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UTILIZATION OF AGRO-WASTE BIOMASS FIBERS FOR 3D HYBRID COMPOSITE CONSTRUCTION MATERIALS

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Abstract. *The global increase in energy consumption, combined with the finite nature of natural resources and the push toward renewable energy production, has highlighted thermal insulation's critical role in preventing energy losses. However, when insulation materials can offer additional benefits, they become even more attractive. Exterior surfaces and walls where insulation materials are used can also provide sound insulation, resistance to mechanical forces, and biodegradability. This research aims to develop structures that meet all of these requirements simultaneously. Technical textiles made of natural fibers and yarns with reduced mass in the center offer the possibility of air entrapment and improved flexural strength, making them suitable for these purposes. The textiles are woven using jute yarn and a face-to-face weaving machine, with natural resins serving as the matrix. By combining high-strength yarns with natural fibers that have a high modulus of elasticity, this material can be classified as a composite hybrid with superior mechanical properties.*

Keywords: *3D spacer panels, biodegradable construction materials, eco-friendly solutions, sustainable biomass management, thermal insulation, acoustic insulation.*

Introduction

The use of thermal insulation is considered one of the most effective means of energy conservation in buildings. The thermal resistance offered by an insulation layer increases with increasing layer thickness and decreasing thermal conductivity. Under dynamic conditions (as the case in most practical applications), insulation materials also play an important role in the effect of other thermal characteristics (e.g., peak transmission loads, etc.). The thermal conductivity categorization of polyester composites reinforced with bamboo fibers was studied [1]. It was clearly shown that the thermal conductivity of fiber-reinforced composites differed with the volume fraction of the fiber, the angle of the fiber, and the temperature with the volume fraction of the fiber. As a result, energy conservation becomes the ultimate goal of various industries [2-5]. The main characteristics of these composites are low-density, high specific strength, high specific stiffness, and excellent hardness [6-9]. The benefits of natural fiber composites include reduced dependence on non-renewable energy/material sources, lower pollutant emissions, enhanced energy recovery, and biodegradability [10]. Natural fiber cellulose can be used to reinforce thermoplastics and thermosetting polymers. In recent years, there has been an expanding search for new materials with high performance at affordable costs. Increasing environmental awareness has led to a focus on eco-friendly materials such as "renewable", "recyclable", and "sustainable". Composite materials, which

are prepared using natural or synthetic reinforcements and a variety of matrix materials, are included in this philosophy [11].

Materials and Methods

Natural hemp threads with a count of 16 Lee were used for weaving the fabric. After weaving the 3D technical fabric, it is necessary to impregnate the fabric with a natural resin based on tree gum to stabilize the dimensional and shape stability of the piece and the distribution of the incoming forces. To hybridize the resulting composite, glass threads with a count of 600 tex can also be used simultaneously with the hemp threads (intertwined in all three x, y, and z directions). To do so, a face-to-face weaving machine is used.

The measurements of thermal insulation parameters were performed on spacer fabrics with the use of the ALAMBETA device constructed in Czech Republic. Several main parameters such as thermal conductivity, thermal absorption, thermal resistance and others were determined. Thermal conductivity coefficient measurements were carried out using a device that can accommodate plates up to 3 cm in diameter.

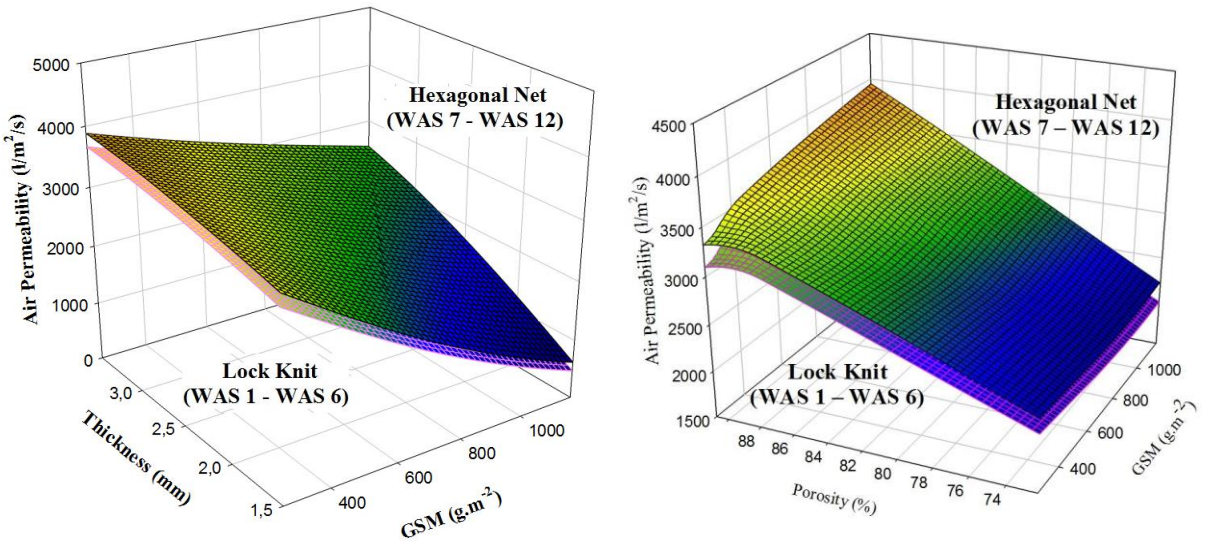
Further, the impedance tube method was used to measure the normal incident sound absorption coefficient, SAC (α). A minimum of three specimens for each sample were tested according to ASTM E 1050-07.

Results and Discussions

Initial tests showed a thermal insulation coefficient of 0.08 W/mK for components produced by this method, which is significantly superior to other insulators that do not have good acoustic and mechanical properties [12, 13].

According to the results, the thin spacer fabric with high density has higher airflow resistance. The increase in the torturous path of the middle (spacer) layer has the ability to entrap more air, therefore, causing higher flow resistance with more sound absorption. The spacer fabrics (WAS 4 – WAS 6 & WAS 10 – WAS 12, see Fig. 1.) shows higher density and lower porosity, allows sound waves to attenuate easily. It was noticed that the sound absorption capacity of spacer fabrics depends not only on airflow resistivity but also on the surface structure structural pores, thickness, and density [12, 13].

To conclude, the 3D spacer fabric is considered to create a suitable construction material that improves thermal performance. Due to its porous and highly permeable nature, the warp knit spacer fabrics have lower thermal conductivity than the weft knitted spacer fabrics. The ANOVA confirmed that the thickness and surface structure significantly impact the thermal comfort properties of spacer fabric.



(a) (b)

Fig. 1. Influence of structural parameters on air permeability of warp knit spacer fabrics (lock knit and hexagonal net)

Our research is focused on the development of a small-volume, environmentally friendly 3D hybrid composite using biomass reinforced with jute. This composite exhibits excellent properties, including thermal, moisture, and acoustic insulation, as well as significant mechanical strength, particularly in bending. Thus, the research aims to create a compact, sustainable material that offers impressive performance characteristics.

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