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Performance evaluation and research of alternative thermal insulations based on sheep wool

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ABSTRACT

Sustainability and energy efficiency in buildings are currently evaluated not only based upon thermal insulation thickness and heating demand, but also according to primary energy demand, CO_2 reductions, and ecological properties of the building materials. These properties are essential for a holistic assessment. To meet the requirements which are increasing in rigor, the demand for ecological building materials is growing dramatically, particularly insulating materials from renewable resources. Ecological insulation materials have been available on the market for a long time; however, conventional materials are still predominantly used.

Most builders are unsure whether the alternative materials meet the same performance requirements as conventional building materials and supporting scientific research and publications are difficult to find. In a joint project of the Brno University of Technology and Vienna University of Technology, the thermal insulation from sheep wool has been tested under various conditions. The building physics and acoustic properties were specifically tested which are important for durable and undamaged applications. The tests results show that the thermal insulation from sheep wool has comparable characteristics with mineral/rock wool, and in some applications even performs better. Additionally, in comparison to mineral wool, sheep wool is more ecological and has fewer damaging health aspects.

1. Introduction

The new approaches to energy-efficient and sustainable design do not only have goals to realize lower energy consumption, but also to apply of natural and local building materials while keeping construction costs to a minimum. The DIRECTIVE 2010/31/EU of the European Parliament and the European Council of 19 May 2010 on the energy performance of buildings requires that "the energy performance certificate should also provide information about the actual impact of heating and cooling on the energy needs of the building, on its primary energy consumption and on its carbon dioxide emissions" [1]. A new term is also introduced, "nearly zero energy building". A zero energy building (ZEB) is a conditional definition as each building needs and consumes energy. ZEB is a highly complex theoretical concept as it considers highly energy-efficient building designs, building materials, technical systems, and equipment to minimize the heating and electricity demand, mitigation of CO_2 emissions while maintaining sustainability [2]. These requirements are now being implemented across Europe. In order to obtain certificates with the best values, many building owners strive to obtain the lowest possible primary energy demand and CO_2 emissions.

Environmental certificates are widespread and increasingly popular such as BREEAM, LEED, DGNB, and Green Mark to name a few. The ecology of building materials is an extremely important requirement in all of the listed certifications.

The focus of some research is the importance of ecological and healthy design. Environmental awareness is now not only constrained to energy savings, but also is contained within ecologically sound construction, i.e. minimum energy input, resource consumption, and pollution production as a part of the production, installation, and use of insulation materials [3]. By using natural building materials in structures, human health can also be positively influenced [4]. Natural building materials regulate internal air humidity well and their characteristic aromas have a positive effect on the human psyche. In a straw bale test house in Germany, several important properties were systematically measured and showed excellent results for healthy living conditions [5]. Organic materials are generally water vapour permeable and can accumulate moisture by adsorption from the air. Other favourable properties of organic materials are the moisture absorption capacity into the internal porous system at increased air humidities, and

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Fig. 1. Photo of sheep wool and its applications in building construction.

conversely, gradual moisture release into the surroundings with decreasing air humidity [6]. This mechanism positively influences the indoor air humidity primarily in winter when prolonged periods of low indoor air humidity may be experienced.

The organic materials are more sensitive than common construction materials. Therefore, the possible applications of these materials should be precisely defined using proper measurements and simulations to verify functionality and durability [7].

The objective of a previous joint project between Brno University of Technology (VUT Brno) and the Vienna University of Technology (TU Vienna) was the development, optimization, and observation of the behaviour of thermally insulating materials composed of easily renewable raw material resources originating from agricultural sources (jute, flax and hemp) which could be used in new building structures and for renovation the existing buildings [8]. All input components were varied in the tests. The tests results have shown that the performance of the correct combination of natural materials is absolutely comparable with convectional building materials. Also in [9] was shown that natural materials can obtain very good properties.

Because of its natural properties and especially thermal efficiency, sheep wool is an excellent insulation material. Research and development of environmentally friendly thermal insulation materials made of natural sources have been underway for many years at the Institute of Technology of Construction Materials and Components to the Construction Faculty, VUT Brno. The effective cooperation with the TU Vienna was an incentive to study other possible alternative material sources that would be possible to apply as insulation materials. The main idea was to obtain a high-quality, environmentally friendly, and cost-effective insulation material with potential use in construction practice. The aim of the here presented study was to determine the basic physical characteristic values for thermal and acoustic insulation products from sheep wool, and the behaviour of these materials under diverse humidity conditions. Many different measurements were carried out in order to obtain the application limits of the sheep wool insulations and to explore the comparability with common insulations. The results of these measurements provided the basis for determining the general pre-requisites of suitability when using this natural and environmentally friendly insulation material.

2. Sheep wool and its qualities

Sheep wool is an easily renewable, easily recyclable and environmentally friendly source of raw material, which consists on average of 60% animal protein fibres, 15% moisture, 10% fat, 10% sheep sweat and 5% impurities.

The benefits of sheep wool include the following:

- Clean and easy to renew natural material source,
- Comfortable and easy to handle without potential risk to human health (irritation of the skin, mucous membranes etc.),
- Easy to recycle, eco-friendly,
- Self-extinguishing capability, the fibres do not support combustion, but char at high temperatures,
- Relaxation of the material, there is neither change in volume nor loss of elasticity,
- Highly hygroscopic, up to 35% [10] (Fig. 1).

The use of sheep wool as a source for the production of thermal insulation is interesting especially due to positive ecological and health properties. In addition to the “thermal and acoustic properties”, the “indoor climate healthiness” for each material should be evaluated. Further research needs are outlined in [11], drawing attention to the role of harmony and interdisciplinary teams in synergetic building health/sustainability studies.

A comparison between the environmental impacts of some traditional and natural insulation materials is shown in Fig. 2 [12]: cellulose, flax and sheep wool have the lowest impacts in the considered categories.

3. Preparation of test samples from sheep wool

Based on preliminary market research, raw sheep wool was prepared by washing with soap and water to remove the sheep fat to a maximum fat content of 1%. Test samples were prepared by laying carded sheep fleece perpendicularly (Struto technique) without the use of binders to a thickness of 80 mm. The mixture of sheep wool was mechanically fastened to a reinforcing cloth to strengthen the mat and enable insulation laminating to the desired thickness. To

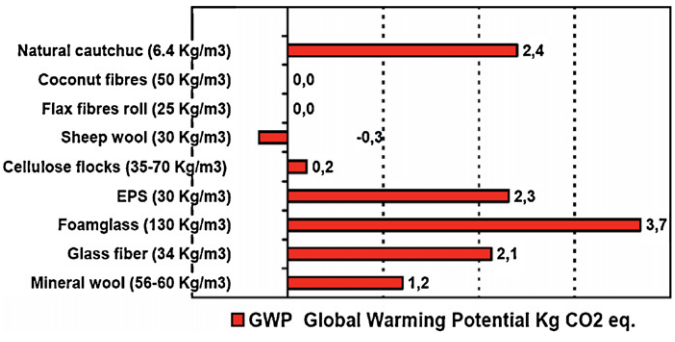

Fig. 2. Comparison of environmental impacts of conventional and natural materials.