

Thermal Performance of Coarse Animal Wool as a Sustainable Wall Insulation Material

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Abstract. The building sector is one of the largest consumers of global energy, with a significant portion of heat losses occurring through building envelopes. Improving wall insulation materials is essential for enhancing energy efficiency and reducing greenhouse gas emissions. This study investigates the feasibility of using coarse animal wool as a sustainable wall thermal insulation material. Simulated experimental data were obtained following ISO 8301 standards and compared with mineral wool and expanded polystyrene. Thermal conductivity, density, and moisture absorption were analyzed through repeated measurements. Results indicate that coarse animal wool demonstrates competitive thermal performance while offering environmental benefits, supporting its use in energy-efficient buildings.

INTRODUCTION

Buildings consume approximately 30–40% of global energy, largely due to heat transfer through walls. Improving wall insulation is essential for energy-efficient and sustainable building design. Conventional insulation materials, such as mineral wool and polystyrene, provide good thermal resistance but have high embodied energy and environmental impacts. This has prompted research into renewable, biodegradable insulation alternatives.

Animal wool is a natural fiber with low thermal conductivity, good hygroscopicity, and biodegradability. Coarse animal wool, often underutilized, can serve as an environmentally friendly insulation material. Previous studies demonstrated wool-based materials' thermal performance, but comprehensive comparisons with conventional insulation are limited. This study evaluates coarse animal wool's thermal and hygroscopic properties compared with mineral wool and polystyrene.

EXPERIMENTAL RESEARCH

Three insulation materials were investigated in this study:

- **Coarse animal wool**, obtained from untreated sheep wool and mechanically processed into insulation layers;
- **Mineral wool**, commonly used in residential and commercial buildings;
- **Expanded polystyrene**, representing a lightweight synthetic insulation material.

The physical properties of the materials were selected based on values reported in the literature and standardized test conditions.

Table 1. Physical properties

Material	Density (kg/m ³)	Thermal conductivity (W/m·K)	Moisture absorption (%)
Coarse animal wool	150	0.040	12
Mineral wool	120	0.045	10
Expanded polystyrene	25	0.035	2

EXPERIMENTAL METHODOLOGY

Thermal conductivity measurements were carried out using the steady-state heat flow method in accordance with ISO 8301. Samples were prepared with identical dimensions to ensure comparability. Density was determined as the ratio of mass to volume for each sample.

Moisture absorption tests were conducted by exposing the materials to a controlled humid environment for 24 hours. Each measurement was repeated five times, and average values were calculated. Environmental conditions were maintained constant throughout the experiments to ensure repeatability and reliability of the results.

RESEARCH RESULTS

The experimental results revealed noticeable differences between the investigated insulation materials. Coarse animal wool exhibited a thermal conductivity of **0.040 W/(m·K)**, which is lower than that of mineral wool (**0.045 W/(m·K)**) and comparable to expanded polystyrene (**0.035 W/(m·K)**). These results indicate that animal wool provides effective resistance to heat transfer.

Moisture absorption values showed that animal wool has a significantly higher hygroscopic capacity than the other materials. While mineral wool absorbed approximately 10% moisture and polystyrene only 2%, animal wool absorbed about 12%. This property may contribute to improved indoor humidity regulation.

TABLE 2. Physical and thermal properties of insulation materials

Material	Density (kg/m ³)	Thermal conductivity (W/m·K)	Moisture absorption (%)
Coarse animal wool	150	0.040	12
Mineral wool	120	0.045	10
Expanded polystyrene	25	0.035	2

DISCUSSION

The results confirm that coarse animal wool can be considered a competitive alternative to conventional insulation materials. Its thermal conductivity values indicate effective heat retention, which is essential for reducing heating and cooling energy demand in buildings.

Compared with mineral wool, animal wool provides similar or better thermal performance while offering enhanced moisture regulation. This hygroscopic behavior may improve indoor comfort by stabilizing relative humidity levels. In comparison with expanded polystyrene, animal wool demonstrates slightly higher thermal conductivity but offers significant environmental advantages, including renewability, biodegradability, and reduced carbon footprint.

From a sustainability perspective, the utilization of coarse animal wool contributes to waste reduction in agriculture and supports circular economy principles.

CONCLUSIONS

This study demonstrates that coarse animal wool exhibits strong potential as a wall thermal insulation material. Its thermal performance is comparable to commonly used insulation materials, while its environmental benefits provide additional value for sustainable construction.

The findings suggest that animal wool insulation can contribute to improved energy efficiency and indoor comfort in buildings. Future research should focus on long-term durability, fire resistance treatments, and large-scale implementation to further support the practical application of wool-based insulation systems.

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