmental impact.

Overall, the use of waste materials in concrete production can help reduce the environmental impact of construction and create a more sustainable and energy-efficient building material. By enhancing the thermal insulation properties of concrete through the addition of waste materials, it is possible to reduce energy consumption and lower greenhouse gas emissions in the construction industry.

MATERIALS AND METHODS

The materials and methods for enhancing thermal insulation in concrete by adding date palm fiber, plastic waste fiber, and thermocol beads are as follows:

Materials

i. Cement
ii. Aggregates (such as sand, gravel, or crushed stone)
iii. Water

iv. Date palm fiber
v. Plastic waste fiber
vi. Thermocol beads

The physical properties of cement, sand, aggregate, water, date palm fiber, plastic bag waste fiber, and thermocol beads (Fig. 1 and 2), along with the corresponding experimental test results and relevant code standards, are given below,

i. Cement:
- Physical Properties: Fineness - 350 $m^2.kg^{-1}$, initial setting time - 35 min, specific gravity – 3.10.
- Code Standards: ASTM C150

ii. Sand:
- Physical Properties: Water absorption–1 %, fineness modulus–2.7, specific gravity – 2.8.
- Code Standards: ASTM C33 (concrete aggregates)

iii. Coarse Aggregate:
- Physical Properties: Fineness modulus –6.5, specific gravity – 2.8, absorption – 1%.
- Code Standards: ASTM C33 (concrete aggregates)

iv. Water:
- Physical Properties: Density – 1000 $kg.m^{-3}$, pH – 7.0, chloride content -990ppm.
- Code Standards: ACI 318 (American Concrete Institute)

v. Date Palm Fiber:
- Physical Properties: Fiber length – 50 mm, diameter - 200 µm, tensile strength – 300 Mpa, moisture content – 12%
- Code Standards: ASTM C1116 (fiber-reinforced concrete), ASTM D638 (standard for tensile testing).

vi. Plastic Bag Waste Fiber:
- Physical Properties: Fiber length – 50 mm, diameter - 200 µm, tensile strength – 600 Mpa, moisture content – 5%
- Code Standards: ASTM C1116 (fiber-reinforced concrete), ASTM D638 (standard for tensile testing).

vii. Thermocol Beads:

Fig. 1: Date palm fiber concrete.

Fig. 2: Thermocol beads concrete.

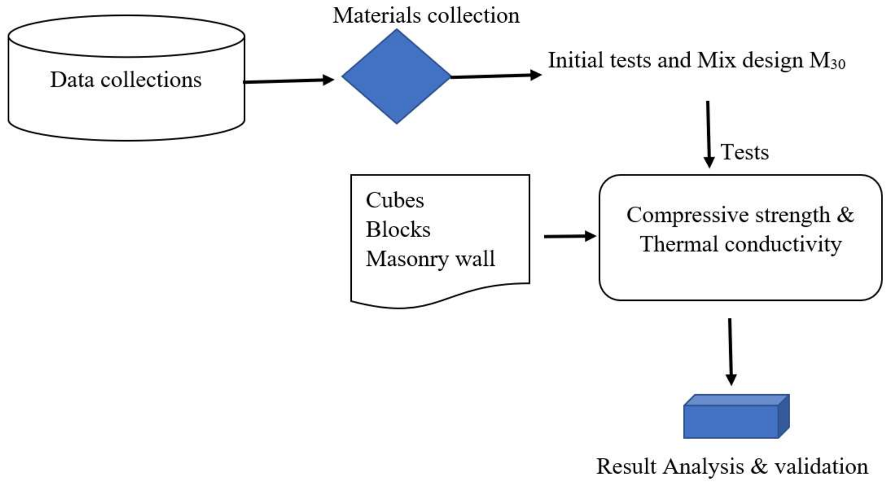

Fig. 3: Road map for the research program.

- Physical Properties: density – 20 kg.m^{-3}, compressive strength – 150 kpa, thermal conductivity –0.05 W.m^{-1}.K^{-1}, water absorption –2%
- Code Standards: ASTM C578

Methods

- Determine the appropriate proportion of each waste material to be added to the concrete mix. This can be determined through trial mixes or by consulting previous research studies.
- Prepare the waste materials for use. The date palm fiber should be cleaned, dried, and chopped into small pieces. The plastic waste fiber should be cleaned and shredded. The thermocol beads should be cleaned and separated from any impurities.
- Mix the cement, aggregates, water, and waste materials in the appropriate proportions. The mixing process should ensure that the waste materials are evenly distributed throughout the mix.
- Pour the mixed concrete into the desired mold or form.
- Allow the concrete to cure according to the manufacturer's instructions.
- Test the thermal insulation properties of the concrete using appropriate testing methods such as thermal conductivity measurements or infrared thermography.
- Compare the thermal insulation performance of the concrete with and without the added waste materials to determine the effectiveness of the insulation.

It is important to note that the specific materials and methods used may vary depending on the specific waste materials being used and the desired insulation performance (Fig. 3). Additionally, safety precautions should be taken when handling waste materials to protect workers and the environment. The addition of date palm fiber, plastic waste fiber, and thermocol beads to concrete can have positive effects on its thermal insulation properties. It may provide a sustainable solution for energy-saving buildings.

The experimental research on enhancing thermal insulation in concrete by adding date palm fiber, shopping plastic bag fiber, and thermocol beads has identified several reasons or causes for the improvements observed. These include:

- **Reduced thermal conductivity:** The addition of date palm fiber, shopping plastic bag fiber, and thermocol beads to concrete has been shown to reduce its thermal conductivity. This is because these materials have low thermal conductivity and act as insulators, which reduces the amount of heat that can pass through the concrete.
- **Increased thermal resistance:** The addition of these materials to concrete has also been shown to increase its thermal resistance. This means that the concrete is better able to resist heat transfer, which helps to keep buildings warmer in winter and cooler in summer.
- **Improved mechanical properties:** The addition of date palm fiber and shopping plastic bag fiber to concrete mixtures has been shown to improve its compressive strength and reduce its weight. This is because these fibers reinforce the concrete, making it stronger and more durable.
- **Sustainable approach:** Using waste materials such as date palm fiber, shopping plastic bag fiber, and

thermocol beads in concrete mixtures is a sustainable construction approach. This approach not only reduces waste but also reduces the need for new raw materials, which can help to reduce the environmental impact of the construction industry.

In summary, the research has identified that the addition of date palm fiber, shopping plastic bag fiber, and thermocol beads to concrete can improve its thermal insulation properties mechanical properties, and promote sustainable construction practices.

Experimental Setup

The primary measure of the thermal conductivity of date palm fiber concrete requires an experimental setup that allows for controlled temperature conditions and accurate measurement of heat transfer through the material. The overall arrangement of the various components and measuring instruments used in the setup is shown in Fig. 4. Moreover, the photographic view of the setup and the heat flow pattern are given in Fig. 5. Here is an outline of the basic steps and components required for such an experiment:

RESULTS AND DISCUSSION

Compressive Strength Results

Fig. 6 shows the results of a compressive strength test conducted on a concrete cube containing various percentages of thermocol beads, date palm fiber, and shopping plastic fiber. Based on the comparison of the optimal % substitutions in numerous experimental tests. The compressive strength values of thermocol beads (30%), date palm fiber (3%), and shopping plastic bags (3%) were compared. When comparing, the additive of 3% shopping plastic bag fiber produced the highest result, which was 30.25 $N.mm^2$. For these tests, all concrete is deemed to be M_{30} grade. Conventional concrete (CC) compressive strength was 27.25 $N.mm^{-2}$. In all of these comparisons, the strength of the thermocol beads was too low (18.8 $N.mm^{-2}$), while

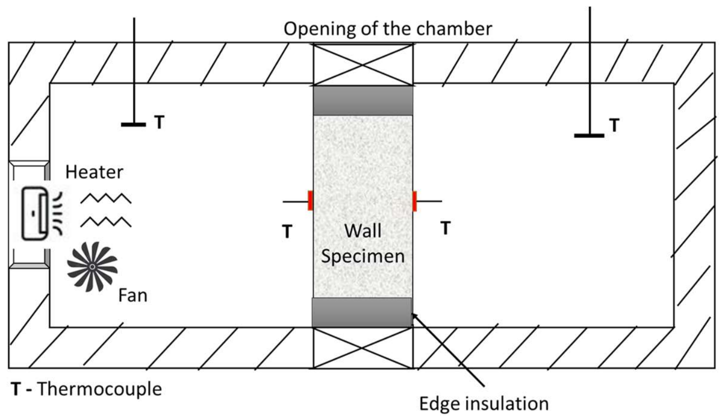

Fig. 4: Thermal conductivity experimental setup.

Fig. 5: Testing setup for finding Thermal conductivity of green masonry wall.

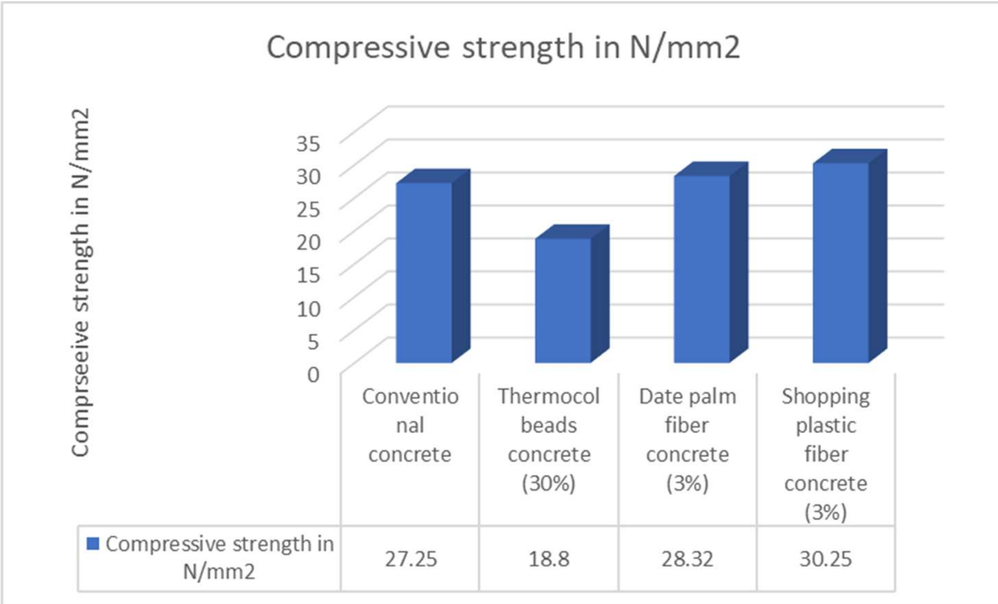

Fig. 6: Compressive strength of cube with various % of thermocol beads.

the strength of the shopping plastic bags was higher (30.25 $N.mm^{-2}$). When comparing these strengths to traditional concrete, shopping plastic fiber has a 10% higher percentage, date palm fiber has a 4% higher percentage, and thermocol beads have a 31% lower percentage.

Measurement of Thermal Conductivity

The thermal conductivity (k) of green and conventional concrete and slab units are determined using the thermal conductivity setup developed at UTAS-Shinas. A thermal conductivity setup is used to measure the rate of heat flow and temperature variation in and out of wall/slab units. The results of the tested concrete and wall units are shown in Fig. 7. Based on the experimental study, it was found that thermocol beads have better thermal conductivity than conventional concrete. The presence of air pockets and voids in the concrete results in a reduction in weight and a reduction in thermal conductivity.

The following equation has been used to determine the thermal conductivity of structural models.

$$\text{Thermal conductivity (k)} = \frac{Q\,\Delta X}{A\,(T_2 - T_1)}$$

Here, k represents thermal conductivity, Q represents the rate of power, ΔX represents the thickness of the wall, T_2 represents the outer wall surface

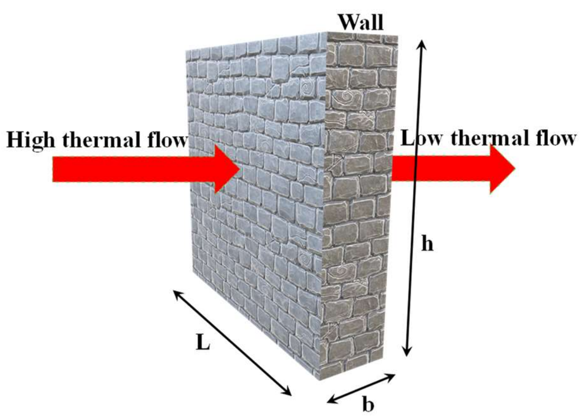

Fig. 7: Thermal flow measurement.

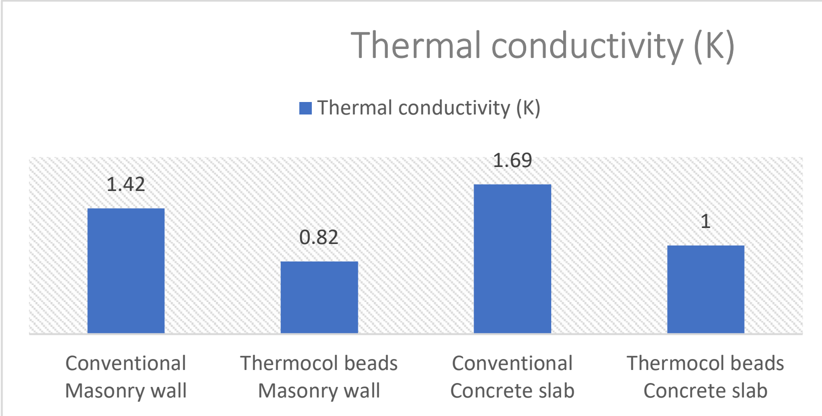

Fig. 8. Comparison of thermal conductivity between thermcol beads and CC.

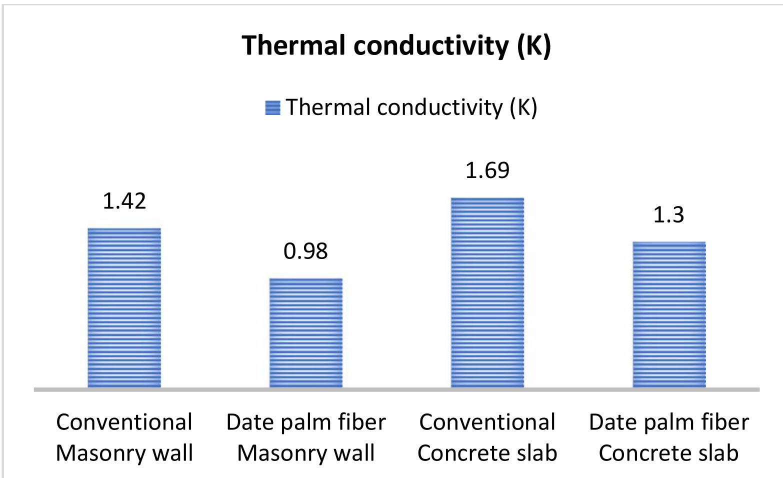

Fig. 9: Comparison of thermal conductivity between date palm fiber and CC.

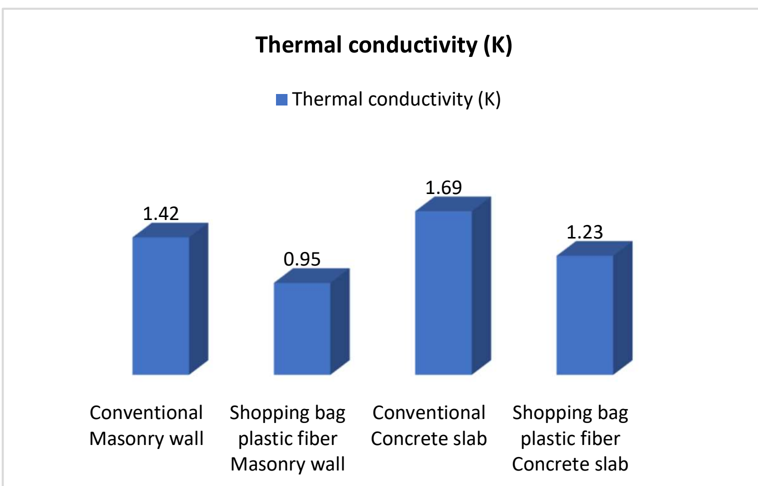

Fig. 10: Comparison of thermal conductivity between shopping plastic bag fiber and CC.

temperature, and T_1 represents the inner wall surface temperature.

Fig. 8 shows that thermocol beads wall and concrete have 42.3%, 41% higher thermal resistance than conventional wall and concrete, which was tested from the thermal conductivity setup and measured for a long duration every five min. interval. Fig. 8 shows that the value is the average value of the entire time of the experiment.

Fig. 9 shows that thermocol beads wall and concrete have 30.1%, 23% higher thermal resistance than conventional wall and concrete, which was tested from the thermal conductivity setup and measured for a long duration with every 5 min interval. Fig. 9 shows that the value is the average value of the entire time of the experiment.

Fig. 10 shows that thermocol beads wall and concrete have 33% and 27.2% higher thermal resistance than conventional wall and concrete, which was tested from the thermal conductivity setup and measured for a long duration with every 5 min interval. Fig. 10 shows that the value is the average value of the entire time of the experiment.

The research demonstrates the successful utilization of date palm fiber, shopping plastic bags, and thermocol beads in producing thermal insulation concrete. The results show that incorporating these waste materials into concrete mixtures enhances the composite‘s thermal performance and energy-saving potential. Date palm fiber improves mechanical properties and contributes to sound insulation. Plastic bags and thermocol beads contribute to lightweight and low thermal conductivity. The study justifies these materials‘ effectiveness in creating an innovative and sustainable solution for energy-efficient buildings, offering waste reduction, improved insulation, and enhanced construction possibilities.

CONCLUSION

Based on the experimental research conducted, it can be concluded that the addition of date palm fiber, shopping plastic bag fiber, and thermocol beads to concrete can significantly enhance its thermal insulation properties. The highest compressive strength of concrete was found when 3% shopping plastic fiber was added and produced the highest result of 30.25 $N.mm^{-2}$. According to the findings of thermal resistance, increasing the date palm fiber, plastic fiber, and thermocol beads % results in an increase in heat resistance. Comparing all these trials, thermocol beads have higher thermal resistance than CC, such as concrete and wall, 42.3% and 41%, respectively. The study found that the thermal conductivity of concrete decreased with the addition of these materials, increasing thermal resistance and insulation performance. The results also showed that the addition of date palm fiber and shopping plastic bag fiber in concrete mixtures improved its compressive strength and reduced its weight. This suggests that these fibers can also enhance the mechanical properties of concrete. Furthermore, the use of these materials in concrete mixtures is a sustainable approach to construction because they are recyclable and reusable waste materials. This makes them a cost-effective and environmentally friendly solution for enhancing the thermal insulation properties of buildings.

In conclusion, the experimental research supports the notion that the addition of date palm fiber, shopping plastic bag fiber, and thermocol beads to concrete is a novel and effective solution for enhancing thermal insulation in buildings and reducing energy consumption. This approach can also promote sustainable construction practices and reduce the environmental impact of the construction industry.

ACKNOWLEDGMENT

The authors are thankful to the management of the University of Technology and Applied Sciences-Shinas, Sultanate of Oman, and the Head of the Engineering and Civil Engineering Section for their continuous support and encouragement in carrying out this research.

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