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Application of TDR measurement technology for construction materials in semi-scale experiments: A practical example**

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A b s t r a c t. A practical example of the application of TDR (Time-Domain Reflectometry) measurement technology for investigation of hygric performance of systems of construction materials in a semi-scale experiment is presented. An interior thermal insulation system based on mineral wool applied on a brick wall is tested for the time period of six months.

K e y w o r d s: moisture content, TDR, thermal insulation

INTRODUCTION

In contemporary building science, the common approaches consisting in either computational analysis of the tested building structure or in the measurements of temperature and moisture fields directly on real buildings or on specially built test houses prevail in the investigation of the hygrothermal behaviour of building envelopes. Semi-scale testing of hygrothermal performance of systems of construction materials was applied only exceptionally until now, although it has a great potential into the future mainly because the expenses of such experiments can be kept considerably lower compared to a real test house. The main reason for the lower frequency of application of the semi-scale testing might be that it can still be considered as a relatively novel technique. So, its main advantage, that is simulation of conditions which are as close as possible to the real conditions on the building site while still maintaining its laboratory character, is not yet fully utilized in both research and practice.

One of the first semi-scale systems for testing the hygrothermal performance of construction materials and structures was introduced by Pavlík *et al*. (2002). In this paper, we present an example of the practical application of this system, namely an analysis of the hygric functionality of a contact interior thermal insulation system based on mineral wool.

CONTACT INTERIOR THERMAL INSULATION SYSTEM BASED ON MINERAL WOOL

Interior thermal insulation systems are usually constructed by placing a vapour barrier just under the internal plaster on the surface of the insulation layer, so that both the insulation layer and the load bearing structure are protected against water vapour. However, this is a solution which can perform well on the theoretical level only. In practice, it is very difficult to avoid mechanical damage to water vapour barrier placed in such an inappropriate way. A single nail or hook driven into the wall, for instance if hanging up a painting, can damage the proper function of the barrier. In addition, even in the case that the barrier would perform without mechanical damage, the absence of water vapour removal from the interior through the envelope in the winter period, when the air ventilation in the interior is usually limited, can lead to an undesirable increase of relative humidity in the interior and to the worsening of the internal microclimate.

Mechanical damage to water vapour barrier can be avoided by placing the barrier between the thermal insulation material and the load bearing structure. However, the amount of water condensed in the insulation layer would be, in this case, relatively high for a certain time period during the year. It is naturally possible to use such a thermal insulation material which cannot be damaged by long-term

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water exposure, but the presence of water will always have a negative effect on the thermal insulation properties of the material. In the climatic conditions of the Northern and Central Europe, the danger of liquid water generation is limited to winter months mostly. Therefore, the worsening of thermal insulation function would occur just in the winter period of year, when it is absolutely undesirable.

An alternative to the application of traditional water vapour barriers is using a vapour retarder instead, which permits a part of water vapour to diffuse further to the load bearing structure. Then, even if the retarder is placed between the thermal insulation layer and the load bearing structure, the amount of condensed water in the thermal insulation layer is lower, and the structure is not damaged because it is exposed only to such a water vapour flux that can be transported through it without condensation.

The requirements for the thermal insulation layer in the above arrangement are quite high. It should have a low thermal conductivity in dry state, and the thermal conductivity should not increase too much even if moderate presence of liquid water appears. In addition, the material should have a high capability of liquid water transport because it is supposed to redistribute the condensed water backward to the indoor room as fast as possible in order to maintain a sufficiently low moisture level and corresponding sufficiently good thermal insulation properties of the layer.

The application of capillary active or hydrophilic materials as a dehumidification method is a big innovative step in the building insulation/renovation technology and offers the possibility to develop new solutions for old, long-lasting problems, where expensive traditional renovation methods fail. The first attempt in this direction was probably made by Häupl *et al*. (1999) where calcium silicate plates were used as capillary active thermal insulation. An idea of the application of an interior thermal insulation system based on hydrophilic mineral wool was introduced by Černý *et al*. (2001).

The interior thermal insulation system analyzed in this paper was based on the idea from Černý *et al*. (2001) and was applied on a brick wall 450 mm thick (Fig. 1). The DU hydrophilic mineral wool boards (Rockwool, SA) were used as the thermal insulation. The DU boards of 100 mm thickness have dual density (hard and soft layer) because of their two functions, mechanical and thermal insulation. The hard layer has the thickness of 30 mm, the soft layer with the main thermal insulation function is 70 mm thick. The boards were fixed on the brick wall using water vapour retarder KAM on cement base (Sakret, Ltd.) having good adhesive properties. The thickness of the retarder layer was 10-15 mm. Exterior interior render was not used on the tested building structure because of its supposed low effect on the hygrothermal performance of the system.

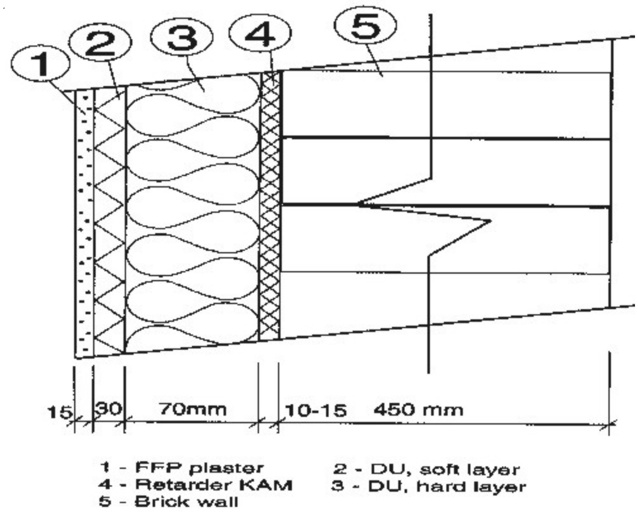

Fig. 1. Schematic of the analyzed interior thermal insulation system applied on a brick wall.

APPLICATION OF THE MEASUREMENT TECHNOLOGY AND SAMPLE ARRANGEMENT

The measuring technology was applied in accordance with the basic principles given by Pavlík and Černý (2004). First, the TDR sensors for the determination of water content were individually calibrated to obtain their particular reference travel times, t_{ref}, and characteristic probe lengths, *lp*, using the technique suggested by Plagge *et al*. (1999). In this calibration, the travel times for water, *tw*, and benzene, *tb*, experimentally determined for each sensor were used. In the practical measurements, the volumetric moisture content was determined using the formula from Malicki *et al*. (1992). Then, the sample of the tested building envelope was constructed and the probes were installed into the sample in the way described by Pavlík and Černý (2004).

Finally, the sample was positioned in the tunnel between the climatic chambers which was then connected by sleeve connectors with the chambers. The sample, placed in the connecting tunnel, was thermally insulated from the tunnel wall using extruded polystyrene boards in combination with mineral wool and provided with a water- and water vapour-proof coating. The details of the sample preparation are shown in Figs 2-4.

MONITORING THE HYGRIC PERFORMANCE OF THE INSULATION SYSTEM: RESULTS AND DISCUSSION

The external and internal conditions simulated in the particular climatic chambers were chosen as close to the reality as possible. We employed hourly reference-year based data for temperatures and relative humidity for Prague in the chamber simulating external climate and constant

Fig. 2. Placing of TDR sensors into the tested structure.

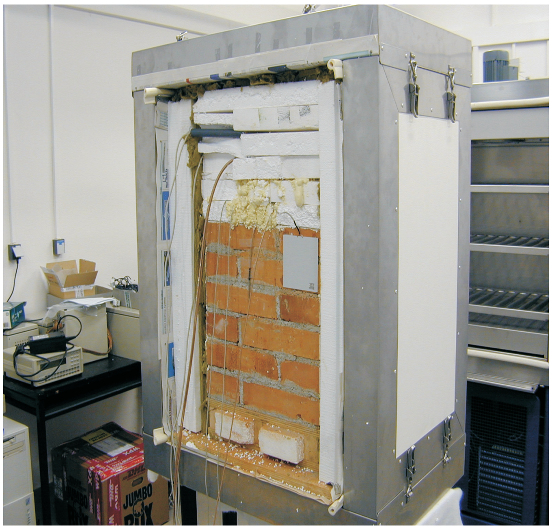

Fig. 3. Specimen insulation in the connecting tunnel (exterior surface).

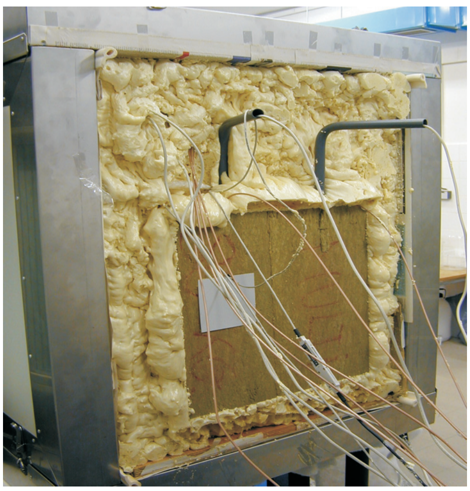

Fig. 4. Completely prepared specimen (interior surface).

corresponding to living houses in the chamber simulating the internal conditions. Reference-year data were constructed according to generally recognized international methodology. The measurement was first performed on non-insulated wall to achieve more representative initial conditions, and after 10 days the designed insulation system was installed. The climatic loading of the building envelope began with the climatic data for October 1. The measurement took 165 days and was finished with the climatic data for the April 4. So, the whole winter period was simulated in the chambers.

The examples of measured moisture profiles are shown in Fig. 5. They reveal a reasonably good performance of the interior thermal insulation system. Some over-hygroscopic moisture can be observed in the brick wall during the whole time of the experiment, and a part of it remained there until the end of the winter period. However, it should be noted that the conditions of the experiment were more severe than in reality.

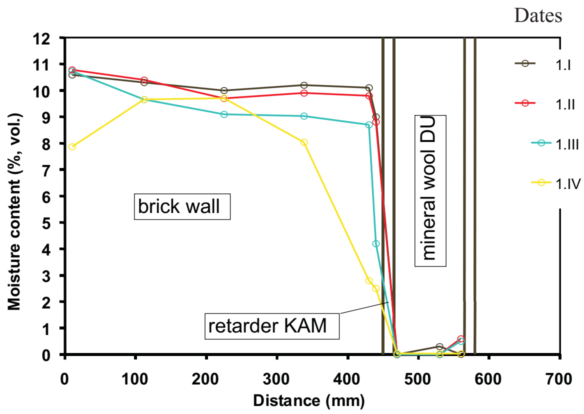

Fig. 5. Moisture profiles in the analyzed structure.

In the beginning of the experiment, the brick wall was freshly built in the laboratory *ie* it contained a relatively high amount of moisture and was at a relatively high temperature. The climatic conditions of the end of September and beginning of October then (due to fast temperature decrease) led to water condensation in a part of the wall. This water could not be fully removed from the wall during the winter period because of the limited possibility of water transport to the exterior and of the continuous transport of water vapour from the interior to the load bearing structure increasing the total amount of water in the brick. On the other hand, the hydrophilic mineral wool material DU remained dry during the whole critical part of the year, which is clearly a consequence of the high values of its moisture transport parameters. Therefore, taking into account all the negative and positive factors, the hygric performance of the wall can be considered as relatively good in general.

CONCLUSIONS

1. The semi-scale experimental analysis of hygrothermal performance of the building envelope with the interior thermal insulation system in variable climatic conditions presented in the paper has shown the applicability of semi-scale experiments in the process of testing new building structures and new technological solutions.

2. In a combination with computational analysis, it could also be conveniently utilized for calibration and validity tests of current or newly developed computational models solving the problem of combined moisture and heat transport.

REFERENCES

Černý R., Maděra J., and Jiřičková M., 2001. Computational design of interior thermal insulation systems. Proc. 2nd Int. Conf. Advanced Engineering Design, (Ed. L. Smrcek), Univ. Glasgow, 425-430.

Häupl P., Grunewald J., and Fechner H., 1999. Moisture behaviour of a 'Gründerzeit' - house by means of a capillary active calcium silicate inside insulation. Proc. 5th Symp. Building Physics in the Nordic Countries, Göteborg, Vasastaden, AB, 225-232.

Malicki M.A., Plagge R., Renger M., and Walczak R.T., 1992. Application of time-domain reflectometry (TDR) soil moisture miniprobe for the determination of unsaturated soil water characteristics from undisturbed soil cores. Irrigation Sci., 13, 65-72.

Pavlík Z. and Černý R., 2004. Application of TDR measurement technology for construction materials in semi-scale experiments. Int. Agrophysics, 18, 249-252.

Pavlík Z., Pavlík J., Jiřičková M., and Černý R., 2002. System for testing the hygrothermal performance of multi-layered building envelopes. J. Thermal Envelope Build. Sci., 25, 239-249.

Plagge R., Grunewald J., and Häupl P., 1999. Application of time domain reflectometry to determine water content and electrical conductivity of capillary porous media. Proc. 5th Symp. Building Physics in the Nordic Countries, Goteborg: Vasastaden, AB, 337-344.