IN-SITU MONITORING OF TEMPERATURE AND RELATIVE HUMIDITY FIELDS IN A HISTORICAL BUILDING PROVIDED WITH ADDITIONAL THERMAL INSULATION

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Abstract:
Long-term on-site assessment of hygrothermal performance of an interior thermal insulation system on hydrophilic mineral wool basis without water vapour barrier applied on a brick wall is presented in the paper. Experimental results show that the system functioning is flawless during the whole studied time period of four years after reconstruction of the building.

Keywords:
Interior thermal insulation system, hygrothermal performance, long-term on-site assessment

INTRODUCTION

Building envelopes provided with the additional interior thermal insulation systems on the basis of hydrophilic mineral wool without water vapour barrier were subjected to extensive computational analyses during the last few years [1-3]. Several semi-scale tests of their hygrothermal performance in the conditions very close to reality were performed as well [4-6]. The computational and experimental results revealed very good hygrothermal performance of hydrophilic mineral wool in the interior thermal insulation systems applied for several different load bearing structures. However, a convincing proof of the proper hygrothermal function of these systems in on-site conditions was not given yet.

In this paper, long-term on-site assessment of hygrothermal performance of an interior thermal insulation system on hydrophilic mineral wool basis without water vapour barrier applied on a brick wall is presented.

DESCRIPTION OF THE LONG-TERM ON-SITE TEST OF HYGROTHERMAL PERFORMANCE

A kindergarten building in Prague was chosen for the pilot-scale application of the developed interior thermal insulation system. The main reason for this choice was its broken façade, which had to be maintained in its original appearance.

The building was built at the end of the 19th century and corresponds to the urban planning typical for that time. It is a two-storied brick building including a partial cellar. The building has wagon-headed trusses and in the basement there are brick-built wagon-vaults. The truss is wooden with intermediate and apex purlines. The roofing is from Bonn’s shingle loaded on the clapboards. The main stairways are two-armed with the stairs on the stair carriages. The walls have stuccos. There are wooden double windows on the eastern, southern and western part of the facade. Wooden windows with double glass in a simple construction are in the yard part. The doors are mainly of a modern design. They have steel pressed doorframes. Most of the floors have vinyl flooring. There is ceramic pavement in some parts of the floors.

The main purpose of the reconstruction work was the increase of the thermal resistance of the building envelope. This increase was achieved mainly by the installation of the hydrophilic mineral wool assemble on the inside surface of a part of the external walls. In order to increase the overall efficiency of the thermal insulation, the ceiling below the roof was thermally insulated using exterior mineral wool insulation.

The preliminary work consisted in careful scaling of all painting coats. Damaged plasters were repaired with lime-cement plaster with stucco surface finish. All damaged places in the plaster due to the inner arrangement and decoration were also repaired. A base coat for the application of the interior thermal insulation system was obtained in this way. The surface where old paint was removed was covered with a universal underlying paint. The inside wooden wall facings were displaced.

The interior thermal insulation was placed on the external walls of all rooms, where the children stay most of the time (playrooms, cabinets, bedrooms) and in the neighboring staff cloak-rooms. The insulation used for this reconstruction was designed in the thickness of 80 mm, due to the space limitations. The value of the thermal resistance of this insulation was determined in laboratory experiments as R = 1.43 m^2K/W (for 95 % relative humidity). By this account, the total thermal resistance of the construction was higher than the thermal resistance required by the Czech standards with the preservation of the current thickness of the brick-built external walls at 600 mm. The thermal resistance of the construction with additional thermal insulation in the parapet location and with the thickness of the walls of 450 mm achieved the standard requirements.

The DU hydrophilic mineral wool thermal insulation boards consisted of two layers of different density, which were compactly connected. The hard layer had a thickness of 30 mm, and the thickness of the soft layer was 50 mm. The dimensions of the boards were 600 x 1000 mm.

The KAM leveling render was used for gluing of the boards to the wall surface, and played the role of water vapor retarder as well. This render was applied both on the entire surface of the wall and on the entire surface of the boards. The elements sticking out from the basis were padded by the leveling render all around their perimeters.

The mineral wool boards were assembled from the bottom upwards. The vertical board connections were alternating over one half of the board width in order to bond them, and the boards were pinned hard upon the wall. Disk plugs were used for attaching the board. One piece was always used on one board in its center. The holes for these disk plugs broke compactness of the leveling render layer under the thermal insulation. Therefore, the binding assembling foam was put into these holes using an applicator before the disk plugs were inserted and activated. The damaged leveling render layer near the plug shank was sealed in this way.

The internal plaster FFP was applied in the following way. First an FFP layer 3 mm thick was put on the boards, then netting was applied, another layer of FFP covering 1.5 mm thick after that, and finally an FFP layer 1.5 mm thick. The final layer was painted with 2 coats of a common paint. The walls without adaptations were painted with just one coat of the same paint.

The socket outlets on the insulated walls were fixed into the hard layer of the thermal insulation boards. They were anchored with the gypsum mixture. It was necessary to remove the window lining plaster before the application of the thermal insulating system. A curtailed hard layer of hydrophilic mineral wool boards 30 mm thick was used for the thermal insulation of the window heads and window reveals. The adaptation of the window casements and casings, including addition of the external window casements sealing, were carried out to improve the value of the thermal resistance of the envelope. The enlargement of the current wooden window stools over the added hydrophilic thermal insulation was performed at the same time. The constructions of the windows were then painted with two coats of paint. The facing of the wooden walls was fixed on the supporting structure made from lathes. These lathes created the space for ventilation between the thermal insulating surface and the facing of the wooden walls. Gummy foam was used for mounting the frame of the wooden wall facing on the insulating layer. The technology of work and constructive details are demonstrated in Figures 1a, b.

Figures 1a, b Selected constructive details

Common hydrophobic mineral wool boards were laid on the cleansed loft floor. Two layers each 80 mm thick were applied, so that the total thickness of the thermal insulation layer was 160 mm. The building reconstruction was completed between June and August 2002. Since the described reconstruction was considered as a pilot-scale test of the designed insulation system, it was necessary to study the hygrothermal function of the building before and after reconstruction.

The measurements of hygrothermal behavior of the studied structure before building reconstruction were carried out between November 2001 and May 2002. Thermal and hygric parameters were measured in three profiles, on the southern and eastern flank of the ground floor and on the western flank of the second floor. Air temperature at the exterior and at the interior, temperature of the external and the internal surfaces, relative humidity in the exterior and interior and temperature of the radiator surface were measured in every profile.

Combined capacitance probes were used for temperature and relative humidity measurements. In addition, type K thermocouples (NiCr-NiAl) were used for some temperature measurements. The data were recorded in 30-minute intervals and collected in a central unit. The measurements of temperature and relative humidity after reconstruction were carried out since October 2002 until June 2006.

EXPERIMENTAL RESULTS AND DISCUSSION

Figs. 2, 3 show time development of temperatures and relative humidities in the east wall during the last winter before the reconstruction, Figs. 4, 5 during the second winter after reconstruction.

A comparison of temperatures in Figs. 2, 4 shows the positive thermal qualities of the applied interior thermal insulation system. The most substantial temperature changes occurred in the thermal insulation layer.

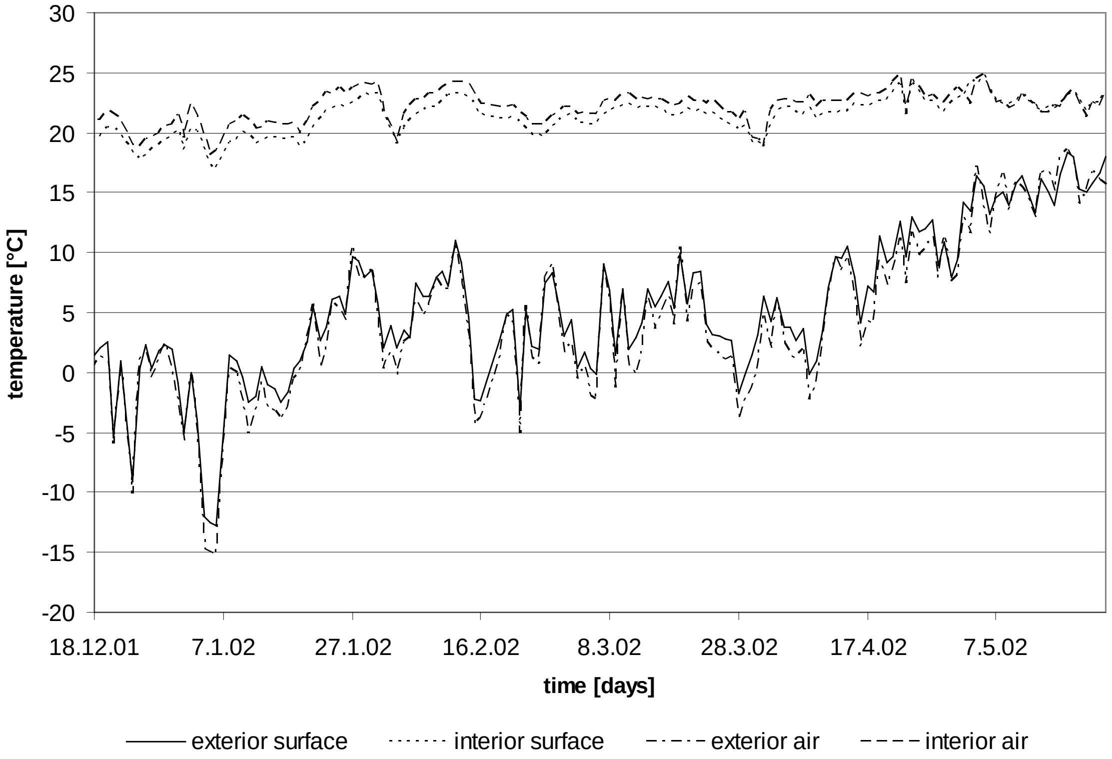

Figure 2 Time development of temperatures in the east wall during the last winter before the reconstruction

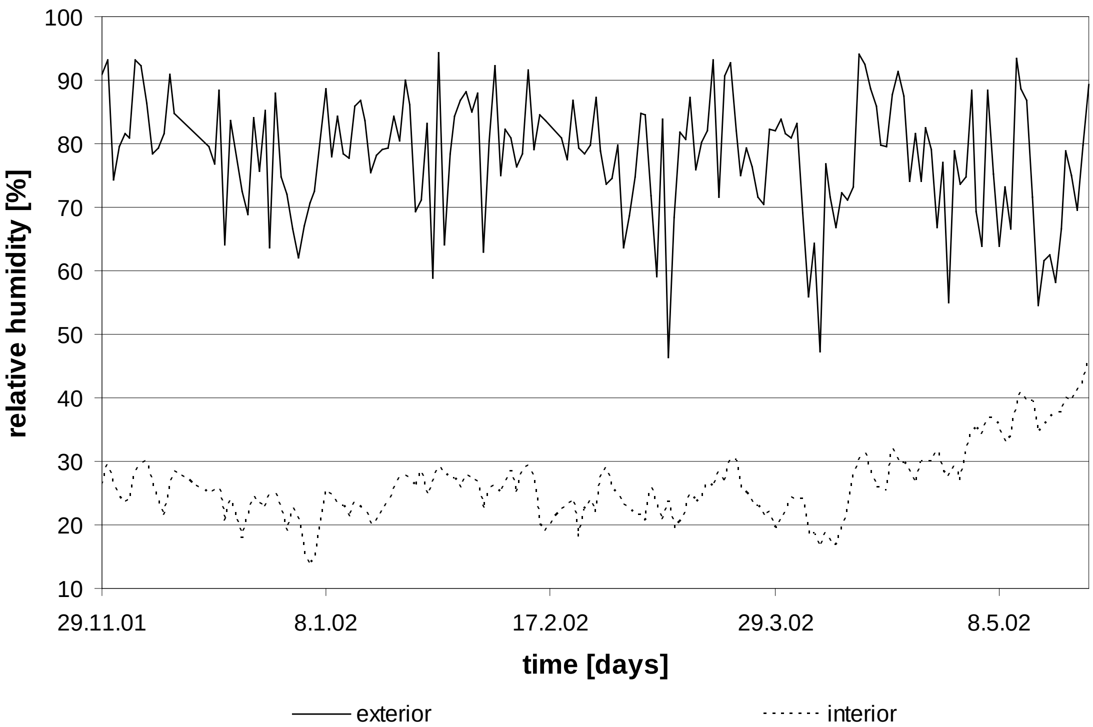

Figure 3 Time development of relative humidity in the east wall during the last winter before the reconstruction

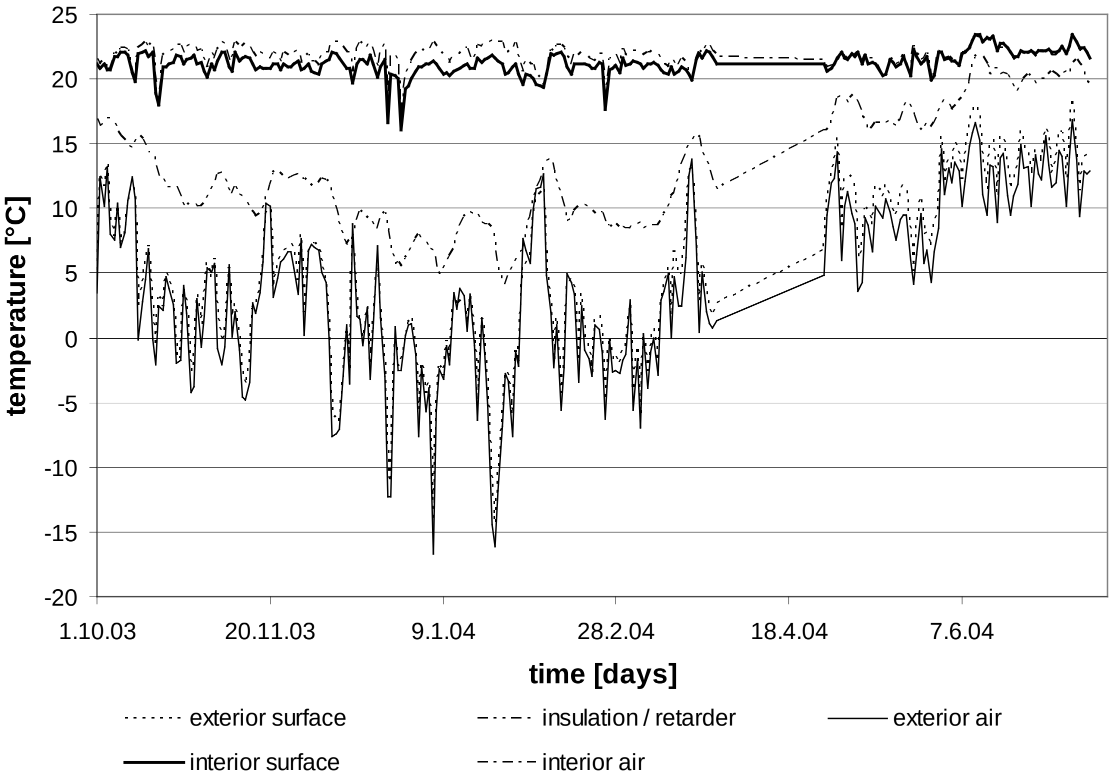

Figure 4 Time development of temperatures in the east wall during the second winter after reconstruction

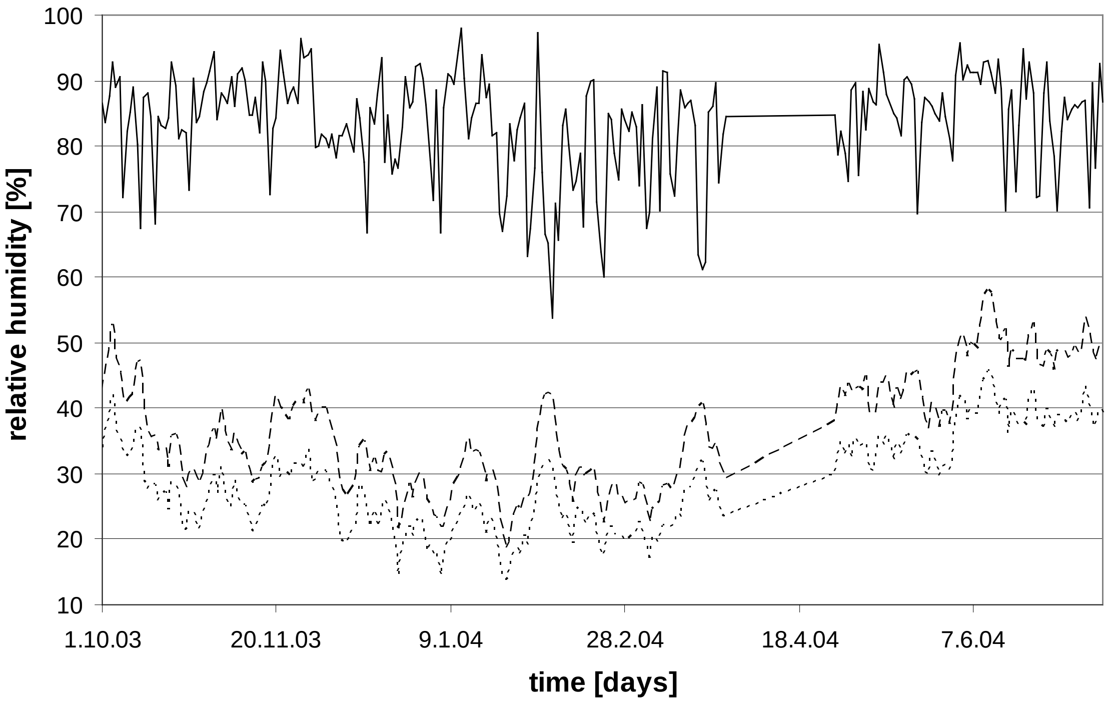

Figure 5 Time development of relative humidities in the east wall during the second winter after reconstruction

The hygric performance of the system was also found to be excellent. Fig. 5 shows that the maximum values of relative humidity on the surface of water vapor retarder, which is the critical point of the designed system, were in the winter period approximately 42%. This is very far from any condensation danger. The higher values of relative humidity in the beginning of the summer period (57%) were caused by a period of rain but the condensation was far from occurring either.

CONCLUSIONS

The on-site experimental analysis presented in this paper gave evidence that the hygrothermal performance of the studied interior thermal insulation system was flawless during the whole time period of four years after building reconstruction. The thermal performance was on the expectedly high level. Water condensation never appeared inside the envelope during the whole four years of testing.

The designed system can find application in practice particularly in the field of reconstruction of historical buildings and contemporary buildings with complicated facades where the application of exterior thermal insulation systems is impracticable. It can also conveniently replace the currently used interior thermal insulation systems with vapor tight layer that are susceptible to easy mechanical damage.

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