TRANSFER OF MASS THROUGH WALLS FROM ENERGETICALLY EFFICIENT INNOVATIVE MATERIALS IN ORDER TO ACHIEVE COMFORT CONDITIONS IN PASSIVE HOUSES

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Abstract: The paper presents the analysis of mass transfer through walls from waste sheep wool. The condense accumulation in the outer walls under the conditions of a location in the climatic zone II is analyzed for an ordinary residential building. The conclusions can be used in projecting passive houses and green technologies for passive houses in order to achieve all the performances requested to these types of future buildings.

Key words: efficient innovative materials, passive house, building envelope

1. Introduction

More and more is talked about the need for rigorous analysis of existing and new constructions, which face the extreme climatic conditions, they require the development of new protection systems, the implementation of reforms to allow resistance to climatic changes and, above all, the probing of new materials. [1-2]

Of course, this requires, first of all, a model to allow the study of the durability of a building, starting from the materials used, the design, the location, the structural characteristics, and the energy consumption. Based on these data, various scenarios can be developed and the effects that will be produced during the construction over a long period of time. [3]

It is necessary to ensure that the selected material has a low permeability to water vapor, so that water absorption is small and reduces condensation and corrosion. So, it must be waterproof, dissolvable and chemical resistant. It must be durable and not lose its insulating properties quickly. It must allow the use of a variety of adhesives for its application. It should be simple and easy to install, weigh a little and be easy to handle, allow assembly with ordinary tools.

It has to be economic, both in terms of initial investment and long-term profitability. It should not discharge or absorb odors. It should not be affected by fungus, dampness, nor attract parasites. It should be stable in size, so it does not fall apart.

The material should be qualified as non-flammable and not explosive. If it happens to burn, the products of its burning should not pose a risk because of their toxicity.

Lastly, the selection and thermal insulation of a material is based on several factors that should be considered:
1. Climate;
2. The ease with which they are installed, some materials, for example, cannot be adapted from the cause of access or toxicity;
3. Durability, resistance to compression, humidity, degradation;
4. The cost that is usually related to efficiency and durability. [4-6]

Heat transfer mode, heat insulating materials are more useful in cold conditions, where there are significant losses, so they are less useful in warm environments, where solar radiation is an important source of heat.

2. Characteristics of heat-insulating material from sheep wool. Advantages and Usage

It is important to research new materials, which are the key elements for the safety and convenience of buildings. In the present, large investments are being made to obtain more resilient, greener and long-lasting materials. The heat insulation material used for the analysis is sheep wool.

The sheep wool, a natural and organic product with thermoinsulating qualities known for hundreds of years, since 2003, is officially recognized as a building material in the European Union under the name Alchimea wool, thanks to a German producer, Naturwaren Alchimea, which invented a treatment process, thanks to which the sheep wool has improved, becoming fireproof and resistant to caries and moths. [7] See Fig. 1.

The sheep wool used for thermo and sound insulation is a natural, insulating material:
- Easy to mount without irritation or dust;
- Without hazardous materials;
- Sound and thermal insulator;
- With the ability to bind formaldehyde in the air;
- With the ability to store the humidity in the air; [8]
- 100% ecological;
- it is easy to procure because the wool is rejuvenated by the sheep;
- accessible to use by allergic persons and with lung conditions;
- costs easy comparable to those for classical materials such as polystyrene or mineral wool;
- the wrinkled surface of woolen fibers makes the insulation also become an excellent soundproofing support;
- is manufactured in different widths and thicknesses, in the form of homogeneous fiber rollers and very easy to handle;
- assembly is very. [3]

![Fig. 1 Sheep wool mats used for thermal insulation](image)

Sheep wool is a fairly effective thermal insulator that has been used for centuries; in fact, Mongolian nomads already used sheath wool pastels and lining as an insulating layer for the walls of its yurts. This material is composed of sheep wool and a polystyrene binder. It achieves a natural thermoregulation, due to its hydroscopic properties, when the outdoor temperature rises, the fibers heat
up, emit moisture and cool. On the contrary, when the outside temperature decreases, the fibers cool down, absorb the moisture and heat up. 

Sheep wool helps prevent condensation and is one of the most durable natural thermal insulators. If the installation was correct, it maintains its density and cohesion for decades. It comes in the form of flexible, lightweight roles that can be cut with simple utensils for various surfaces. Its thermal conductivity is 0.039 W (mK) and the density is 25 kgm$^3$. It is sweaty without losing its thermal properties, helping the inside breathe creating dry spaces. It is a natural product that absorbs moisture.

The energy consumption used for their production and the CO$_2$ emissions are different, lower in the case of sheep and higher in the other types of classic thermoinsulations. In Fig. 2 compares the energy used for the realization, the emissions and toxicity level of sheep's wool to expanded polystyrene, mineral wool.

![Fig. 2 Production energy, CO2 emissions and toxicity level for sheep wool and mineral wool](image)

It can easily be observed that from all three points of view, sheep wool is superior to other types of classic thermo-insulators. [9-10]

From the use point of view, sheep wool can be used to isolate houses on the wood or brick structure, in the case of bridges, roofing, under floor insulation, sound insulation between levels, etc. The products have no smell, they have a pleasant look, and their installation is very simple, with a scissors and a stapler. **For installation, the following components are very easy to obtain:** Stapler, Scissor, Adhesive (based on natural latex), ruler, brush or roller (for glue). Thanks to its soft texture, wool can be easily inserted into any type of construction. Regardless of vertical or inclined mounting, stapling or bonding of material gives stability.

**There is insulation of different thicknesses** for sheep wool being available in different thicknesses. Depending on the type of construction, the wool can be mounted in a single layer or multiple layers of various thicknesses.

**For installation in the partition walls (gypsum board and metal support) the following technology can be used:** The wool can be simply glued to drywall (with brush or roller applied adhesive). The projections are screwed, and on dry wall simply with staples. This type of thermal insulation has excellent thermal insulation properties, sound insulation, vapor-permeable, multi-purpose, efficient, easy to apply. The product has diffusion capacity, i.e. it does not
influence moisture release and is made of natural ingredients. It is an insulating material that retains its shape. A thermal insulator that removes formaldehyde from the air with an excellent conductivity of only $\lambda = 0.0356 \text{ Wm}^{-1}\text{K}^{-1}$. It is also a treated and flame retardant and easy to mount product.

![Thermal sheep wool resistance compared to other classic thermo-insulators](image)

The excellent thermal insulation properties of the wool are kept even in a wet condition. By absorbing and quickly disposing of moisture it greatly attenuates extreme temperature variations, for example at the roof of the house. Alchimea wool keeps its shape. Due to the genetic fixation of wool fibers, it always returns to its original thickness and density. Wool also possesses the ability to reduce noise. It has proven to be a very good sound absorber on both walls and ceilings. Alchimea wool® can remove formaldehyde and other pollutants from the air. This effect is based on the chemical composition of the wool. Reaction products are very stable, and formaldehyde is no longer released.

In Fig. 3 it can be seen the value of the heat resistance of sheep wool compared to other classical heat insulators.

### 3. Mass Transfer through Sheep Wool Insulation

A residential model from the climatic zone II is used as a model of study with the following characterizations regarding the indoor and outdoor climatic parameters given in tab. 1 and assess the risk of condensation and water build-up in the cold season [11-12]. Being a residential building, the indoor air temperature is 20°C, and the average annual outdoor air temperature is 9.50°C. The construction and features of the building element are shown in Table 2. It was considered a brick wall with vertical holes of 35 cm thickness and the thickness of the thermal insulation is 10 cm, similar to a classical EPS thermal insulation. [13-16]

#### Tab. 1 Indoor and outdoor climatic parameters needed to verify progressive water flow

| Indoor climatic parameters       |        |
|---------------------------------|--------|
| Indoor air temperature          | 20 °C  |
| Relative humidity of indoor air | 60 %   |
| Coefficient of thermal transfer to the inner surface | 8 W/m²°C |

| External climatic parameters   |        |
|--------------------------------|--------|
| Average annual outdoor air temperature | 9.50 °C |
| Relative humidity of outdoor air  | 80 %   |
| Heat transfer coefficient at outer surface | 24.00 W/m²°C |
Tab. 2 Construction and features of the building element

| Code | The layers of the building element (They are mandatory to be inserted from the inside out) | Layer thickness (m) | Thermal conductivity (W/m°C) | The vapor permeability resistance factor (–) |
|------|------------------------------------------------------------------------------------------|---------------------|-----------------------------|-------------------------------------------|
| 52   | Mortar of lime                                                                            | 0.0100             | 0.700                       | 5.30                                      |
| 202  | Brick masonry with vertical holes, GVP type                                              | 0.3500             | 0.580                       | 4.50                                      |
| 204  | Sheep wool                                                                                | 0.1000             | 0.033                       | 0.50                                      |
| 511  | Cement mortar and lime                                                                   | 0.0100             | 0.870                       | 8.50                                      |

The outside air temperature at which the condense appears –8.38°C, at a relative humidity of 85%.

Tab. 3 Temperature and partial pressures on the surfaces of the layers

| S. No. | Layers surfaces | Partial pressure (Pa) | Saturation pressure (Pa) | Temperature (°C) | Indoor climatic parameters | Outdoor climatic parameters |
|--------|-----------------|-----------------------|--------------------------|------------------|---------------------------|-----------------------------|
| 0      | Indoor air      | 1402.2                | 2237.0                   | 19.08            | Indoor air temperature: 20 °C | The outside air temperature at which condensation occurs: -8.38 °C |
| 1      | Limit between layers 1 / 2        | 1367.7                | 2193.0                   | 18.98            | Relative humidity of indoor air: 60 % | Relative humidity of outdoor air: 85 % |
| 2      | Limit between layers 2 / 3         | 342.2                 | 1655.0                   | 14.54            | Coefficient of thermal transfer to the inner surface: 8 W/m²K | Coefficient of thermal transfer to the outer surface: 24 W/m²K |
| 3      | Limit between layers 3 / 4         | 309.6                 | 309.6                    | -7.99            | |

Tab. 4 The amount of condensed water in the cold season

| Indoor climatic parameters | External air temperature during condensation: -13.38 °C |
|---------------------------|-----------------------------------------------------------|
| Indoor air temperature    | 20 °C                                                    |
| Relative humidity of indoor air | 60 %                                             |
| Coefficient of thermal transfer to the inner surface | 8 W/m²K                                             |
| Outdoor climatic parameters |                                                          |
| Relative humidity of outdoor air | 85 %                                               |
| Coefficient of thermal transfer to the outer surface | 24 W/m²K                                             |

Fig. 4 Diagram of pressure variation graphs
The outside air temperature during condensation is –13.38°C. Tab. 5 shows the indoor and outdoor climatic parameters during evaporation. It is noticed that the temperature of the outdoor air during the evaporation is 7.62°C. It is noticed that there is no risk of water accumulation - Tab. 6 by checking successive moisturizing.

**Tab. 5** Indoor and outdoor climatic parameters during evaporation

| Indoor climatic parameters |  |
|---------------------------|--|
| Indoor air temperature     | 20 °C |
| Relative humidity of indoor air | 60% |
| Coefficient of thermal transfer to the inner surface | 8 W/m²K |

| Outdoor climatic parameters |  |
|----------------------------|--|
| Outdoor air temperature during evaporation | 7.62 °C |
| Relative humidity of outdoor air | 70% |
| Coefficient of thermal transfer to the outer surface | 24 W/m²K |

**Tab. 6** Calculation Parameters for Excessive Humidity Verification

| Calculation Parameters for Excessive Humidity Verification |  |
|------------------------------------------------------------|--|
| The amount of water vapor that can condensate during the cold season of the year | 0.0720 kg/m² |
| Density of the material saturated by condensation | 20.00 Kg/m³ |
| The thickness of the material layer in which water builds up | 0.10 m |
| Increasing the mass moisture at the end of the condensation period | 3.66 % |
| Maximum admissible increase in mass humidity | 15.00 % |

In Fig. 5 are centralized mass transfer data for the studied model. We observe an amount of water accumulated during the cold season of 0.0720 kg/m², and the increase in humidity at the end of the condensation period is 3.60% <15% the maximum allowable value of the mass humidity.

**Fig. 5** Assessment of condensation risk in sheep wool thermoinsulation and results centralization

**Conclusions**

The assessment of hygroscopic characteristics is important both for ensuring the fundamental requirement for hygiene, health and environmental constructions and for ensuring the fundamental requirement of energy saving and thermal insulation. Determination of hygroscopic performances of building exterior protection / plating systems is useful for: - designers, choice of closure components, thermal calculation and calculation of water vapor diffusion; - Manufacturers of building materials who must indicate in the Product Performance Declarations, thermal conductivity / thermal resistance and water vapor permeability characteristics. Achieving closure elements that have a favorable effect on water vapor diffusion also meets the durability of constructions, an essential component of the fundamental requirement of sustainable use of natural resources.

Sheep wool is an effective heat insulator that competes with the widely used thermoinsulations that thermoregulate naturally. As it follows from the study presented sheep wool helps to prevent condensation. This type of heat insulator has diffusion capacity, i.e. it does not influence moisture
release. Considering that it is a very good sound insulator, this product can be recommended as an excellent green product for thermo-hygro-phono insulation of homes.

All the conclusions of this research can be used in projecting passive houses and green technologies for passive houses in order to achieve all the performances requested to this type of future buildings.

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