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DETERMINATION OF THERMAL TECHNICAL PROPERTIES OF ORGANIC THERMAL INSULATING MATERIALS BUILT-IN TO HISTORICAL BUILDINGS

Jiri Zach, Jiri Brozovsky, Ivana Sedlarova
Brno University of Technology, Faculty of Civil Engineering,
Technology Institute of Building Materials and Elements,
Veveri 95, 602 00 Brno, Czech Republic
e-mail: zach.j@fce.vutbr.cz, brozovsky.j@fce.vutbr.cz, sedlarova.i@fce.vutbr.cz
fax : +420 5 4114 7502

ABSTRACT

Thermal insulating materials provides thermal protection to building structures, lower energy demand for heating and provides in inner environment of buildings thermal comfort in both winter and summer. For historical buildings were for insulation used natural materials for example: wood, straw, sheep wool, etc. Due to the character of these natural materials and degradation factors (temperature, moisture content, and microorganisms) deterioration of their use property and lower durability occurs.

For rehabilitation of historical buildings it is necessary to evaluate degradation rate of built-in materials and also determine their real in-situ thermo insulating properties according to moisture content, and volume changes.

The paper is describing possibilities for determination heat conductivity coefficient on organic materials with moisture content and also prediction of change of this coefficient depending on change in moisture content.

INTRODUCTION

The building materials absorb molecules of water from the ambient air by adsorption and also by capillary condensation. Under normal climatic conditions, the building materials built in structures are newer quite dry, they always contain a certain quantity of water, in dependence on ambient conditions. This is connected with the fact that the building materials are permanently exposed to the ambient "humid" atmosphere and they absorb more or less the humidity from the air. The building materials in newly built buildings receive the moisture on the one hand during the production, on the other hand during building works as the result of wet building processes but mostly by combination of both this ways. The natural drying, causes during a longer period a moist state in the material, which can be specified as the practical content of building material moisture. This is defined as the value which corresponds to the values determined as the results of practical measurements in the structure, in which the equilibrium state of moisture was reached.

The only possibility in the case of rehabilitation and reconstruction of historical buildings is to realize the internal insulation of walls. It is important in this case that the material should be able to transport the moisture by its capillary system in the direction to the outer surface, where the water evaporates. Another important condition is to secure sufficient thermal insulating properties of the insulating material in the case of elevated moisture content.

INFLUENCE THERMAL CONDUCTIVITY VALUE ON MOISTURE CONTENT

The porous system of thermal insulating materials on natural base enables (if it is open) the transport and the accumulation of moisture. The value of the thermal conductivity coefficient of materials on natural base is closely connected with the moisture content. The air in porous systems of these materials is substituted during humidification by water which has multiple higher value of thermal conductivity and this means a significant increase of the thermal conductivity coefficient. The thermal conductivity coefficient λ [$W.m^{-1}.K^{-1}$] of the moist material is determined by the thermal conductivity of the solid matrix, of fluid phase, of gaseous phases and by their quantity, by phase changes and by the spatial arrangement of phases. The thermal conductivity coefficient grows with the increasing moisture content.

TESTING SAMPLES

The following types of testing samples were selected for the measurements of thermal insulating materials:

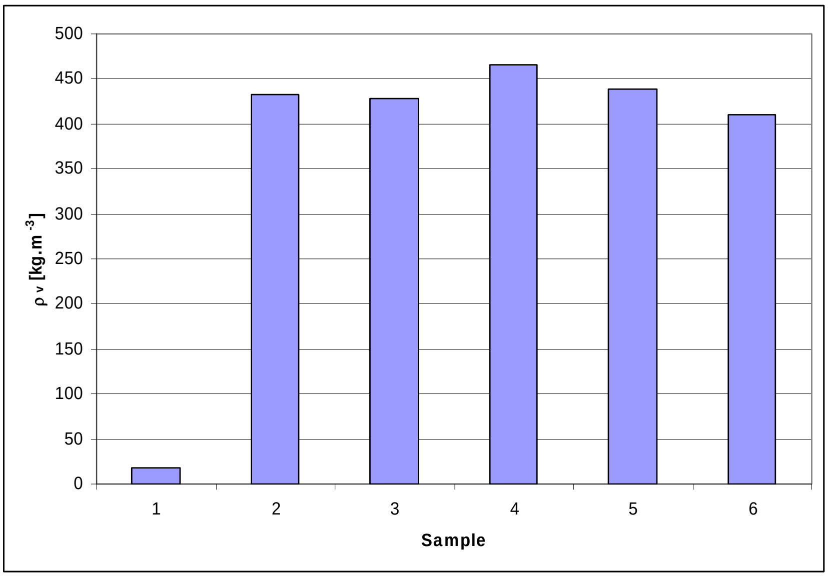
- Ewe wool (sample 1)
- Thermal insulating materials based on organic filler bound with inorganic binder.
  - Cotton stems bound by alkaline activated slag (sample 2)
  - Corn stems bound by alkaline activated slag (sample 3)
  - Corn tailings bound by alkaline activated slag (sample 4)
  - Wood chips bound by Portland cement (sample 5)
  - Technical hemp chaff bound by Portland cement (sample 6)

Samples 300 x 300 x 40 mm were prepared for the determination of thermal insulating properties and further samples 100 x 100 x 100 mm (except of the ewe wool) for the determination for density and sorption properties.

Sample 3. Sample 2. Sample 4.

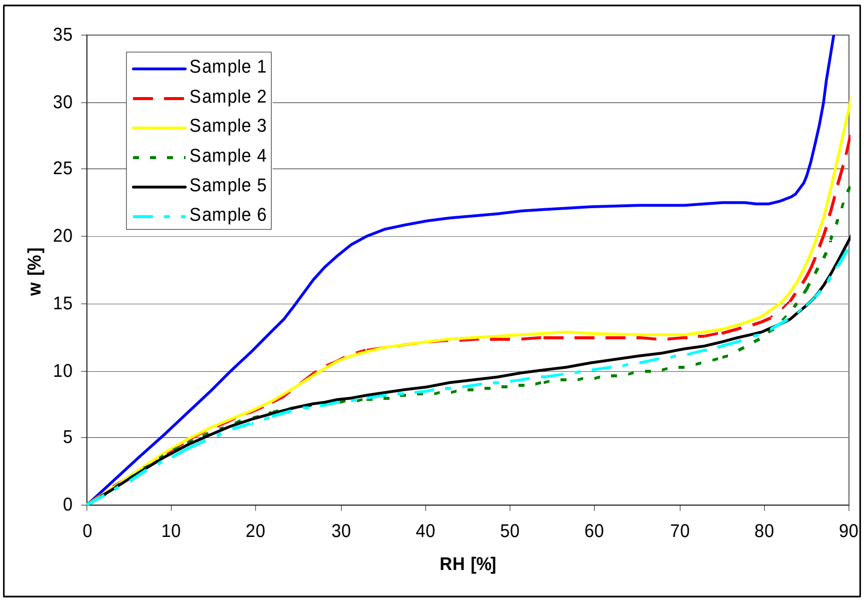
Fig. 1: Photos of testing samples - descriptions are below pictures

The results of the density determinations in dry state are presented in the graph below.



Graph 1: Survey of individual testing samples density

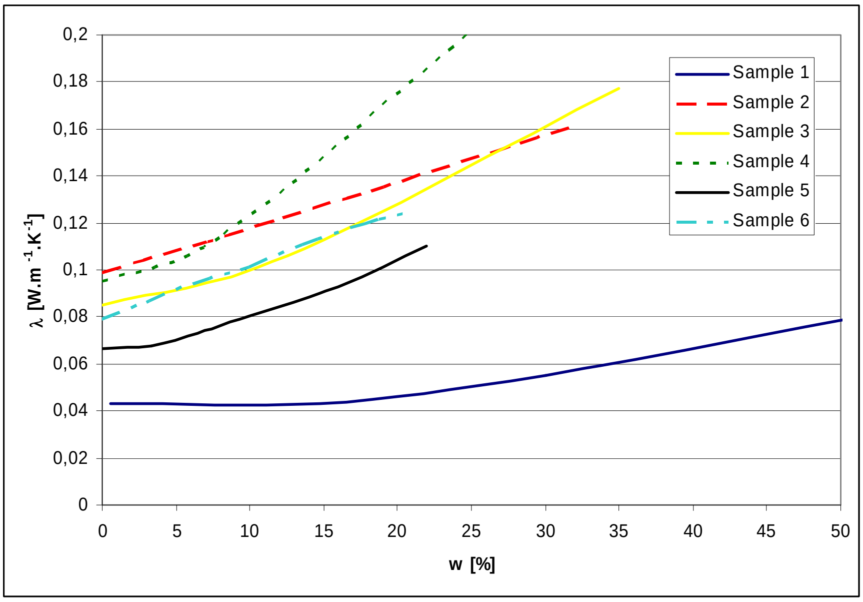
The equilibrium sorption moisture of testing samples was determined at the ambient temperature 24°C for the relative humidity RH ϵ <0: 92> %. The knowledge of sorption properties is of basic importance for the determination of the moisture content of material after build into construction. The results of measurements are presented in the following graph:



Graph 2: Equilibrium sorption moisture courses for individual testing samples at the temperature 24°C.

The results of measurements show that the natural thermal insulation materials are very sensitive on the humidity of surrounding into which they are built-in. This sensibility can be partially eliminated by the addition of inorganic binder which covers and partially closes the porous system of the organic filler. These show first of all the results of testing samples 4 – 6. The sample no.1 represents the pure, natural material, with the highest sensibility against moisture. In the case of samples no. 2 and 3 the higher sensibility against moisture was caused by high porosity of the filler and by lower addition of the inorganic binder.

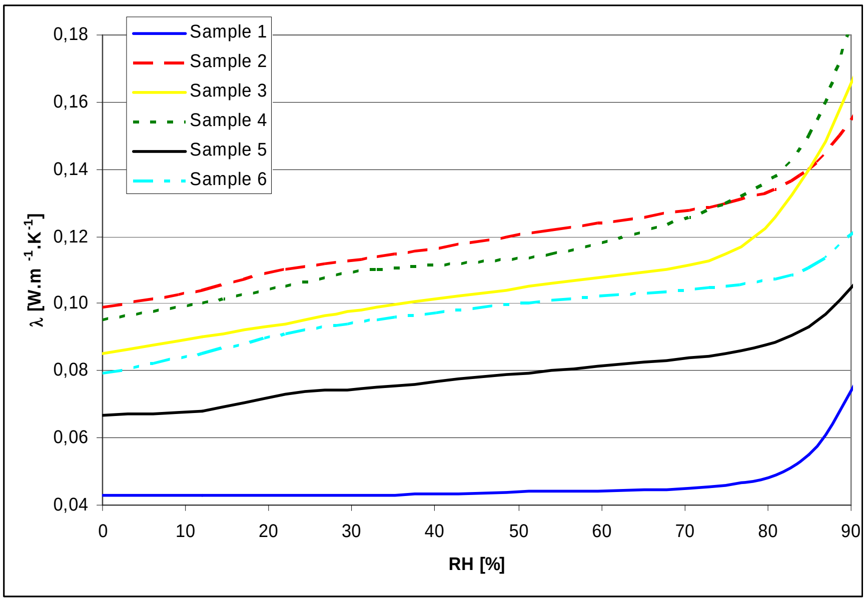
Measurements were made for the determination of the thermal conduction values of testing samples with different range of determined sorption moisture (see above). The results of the measurements are in the following graph:



Graph 3: The dependence of the thermal conductivity value on the moisture content of individual testing samples

The above mentioned courses of the thermal conductivity coefficients in dependence on the moisture show that the sample no.4 has the highest sensitivity and the sample no.1 has the lowest one. This difference is caused by the porosity of the testing sample and by the representation of the solid matrix in the total volume of the given material. The effect of the decreasing porosity (in the case of highly porous heat insulating materials) increases the value of the thermal conductivity.

The dependence of the individual testing samples thermal conductivity on the relative ambient humidity at the temperature +24°C was formulated following the determined curves of sorptive moisture and in dependence on the thermal conductivity of testing samples.



Graph 4: The dependence on the thermal conductivity on ambient humidity of testing samples at the temperature +24°C

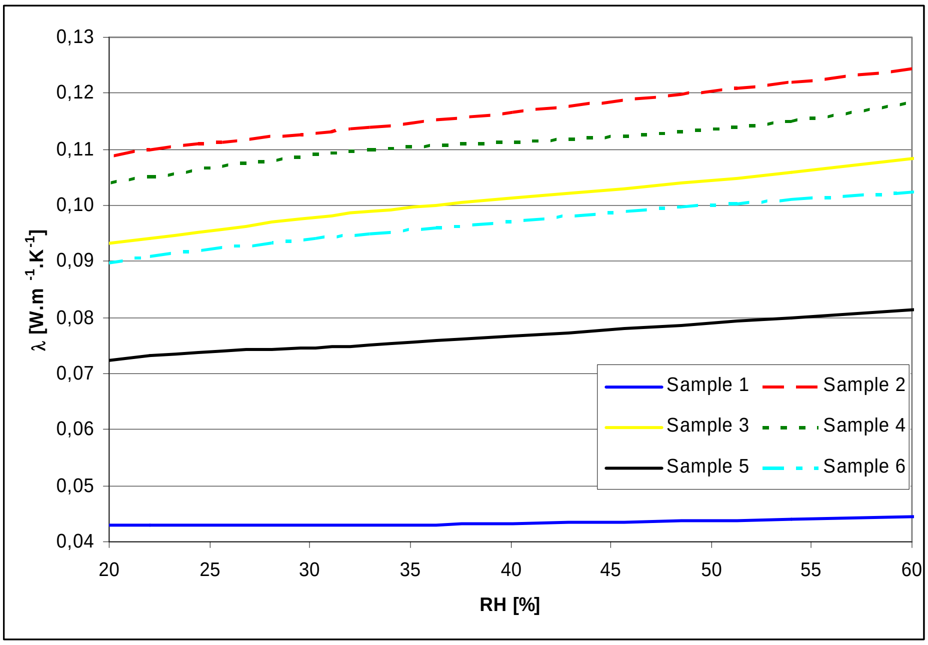
It is apparent in the graph that in the area of low and medium relative humidity the testing samples have lower sensibility. In the area of relative humidity (RH > 60%) the sensibility of testing samples increases gradually. The most sensitive were the testing samples no.3 and 4.

CONCLUSION

The heat insulating materials on natural base are relatively very sensitive on the ambient humidity in which they were applied. It was further proved that the moisture content has basic effect on the value of thermal conductivity coefficient. Nevertheless in the area of normal ambient moisture, where the materials will be applied (in the case of internal thermal insulation) i.e. in the area with the relative humidity 30 – 60%, the moisture sensibility of materials is lower – see the following graph bellow.

It is obvious following this graph that all courses have approximately linear dependence. If we carry out the linear approximation of the thermal conductivity coefficient course, in dependence on relative humidity we obtain the following functional relation:

Sample 1: $\lambda = 0{,}00005\varphi + 0{,}0419$
Sample 2: $\lambda = 0{,}00040\varphi + 0{,}1003$
Sample 3: $\lambda = 0{,}00039\varphi + 0{,}0855$
Sample 4: $\lambda = 0{,}00044\varphi + 0{,}0945$
Sample 5: $\lambda = 0{,}00025\varphi + 0{,}0663$
Sample 6: $\lambda = 0{,}00030\varphi + 0{,}0834$



Graph 5: The dependence of the thermal conductivity value on ambient humidity (from 30 to 60% RH) in itesting samples at the temperature +24°C

From the above mentioned relations follows that the dependence of the thermal conductivity coefficient on the ambient relative humidity is given by the factor of porous surrounding and by the porosity of the material. The lowest sensibility had the sample no.1 and on the contrary the highest sensibility on humidity the sample no.4.

In conclusion we can state that the heat insulating materials on natural organic base are suitable to be applied during the reconstruction of historical buildings in the case of internal insulation. If these materials don't have direct contact with fluid water and they are not exposed to relative humidity higher than 60% they don't show significant deterioration of their thermal insulating properties.

These materials can be in the case of suitably chosen ambient conditions problem-free used in reconstructions and rehabilitations of historical building structures where the maintenance of classical methods of building and the use of easily renewable sources are accentuated.

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Back to Top