USE OF TREE LEAVES-LIME MIXTURE FOR BUILDING INSULATION

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Abstract. The publication explores innovative solutions on tree leaves – lime mixture use for building insulation. Wood leaves are used whole and shredded as bulk ecologically clean heat insulation materials. The optimal density was determined for each type to obtain the lowest thermal conductivity using different equipment and methods. The optimal amount of additives was examined to provide durability, resistance to deterioration of the heat insulation properties of the innovative materials, to reduce rodent and other pest impact. The innovative heat insulation material can be recycled in the environment and used as a fertilizer for soil improvement.

Keywords: ecological materials, recirculation in the environment, fertilizer.

Introduction

From old times tree leaves were used for housing insulation. In the 20th century due to the development of industrialization, many different types of heat insulation materials were developed that contained chemically derived ingredients. The studies of recent years have shown that they adversely affect the human organism in long-term. It is very difficult and expensive to recycle them, that is why accumulation of hazardous waste appears.

In the 21-st century, attention has been paid mostly to the development of new ecologically clean heat insulation materials [1]. Such materials are significantly more expensive and a small part of population can afford to use them.

Renewable materials contain natural fibres (e.g., jute, flax, hemp, cotton, cellulose), and have many positive properties: low thermal conductivity, low density, good specific tensile strength [2-4]. The natural fibre materials have less impact on nature [2; 5].

Parliament of the Republic of Latvia adopted the Latvian National Development Plan till 2020, which emphasizes improvement of energy efficiency in all economic spheres. Large energy savings can be achieved in construction, improving the energy efficiency of buildings by reducing energy consumption in manufacturing and at the same time switching to renewable energy resources [6].

The objective of the publication is to develop a possibly cheaper, more affordable to consumers, durable, ecologically clean heat insulation material that can be recycled in the environment after its use and used for improvement of soil as fertilizers that contain a lot of important microelements for the purposes of ecologically clean plant cultivation. It is possible to collect tree leaves in the autumn during dry periods and get a basic raw material of heat insulation.

Used innovative heat insulation materials of tree leaf-lime mixture can be recycled into the environment by using them as a fertilizer for soil fertility improvement. For many garden plants optimum soil acidity or pH is 6-7. It is known that artificial fertilizers acidify the soil. Acidic soil pH can be increased by its liming. Basic liming of acidic soils may need up to 40-100kg of garden lime per 100 m^2, garden liming needs 10-30 kg per100 m^2 every second or third year. To reduce the acidity of clay or humus you will need more lime than light gravel and sand soils [12].

A good alternative to the commercially available organic fertilizers is homemade compost. A good resource is tree leaves. It is best to put the compost in piles, or before digging up the ground to dispel over the soil 10 to 15 centimetres in thickness [13].

Tree leave heat insulation material optimal density and thermal conductivity detection method

It was experimentally determined that in order to provide durability of an innovative, ecologically clean heat insulation material that can be recycled in the environment you should add quick lime in the amount of 1-5 % of the volume of heat insulation materials – tree leaves to extend heat insulation material longevity, maintain the optimal moisture level and prevent moulding, decomposition, pest and rodent appearance.

Tree leaves thermal properties were determined using the non-stationary heat flow regime taking into account that in the real conditions the stationary regime is realized very rarely. Temperature conductivity of the material plays the decisive role in non-stationary heat flow conditions which cannot be determined in the stationary mode. The non-stationary regime method also requires less time measurement.

The modified heat pulse method lies in the heart of this study (Fig. 1). The heat single impulse was imposed into the analysed sample 1 from the flat quick-response heating element 2 and at a distance R from the heat source the temporal changes of temperature were measured by the thermocouple 3.

The exact solution of thermal conductivity equation in this case (where the heat source is flat) is as follows [7]:

$$T(x,\tau) - T_0 = \frac{q e^{-R^2/4a\tau}}{2c\rho\sqrt{\pi a\tau}}, \tag{1}$$

where T_0 – initial temperature of a sample and the heater;
$T(x,\tau)$ – temperature in the sample at the distance x from the heating element during the time τ;
q – specific heat flow through the cross-sectional area of the sample, $J \cdot m^{-2}$;
a – temperature conductivity of the sample, $m^2 \cdot s^{-1}$;
c – specific heat capacity, $kJ \cdot (kg \cdot K)^{-1}$;
ρ – density of the sample, $kg \cdot m^{-3}$.

From this equation the following parameter can be extracted:

$$\theta = \frac{e^{-R^2/4a\tau}}{2c\rho\sqrt{\pi a\tau}}, \tag{2}$$

which depends only on the temperature conductivity of the material. On this basis in our previous studies we designed a monogram for determination of temperature conductivity using only the temperature relationship T_1 and T_2 [7; 8].

In this study we took the point $T = f(\tau)$ of the curve for calculations at which the temperature reaches maximum.

In this case the density of organic parts of leaves according to the existing sources of information [9] is 0.8 $g \cdot cm^{-3}$. The study showed that depending on the degree of compression the bulk density of tree leaves could vary from 0.094 to 0.136 $g \cdot cm^{-3}$. In our experiments the bulk density of easily compressed samples was 0.1 $g \cdot cm^{-3}$.

So, the calculated porosity P of the samples was about 87.5 %.

The thermal conductivity coefficient λ according to Fourier theory could be calculated by the formula:

$$\lambda = ac\rho . \tag{3}$$

Specific heat capacity of organic parts of leaves can be accepted as c= 0.7 $kJ \cdot (kg \cdot K)^{-1}$ [10; 11].

So, the volume heat capacity will be

$$c_v = c\rho = 0.7 \cdot 100 = 70\ kJ \cdot (m^3 \cdot K)^{-1}.$$

Knowing the P and the volume heat capacity c_a of the air 1.29 $kJ \cdot (m^3 \cdot K)^{-1}$ and that the heat capacity is an additive parameter the volume heat capacity of the sample was calculated as

$$c\rho = 70(1-0.875) + 1.29 \cdot 0.875 = 9.88\ kJ \cdot (m^3 \cdot K)^{-1}. \quad (4).$$

As a result the maple leaves thermal conductivity coefficient

$$\lambda = ac\rho = 4.8 \cdot 9.88 \cdot 10^{-6} = 4.74 \cdot 10^{-2}\ W(m \cdot K)^{-1}.$$

Compression will increase this figure, disintegration will decrease.

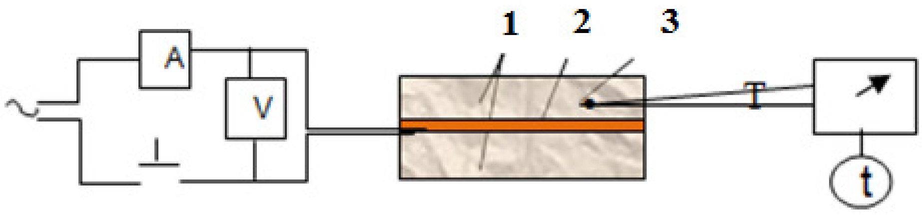

Fig. 1. **Principal scheme of thermal properties measuring method:**
1 – sample; 2 – heating element; 3 – thermocouple

Experimentally obtained parameters of tree leaves heat insulation material and analysis of experimental results

During the experimental research by testing the thermal conductivity for maple leaves (Fig. 1) and mixed leaves the results show minimal difference of thermal conductivity.

To save ecologically clean heat insulation material and protect it from mold, rot, rodents, beetles and other vermin, there was added 1-5 % lime to mixed leaves (Fig. 2).

The thermal conductivity is about 20 % higher for tree leaves – lime mixture compared with rock wool or expanded polystyrene insulation. To use these innovative eco clean and significantly less expensive insulation materials they should be applied in about 20 % thicker layer to reach an equivalent thermal conductivity.

Thermal conductivity dependence of the tree leaves degree of compaction was measured by the device NETZCH HFM 436 Lambda. The density of the samples varied from 10 to 30 $kg \cdot m^{-3}$. It was established that the optimal density at which tree leaves have the lowest thermal conductivity is about 30 $kg \cdot m^{-3}$ (Fig. 3) .

To protect the heat insulation material from mold, decay and various insects it is necessary to add lime to tree leaves mass. After adding lime to the leaves in the amount 5 %; 7 % and 10 % by volume the thermal parameters did not change considerably and remained in acceptable limits.

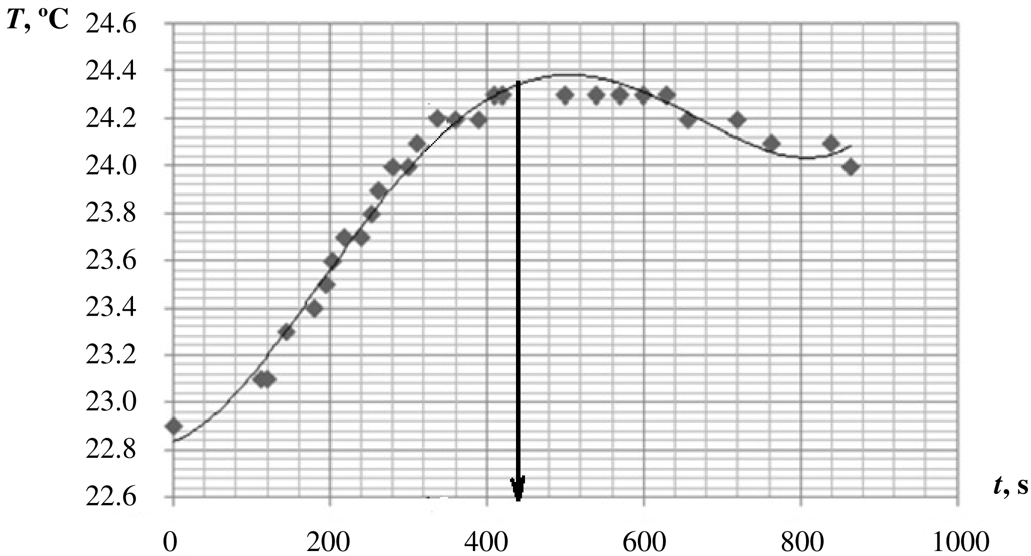

Fig. 2. **Temperature change curve in maple and other tree leaves sample depending on time**

To build a clean passive or 0 heat loss building using tree leaves – lime mixture in insulation for a small private house the thickness of the outer wall should be at least 400-600 mm. If you have a large private house, around 200 m^2 or more, then the space for enclosing the structure surface area is bigger and proportionally there will be bigger heat loss.

To provide such passive or 0 heat loss building walls and the roof it can reach a thickness of 1m tree leaves – lime mixture in heat insulation. Figure 4 shows an innovative solution for bearing walls with thermal insulation filling the building structure and its main assemblies.

For one-store buildings the double structure bearing wooden plank thickness should be at least 50-70 mm, but for buildings constructed loft or bunk it should be at least 100-120 mm.

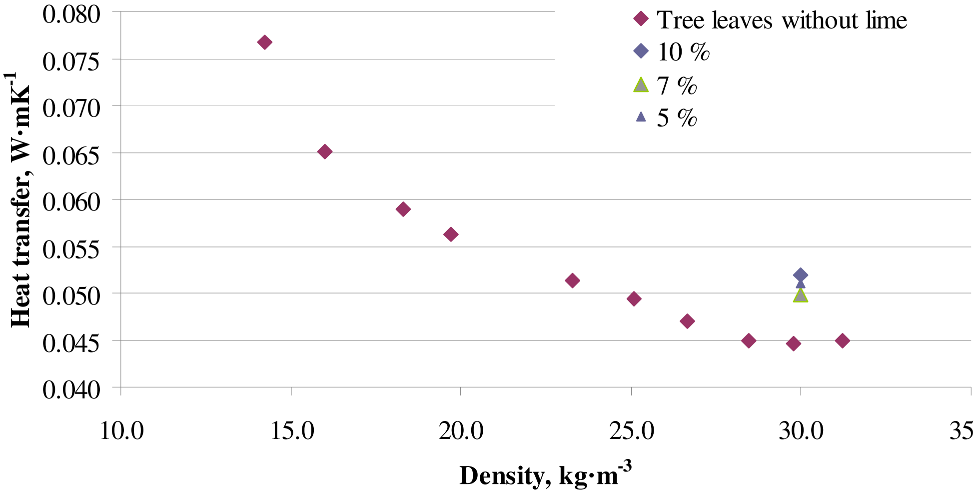

Fig. 3. **Tree leaves heat transfer change curve depends on density and lime admixture**

Ventilated facade is for protecting the exterior wall against precipitation moisture.

Double windows and doors, and the air space provide minimum heat insulation for the building, it can conform for a clean passive or 0 heat loss building [14].

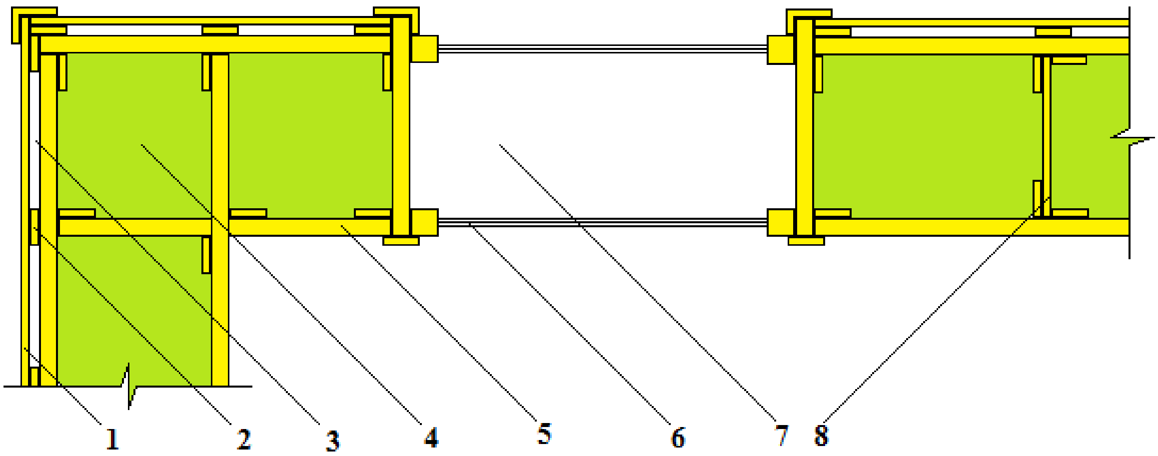

Fig. 4. **Wood wall construction with filling heat insulation material:** 1 – thin wood boards facade for ventilation; 2 – vertical boards; 3 – ventilated facade gap; 4 – filling material of heat insulation; 5 –bearding construction of thick wooden boards; 6 – double windows and/or doors; 7 – air camera for heat insulation; 8 – knob type of wall width fitting

Conclusions

1. To specify the thermal conductivity of wood leaves –lime mixture, the best obtained result is 0.0462 $W \cdot mK^{-1}$.
2. The leaves bulky insulation material can be used in whole and powdered way by adding of 5-10 % quick lime, thereby reducing the risks of deterioration, as well as rodent and other pest appearance.
3. Worn-out tree leaves heat insulation material can be used for soil improvement for cultivation of organic plants and it proves that tree leaves can be used as complete recirculation into the environment.
4. By collecting dry tree leaves and admixing quick lime it is possible to get a thermal insulation which is cheaper compared to commercially available heat insulation materials.
5. To build one or more storey buildings innovative wood buildings with appropriate wall thickness of heat insulation can be used.

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