# THERMAL CONDUCTIVITY OF WALLS INSULATED WITH NATURAL MATERIALS

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**ABSTRACT**
*Using of natural renewable and recyclable materials enables us to construct a comfortable space to live in. The aim of this investigation was to research thermal transmittance and relative humidity of wall fragments with different structures and insulation. Tested wall fragments were built into window openings of an actual outside wall. All the materials used were natural: wood, lightweight clay blocks, reed and straw bales, loose hemp chips and reed. Walls were rendered with clay plaster. Thermal transmittance and relative humidity were measured in four different wall structures during two years. Sensors for measuring temperature and humidity were placed at several points, for one item between the insulation and clay plaster layers. On the basis of the research it may be concluded that it is possible to fulfil minimum energy performance requirements using natural insulation materials and based on the values of the observation period it can be concluded that there was no water condensation in the wall structure. Therefore there was no threat of biodegradation.*

**Key words:** natural construction materials, insulation with loose reed and hemp chips, lightweight clay blocks, reed and straw bales, clay plaster, thermal transmittance, relative humidity

## INTRODUCTION

The use of local construction materials enables us to create a living environment many people strive for. People want to live in an environment with a healthy room climate, the creation of which would harm the surrounding nature as little as possible.
Over the centuries, people in Estonia have used local natural materials (timber, clay, reed), as well as residual materials resulting from the processing thereof (sawdust, flax shives, straw) in construction. Local materials are, in general, renewable, recyclable and, if necessary, easily disposable. These materials are predominantly used in the areas of mining or growing thereof – hence less energy is used to transport these materials. The effect of the use of such construction materials and such ways of construction is minimal to the surrounding environment.
With the use of artificial materials in the 20$^{th}$ century many of the local construction materials lost their importance and gradually people lost the ability to use them properly in construction. Recently more and more importance has been paid to an environmentally friendly and sustainable way of life and therefore people have started to look for alternatives to energy-intensive construction materials produced of non-renewable resources. Hence people have rediscovered local natural construction materials, including natural thermal insulation materials.
Natural construction materials have been studied at the Department of Rural Engineering of the Estonian University of Life Sciences for more than 30 years. In recent years this trend has gained priority, especially in the use of thermal insulation materials, as increasing attention is being paid to the thermal insulation of buildings. Also, valid laws, regulations and norms set higher requirements for the thermal resistance of enclosures.
However, there is relatively little data in the literature as regards to the heat engineering characteristics of natural thermal insulation materials, hence it was extremely interesting to examine the operation and thermal resistance of enclosures insulated with natural materials and different structural solutions.

## MATERIALS AND METHODS

The Department of Rural Engineering of the Estonian University of Life Sciences carried out a test in order to compare the thermal conductivity of outer walls of different structural solutions and use of material. The test was carried out in the framework of the University's baseline financing of scientific research and the Interreg IV-A project ProNatMat. The results of the tests form a basis for consulting people who use natural materials to construct buildings and give them specific recommendations as regards the use of certain materials in external enclosures.
In order to imitate the functioning of a structure truthfully in actual circumstances of the building, measurements were made on the object all year round and the test was carried out in the window openings of the laboratory of building structures. The windows were removed and four different external wall models were built in the openings using different structural solutions (figure 4a).
Test wall S1. A 130 mm thick masonry wall of flax shives and light clay blocks (figures 1 and 4b) was built in the first window opening. Wood planks of 220 x 50 mm were attached to the outer side of the

masonry wall and hemp chips were used as a thermal insulation material to fill the gap between the planks. Then 25 mm boarding was nailed on the planks and that was in turn covered with windproof film. An approximately 5 mm thick sparse reed panel was fixed to the inner surface of the wall. The wall was then covered with clay plaster inside and outside.

Test wall S2. In the next window opening vertical boards were installed on the external and internal surfaces of the existing wall, the window opening was filled with horizontally placed reed and thickened both horizontally as well as vertically (figures 2 and 4c). The wall was covered with about 50 mm thick clay plaster both inside and outside.

**Figure 1.** The building of a test wall of light clay blocks (wall S1)

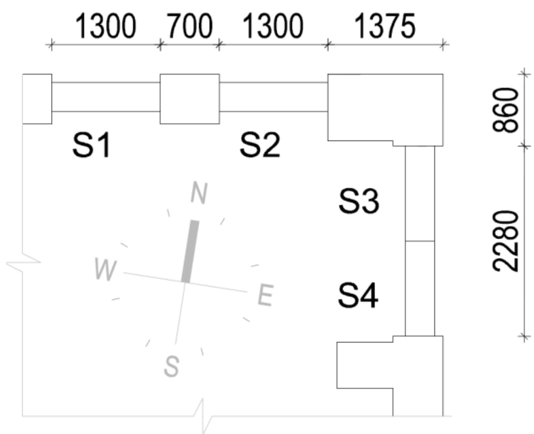
**Figure 2.** The building of a test wall of horizontal reed (wall S2)

Test walls S3 and S4. The third window opening was wider and two walls of different material were built there (figures 3, 4d and 4e). The third and fourth walls were built of 450 mm thick straw and reed bales. The bales were additionally tightened with capron strips. The outer and inner surfaces of the walls were covered with 50 mm thick clay plaster.

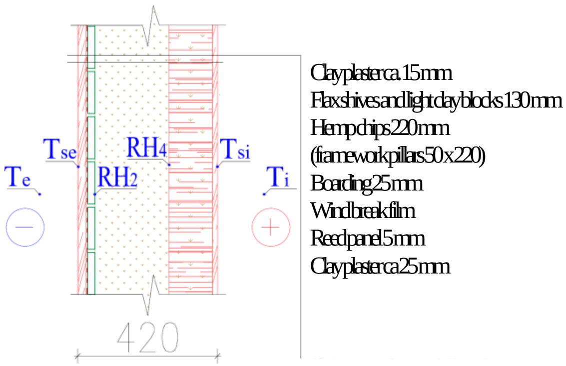
**Figure 3.** The building of a test wall of straw and reed bales (walls S3 and S4)

The wall structures are shown in figure 4. During construction, sensors were placed inside the walls to measure temperature and humidity.

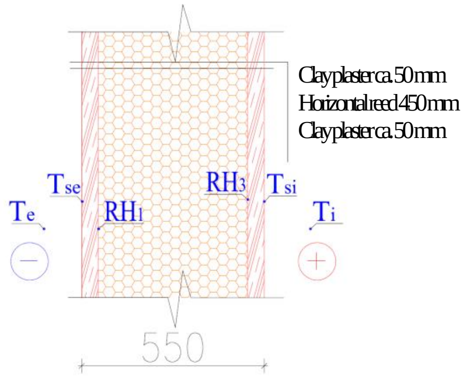
a) locations of the walls



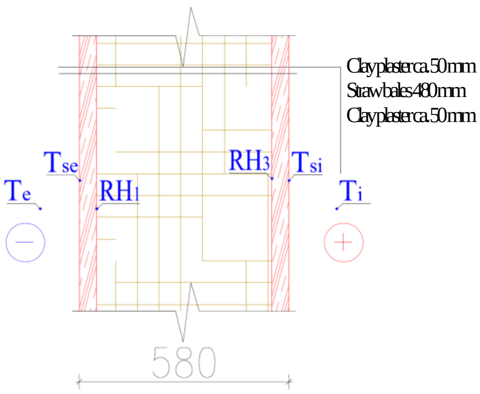

b) S1 – wall built of light clay blocks insulated with hemp chips




c) S2 – test wall built of horizontal reed




d) S3 – test wall built of straw blocks




e) S4 – test wall built of reed blocks

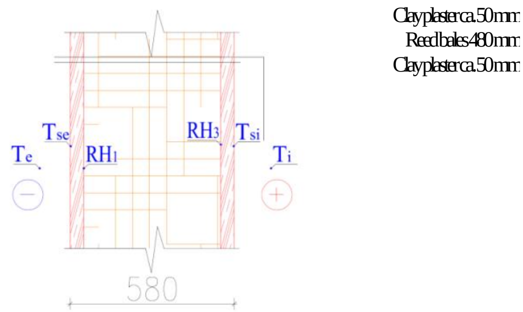



**Figure 4.** Test walls in the window openings of the laboratory of building structures: a) locations of walls; b)–e) cross-sections of test walls

After the completion and drying of the walls, temperature and humidity sensors were placed inside the wall to measure the characteristics of inner and outer surface and the indoor and ambient air. To measure the heat flux transmitted through the wall, heat flow measuring plates were adhered tightly to the wall (figure 5). All readings were recorded with a 15-minute interval in an Almemo data recorder.

**Figure 5.** Heat flow plates to measure the heat transmittance and thermocouples to measure the temperature of surfaces of the wall

The following characteristics were measured to determine the thermal transmittance of the wall:

q – heat flow through the wall [W/m²];
$T_e$ – outdoor air temperature [ºC];
$T_{se}$ – temperature of the outer surface of the wall [ºC];
$T_{si}$ – temperature of the inner surface of the wall [ºC];
$T_i$ – room temperature [ºC].

Based on the readings from the measuring instruments the thermal transmittance U [W/m²K] of the walls was calculated:

$$U = \frac{q}{T_i - T_e}. \qquad (1)$$

## CONCLUSIONS

The test period lasted from December 2009 to May 2011. The measurements were made in a non-steady-state, *i.e.* the temperatures changed continuously in time and hence the heat flow through the wall varied. The data gathered as regards the measuring period can be visualised. The programme also enables thermal transmittance graphs that alter in time to be calculated and printed (Figure 6).

Figure 6 shows data received during the test period with the monthly average values calculated. The data shows clearly that thermal resistance is the best in test wall S2, *i.e.* in the wall insulated with horizontal reed bundles, and the worst in test wall S1, *i.e.* the wall built of light clay blocks insulated with hemp chips.

During the first winter the thermal transmittance decreased remarkably due to the drying of the material (clay plaster). Next year the U-value was more stable.

Based on test data the average thermal transmittance of the test walls was also calculated from October 2010 to March 2011. The results are shown in figure 7.

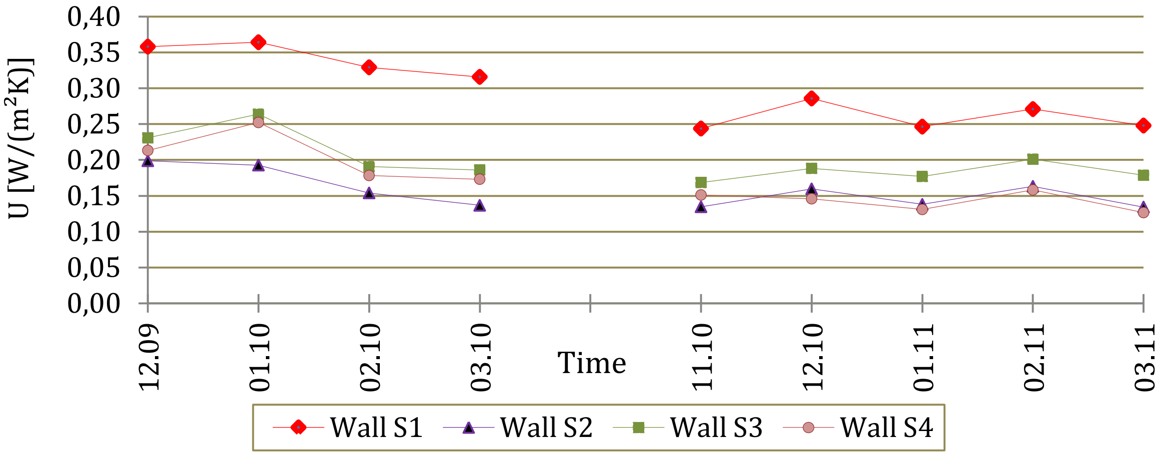



**Figure 6.** The thermal transmittance of different test walls, taking into account the average value in the period from December 2009 to May 2011

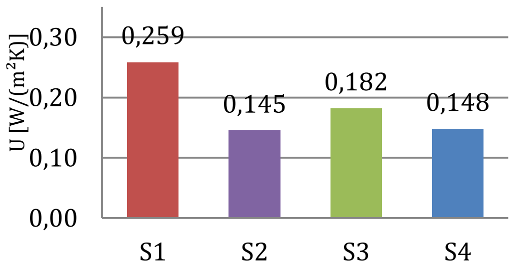



**Figure 7.** Thermal transmittance of test walls

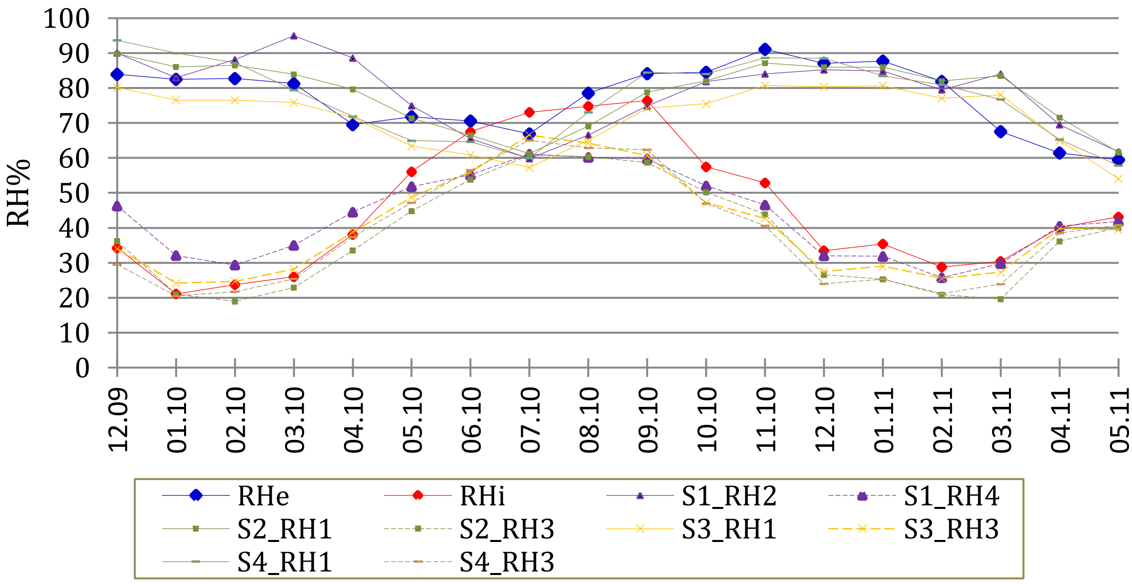



**Figure 8.** The relative humidity of various test walls [RH%], taking into account the average monthly value from December 2009 to May 2011 in the different layers of the walls

According to the government regulations of the Republic of Estonia Minimum energy performance requirements the thermal transmittance value of outer walls must be at least 0,2–0,5 W/($m^2$K) (RT

I:2007). The test results show that only one test wall (S1) does not conform to this requirement of the regulations, which, taking into account the thickness of test walls, is not at all surprising. Based on the tests carried out it can be said that natural insulation materials compete well with their insulation characteristics with artificial insulation materials and these can be successfully used in practice. When using local thermal insulation materials one needs to use thicker layers of insulation, but due to the smaller primary energy content of the material we are friendlier to nature and there are less emissions of greenhouse gases. Figure 8 shows the ratio of the percentage of relative air humidity of the walls to the level of saturation as a monthly average value in the period of December 2009 to May 2011.

The values of relative air humidity were measured at the points between the insulation and clay plaster layers in order to see whether the wall structure is saturated with humidity at that point. The line RHe shows RH changes between the outside clay plaster and the wall structure and the line RHi shows the same between the inside clay plaster and the wall structure. Based on the values of the observation period we can conclude that there was no water condensation in the wall structure.

The investigation of hygrothermal state done by the Austrians show also that there was no water condensation inside the wall and thereof no threat of biodegradation of the natural wall insulation materials due to the clay plaster layer. (Wegerer, P., Bednar, T. 2011).

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