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Long-term experimental performance evaluation of aerogel insulation plaster

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Abstract

Aerogel based insulation plaster has the potential to facilitate the thermal retrofit of historic buildings as its deployment can accommodate the requirements of historical preservation. Thereby, the thermal resistance of historical facades can be increased while maintaining their appearance. The present contribution includes the results of a long-term empirical examination of aerogel containing plaster systems especially for historic buildings under real conditions. In the course of this study, multiple test fields with aerogel insulation plaster were applied to the external walls of an existing room in a university building. Thereby different finishing coatings as well as variations with and without reinforcement mesh were considered. Over a period of three years, external and internal environmental parameters as well as hygro-thermal conditions (temperature, moisture concentration, heat flux) at multiple layers within the test fields were monitored. Moreover, the external appearance of the test fields was regularly captured via observation and photographic documentation. The measured data provided the basis to compare the actual thermal transmittance of the test fields with calculation results based on declared material properties. In addition, the results facilitate the comparison of the different solutions. Specifically, the results suggest a promising thermal performance level (in view of considerably lower U-values) as compared to conventional plaster products. Furthermore, the findings document the role of the finishing layer's composition in view of the occurrence of potential cracks in the façade.

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Keywords: Aerogel plaster, long-term monitoring, performance evaluation

1. Introduction

The thermal retrofit of historic buildings involves a number of challenges. Given mandated preservation considerations, conventional compound insulation solutions are typically not applicable. Recent developments of new high performance insulation plaster based on aerogels can provide alternative opportunities. Specifically, new

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products can help reduce the thickness of the insulation compared, for example, to expanded polystyrene insulation products. The development of special aerogel based plaster systems together with optimal application methods for structured facades can contribute to the future success of respective solutions. Toward this end, amongst other things, the finishing coating of structured facades has to be analysed and evaluated under real conditions. The project Agelfa specifically targeted this issue and considered various alternative solutions. One of the project tasks focussed on an application of the aerogel insulation plaster with different final structured layers together with a long-term monitoring of in situ insulation values, the hygro-thermal behaviour, and the appearance of cracks in the final coating.

2. Aerogels and high performance insulation plaster

Aerogels are solids with an extreme high porosity (up to 99 per cent of the volume), resulting in a correspondingly high thermal resistance. The development of aerogel has a long history and can be traced back to the first published concept to replace water with alcohol or xylene in silica gel by Graham in 1864 [1]. Samuel S. Kistler developed the first syntheses process for the generation of silica aerogel as published in two scientific articles in 1931 [2] and 1932 [3]. This work documented that the structure of the gel is independent of the contained liquid, which could be replaced with a gas later. The main challenge of such a process is the removal of the contained liquid without causing changes in the structure of the material. This could be achieved via supercritical drying that is carried out with high pressure and high temperature. In those conditions the liquid is in a critical stage and, given the minimal difference between liquid or gaseous states, surface tensions do not result in the change of material structure. Kistler used an autoclave for that the drying of gel and documented the resulting material densities with a minimum of 0.02 $g.cm^{-3}$. The involved long duration and high temperatures could be reduced following developments in syntheses of aerogel. Teichner developed in 1968 [4] a process that was simpler but it used the toxic tetramethylorthosilicat. This was later ameliorated by a research team from Lyon in 1986 [5]. A later development of the university Berkeley was able to replace the toxic substance with tetraethylorthosilicat and replaced ethanol with carbon dioxide [6]. This reduced the temperature of the drying from 270 to 40 °C. Parallel to the temperature reduction the drying time was reduced from several days to 10 hours.
Aerogel syntheses processes are still the target of different scientific studies to improve the processes and reduce resource needs. A good overview of the existing processes was provided by Dorcheh and Abbasi [7] in 2008. Recent improvements in aerogel production have reduced the costs, making it possible to integrate the material in construction products such as insulation panels, transparent building components, and insulation plasters. Aerogel plaster based insolation solutions [8] are already available, but deployment in the context of historical buildings requires additional studies.

3. Material test under real weather conditions

A test setup with different applications of aerogel plaster systems for structured facades was implemented within a nationally funded research project called Agelfa. Totally, ten test fields with different compositions of the outer layers were applied on a test facility on the roof of the main building of TU Wien. The main focus of this work was to document the thermal performance of plaster systems for structured facades under real conditions. Test fields on facades faced north, south, and west (see Figure 1-a,b,c). A special case was the south facing façade. Here, temperature and humidity at different position within the wall construction were monitored along with external weather conditions. Figure 1-d shows a cross section of the wall with the different layers and the position of the sensors in the construction. Table 1 gives an overview of the variations of the applied final rendering and coating. A reinforcement mesh was applied only in cases S1 and W1. It should be noted that systems without reinforcement are more likely to be accepted for application in historical buildings.