Hygrothermal characterization of a plaster with recycled materials used as interior insulation

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Abstract

Interior insulation plays a key role in reducing the energy consumption of historic buildings. However, it might cause moisture accumulation and must be thoroughly analyzed. The use of recycled materials allows for further reduction of environmental impact. This paper presents the study of a new insulating plaster containing aerogel and recycled glass used as capillary active interior insulation system. Firstly, the hygrothermal properties of the material are measured in laboratory to obtain a complete characterization. Laboratory tests results are post-processed to obtain the data required as input by the simulation software. Finally, hygrothermal simulations are carried out to investigate the material's behavior in realistic application scenarios and to study how different input parameters affect the results.

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Keywords: internal insulation, recycled materials, hygrothermal simulations, parametric study

1. Introduction/Background

Historic buildings represent an important part of the existing building stock (in Europe 30% of the existing buildings are considered historic [1]) and insulating them to reduce energy consumption is crucial. The use of interior insulation systems is widespread as they allow the aesthetic appearance of the façade to be preserved. However, they must be analysed and planned in detail as they lead to a change in the hygrothermal behaviour of the wall. The use of recycled materials in the production of interior insulation is not yet widespread, however it is essential to reduce the ecological footprint of the intervention [2].

The objectives of the study are twofold: (i) an in-depth analysis of the hygrothermal performance of a new aerogel insulation plaster based on recycled glass when used as interior insulation system; and (ii) a parametric study of the influence on performance of certain input parameters, such as outdoor and indoor climate, insulation thickness and masonry typology.

2. Methodology

In order to obtain a complete hygrothermal characterization of the plaster, several parameters are measured, namely: thermal conductivity and specific heat capacity, moisture storage function at nine different humidities in the hygroscopic range, free saturation water content, vapor diffusion (dry and wet cup conditions), water uptake and drying experiments [3], and apparent and real density. To convert laboratory measurements into the parameters and functions necessary to model the material in a dynamic hygrothermal simulation software, interpolation ([4]) and calibration methods ([5] and [6]) are used.

Hygrothermal simulations are carried out with the WUFI Pro software, which allows for a complete and comprehensive description of the combined transport of heat and moisture in a dynamic regime. First, we set up a reference simulation model considering a 45 cm thick existing granite masonry North oriented, with 12 cm insulation applied internally. The external climate of Bolzano (northern Italy) is used, and the internal climate is calculated with the method defined by [6] for a normal moisture load with a safety factor (moisture class 1 +5%). Then, model input parameters are varied parametrically to evaluate the influence of each of them on the results of simulations. Another internal climate (Moisture class 2) is simulated to investigate how the user behaviour (window opening – moisture production) can influence the performance of this internal insulation material. Different external climates (Brunico – cold climate, Bari – hot climate and Munich – cold and rainy climate) and different orientations (North and worse orientation for driving rain) are also simulated. For the location with the highest driving rain load also the role of the driving rain protection layer is analyzed considering a simulation variant with a hydrophobic treatment applied on the external side. Moreover, the basis simulation is compared with two other different existing masonry: solid brick and tuff. Lastly, the role of thickness of insulating material (4 cm, 8 cm, 20 cm) is investigated.

3. Results and Discussion

The results of the laboratory measurements are shown in Table 1. Thermal conductibility and liquid transport coefficients (derived from the drying curve and water uptake experiment) are in line with other capillary active materials.

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Table 1. Measured parameters and curves.

Density	Thermal conductivity	Specific heat capacity	Vapour diffusion resistance factor		Free saturation	Water uptake coefficient
288 [Kg/m³]	0.043 [W/(mK)]	0.17 [MJ/(m³K)]	μ dry: 4.2 [-]	μ wet: 4.1 [-]	1661.0 [g/kg]	0.230 [kg/m²s$^{0.5}$]

Hygrothermal simulations are evaluated based on the results of relative humidity behind the insulation to investigate the moisture accumulation in this critical layer mainly due to vapor diffusion. Total water content of the whole stratigraphy was considered to ensure that all scenarios had reached a moisture equilibrium at the end of the simulation period.

Figure 1 shows the relative humidity levels reached behind the insulation layer for the simulated cases. Relative humidity values do not show a big difference between the two types of internal climate (1.5% between the maximum peaks), while the difference between hot and cold climate is relevant (8% between the maximum peaks of Bari and Brunico). Regarding the orientation, Munich North shows worse results than Munich West (that has three times more driving rain). Thus, in this case, sun radiation has much bigger influence than driving rain. The change of typology of existing masonry shows, as expected, that the more thermically resistant the existing material and the lower the water vapour diffusion resistance factor is, the lower is the relative humidity behind insulation. This parameter can reach a significant difference (10.5% between the maximum peaks of tuff and granite). The thickness of insulation, often perceived as a key parameter, plays in this case a minor role (2.5% between the maximum peaks). However, it is important to bear in mind that the results presented here do not consider the combined impact of several parameters.

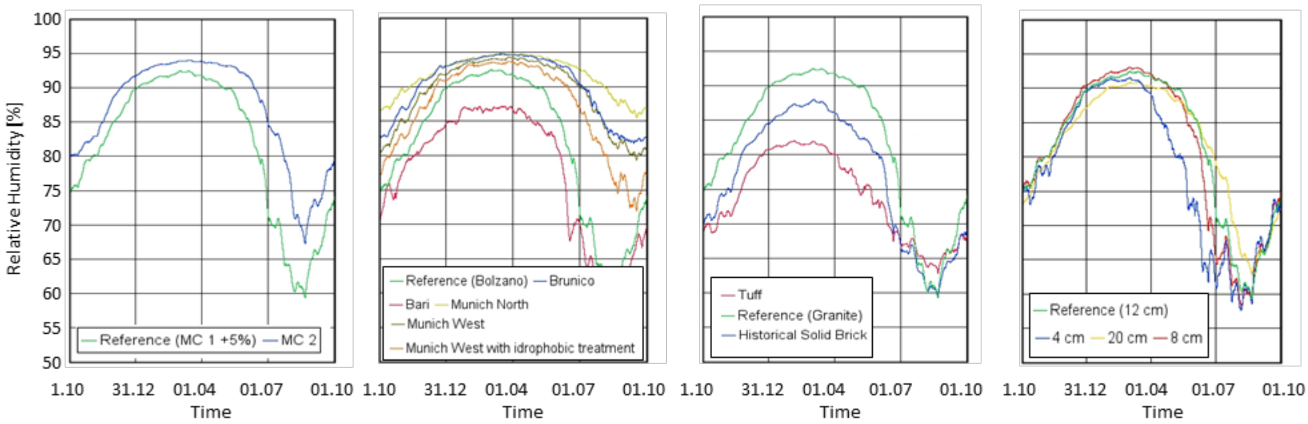

Figure 1. Relative humidity behind the insulation for the simulations of different internal and external climate, different thicknesses of insulation and different existing masonry in the last year of simulation

4. Conclusion

The methodology used in this paper is especially suitable to study the behavior of internal insulation materials as it allows the evaluate the material's performance under varying design conditions. The studied material shows promising results for its use as a capillary active internal insulation system. Thermal conductivity values are in line with those of other capillary active insulation materials and relative humidity in all simulated scenarios remains always under 95%, below which the occurrence of moisture related damages can be excluded for the materials composing the construction under analysis.

The preliminary results of this parametric study show that internal climate and thickness of insulation play a minor role, while orientation, climate and typology of existing masonry can have a strong influence on the system's performance. A wider parametric study that investigates different types of internal insulation and combined parameter variation would enhance the transferability of the results.

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