Aachener Institut für Bauschadensforschung und angewandte Bauphysik
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Forschungsinstitut für Wärmeschutz e.V. München
Bauaufsichtlich anerkannte Prüf-, Überwachungs- und Zertifizierungsstelle von Baustoffen und Bauteilen. Forschung und Entwicklung auf dem Gebiet des Wärme- und Feuchteschutzes
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Long-term performance of humid insulation materials within the structure of flat roof - Practical field experience and laboratory assessments

Summary Account

2018, May

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Conducted by: AIBAU – Aachener Institut für Bauschadensforschung und angewandte Bauphysik, gGmbH, Aachen
and
FIW – Forschungsinstitut für Wärmeschutz e. V., München

Project Manager: Prof. Dipl.-Ing. Matthias Zöller, Dipl.-Ing. Christoph Sprengard

Authors:
Dipl.-Ing. Ralf Spilker
Dr.-Ing. Sebastian Treml
Dipl.-Ing. Géraldine Liebert
Rechtsanwalt Thomas Ziegler
Prof. Dipl.-Ing. Matthias Zöller
Dipl.-Ing. Martin Oswald M.Eng.
Ramona Holland B.Eng.
Chiara Cucchi M.Sc.

1 Introduction

The modernization of buildings in the stock frequently involves the question if, and to what extent, the structure of flat roof surfaces can be retained, or if existing layers should be dismantled and replaced by new ones. One of the relevant criteria to decide this question is the condition of the insulation materials. If they contain moisture they will frequently be removed and disposed of.

On the other hand, most insulation materials currently used in building are resistant to humidity even over long periods. This has been shown in various studies, some of which were also carried out by the Aachen Institute for Research into Building damage and Applied building physics („AIBau“).

Many insulation materials do not show any significant reduction in compressive strength (or compressive stress in tests with a specified degree of compression). Thermal protection is generally reduced by humidity, but often it remains equivalent to a thinner newly-installed dry insulation layer.

The research study presents examples of practical field experience when insulating materials are left in place. It documents the results of laboratory assessments, in which the thermal conductivity of humid materials was tested both under steady and non-steady conditions.

2 The Survey

By evaluating about 100 cases specified in a survey among ca. 1,400 officially appointed building and roofing experts, the research study has compiled typical examples from field work. Over the past ten years, about one third of the experts taking part in the survey had to deal with a total number of 182 cases of wet insulants in roof structures. When those insulants were left in place and covered by new insulation layers, the structure generally remained damage-free.

Further humidity penetration occurred only in 8% of those cases, due to other leakages, which had not been discovered before, or to faulty application of the new insulation, with or without additional layers. None of the damage was caused by the original humid insulants.

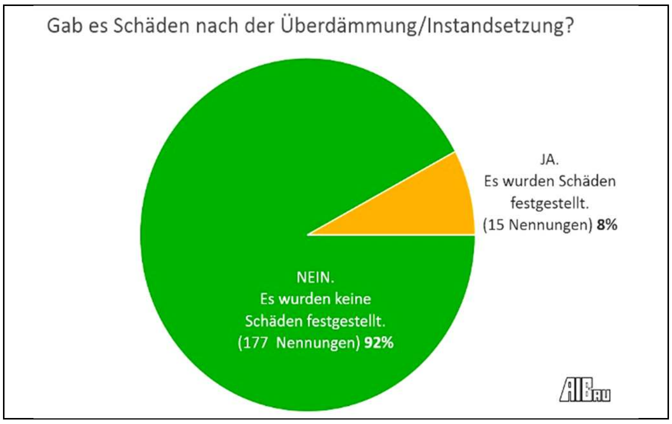

Fig. 1:
Further damage occurred on 8% of the roofs, where the new insulation was placed on top of the old layers.

3 Analysis of individual cases of damage

In the research study, field reports about humid insulation materials are documented and explained. Samples of insulating materials were taken from 6 roofs. Their moisture content, and, to some extent, also their thermal conductivity, were measured in laboratory tests.

Apart from the greatly increased moisture content and the corresponding rise in thermal conductivity, insulating materials made of foam plastics and foam glass proved to be resistant to pressure and functioning properly, even though some of them had remained within the roof for several decades.

Humid sealing layers of mineral wool having a comparable longevity could not be included in the analysis.

Fig. 2:
Roof structure with an old EPS-sealing layer, about 12 cm thick, below, and a new EPS sloping layer above, measuring ca. 26 cm at the opening point.

Fig. 3:
Opening in the surface, showing wet PUR-sealing materials under the original old bituminous roof sheeting

Fig. 4:
A ca. 5 cm thick damp proof course made of foam glass; water seeping in after the insulant was removed

Fig. 5:
Wet mineral wool insulant with water collecting on the damp-proof course

4 Laboratory measurements

The Forschungsinstitut für Wärmeschutz e. V. München conducted measurement of thermal conductivity on thermal insulation materials EPS, XPS, PUR and MW with increased moisture content. For the measurements a heat flux meter apparatus was used. The moisture content was chosen according to experiences covered by real cases of damaged building elements and the specimens were conditioned accordingly. The measurements were conducted both with a constant temperature on the warm and cold side, as well as with transient temperature conditions on the cold side. The temperature profile on the cold side for the transient measurement conditions were chosen according to a typical temperature profile measured on the outer surface of a flat roof in winter. Within 24 h the temperature increases from initial -11°C up to 21°C and drops to -11°C again. By using an instationary temperature profile on the cold side during a night and day temperature shift, a realistic distribution of the moisture content over the thickness of the specimen was induced.

The heat flux through the specimen depends on the temperature profile mainly, but is also influenced by diffusion processes and adsorption and desorption processes of the moisture inside the specimen. In the stationary case with constant temperatures on the warm and cold side the heat flux shall remain constant latest when the redistribution of the moisture content over the thickness of the specimen is finished. While the data evaluation was unproblematic for the rigid foams, the derived measurement values for the mineral wool remained volatile even after a long measurement period. This behaviour indicates for ongoing cyclic changes of the distribution of moisture inside the material.

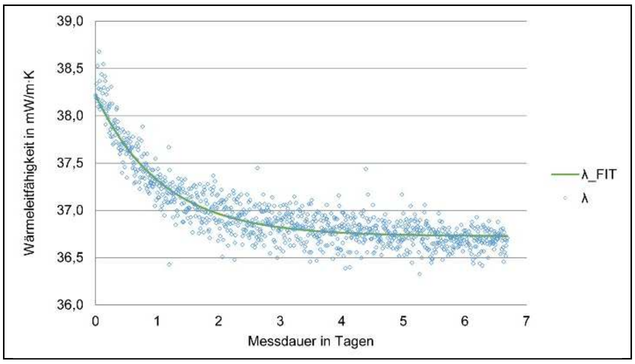

Fig. 6:
Measurement values of thermal conductivity as a function of time and regression curve of material EPS 1 with a moisture content of 1.94 Vol-%

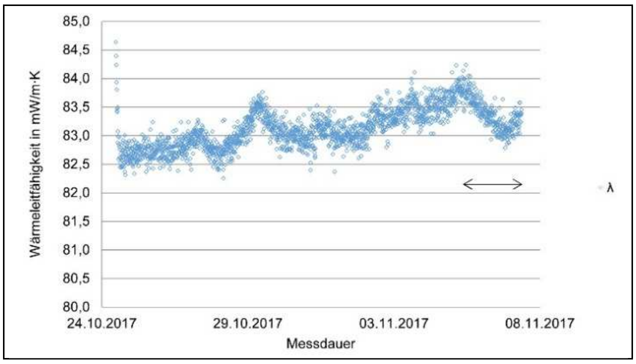

Fig. 7:
Measurement values of thermal conductivity as a function of time and regression curve of material MW with a moisture content of 8 Vol-% (specimen was pre-conditioned)

The tests with an instationary temperature profile show that with increasing temperature on the cold side first a heat flux from the outside environment into the insulation material occurs that changes its direction not till the temperatures drop again in the afternoon. Further on, the heat flux indicates that there are both heat gains (from the outside environment into the insulation material) due to melting heat and also heat losses (from the inside to the outside of the insulation material) due to cristallization heat, when the water freezes.

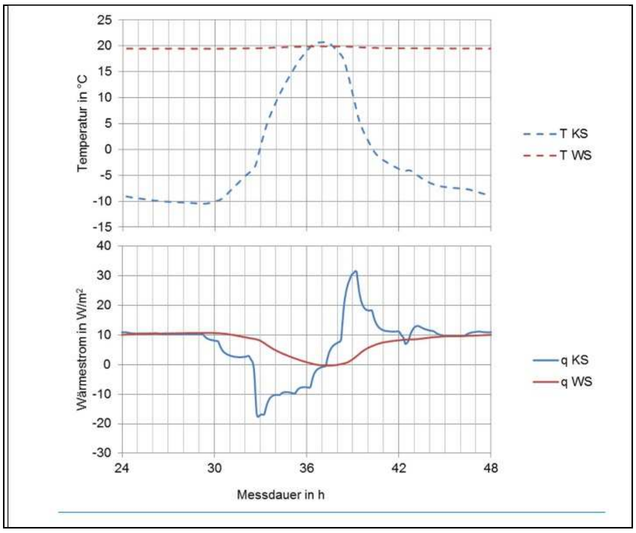

Fig. 8:
Measurement values of temperature and heat flux for the material EPS 2 with a moisture content of 0,005 Vol-% (air-dry)

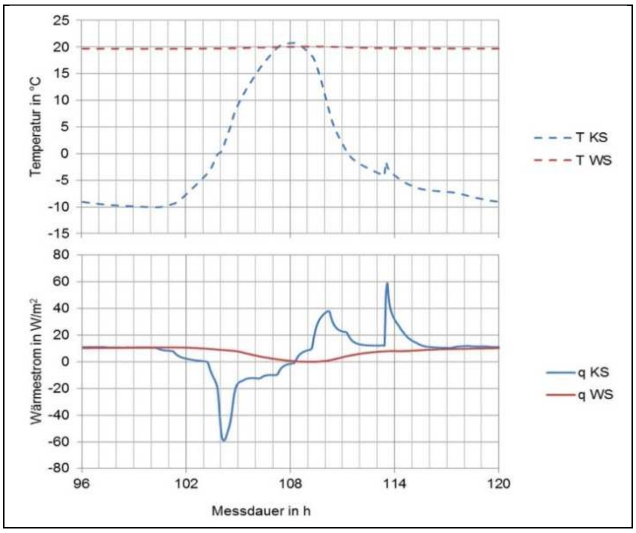

Fig. 9:
Measurement values of temperature and heat flux for the material EPS 1 with a moisture content of 1,7 Vol-%

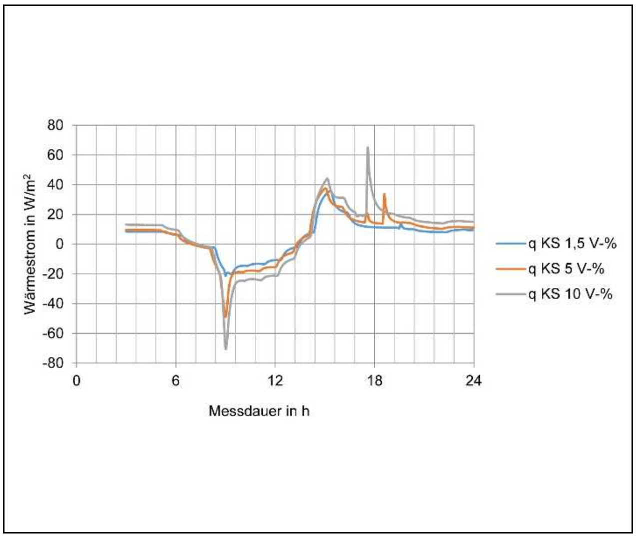

Fig. 10:
Measurement values of heat flux for the materail PUR with a moisture content of 1,5 Vol-%, 5 Vol-% and 10 Vol-%

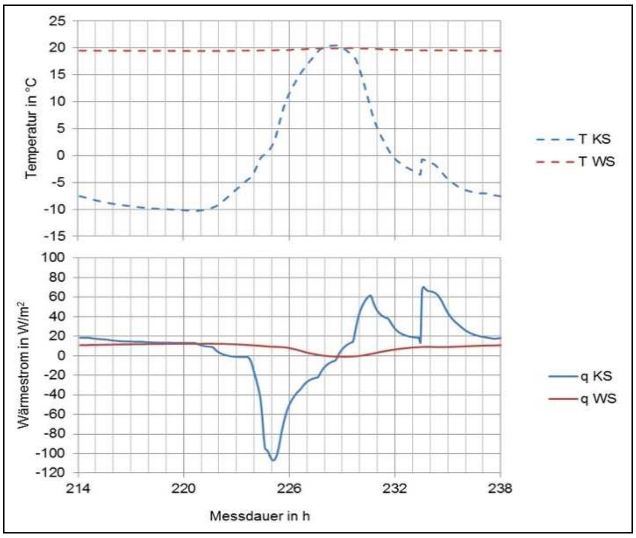

Fig. 11:
Measurement values of temperature and heat flux for the material MW with a moisture content of 1,5 Vol-%.

Figure 8 to 11:
Measurement data of heat flux and temperature on the cold and warm side during determination of thermal conductivity with instationary temperature conditions; Upper plots show temperatures, Lower plots shows heat flux on cold side (KS, blue line) and warm side (WS, red line)

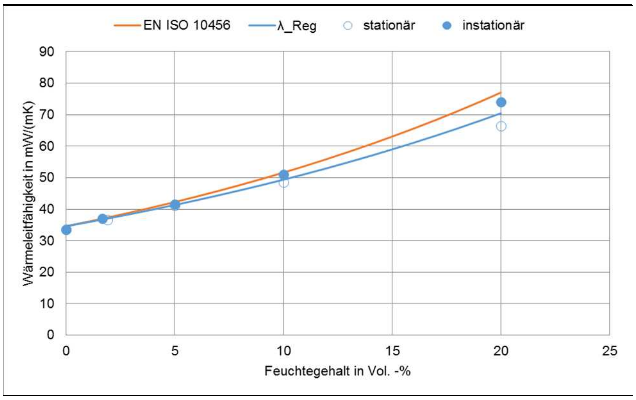

Fig. 12:
Thermal conductivty as a function of the moisture content for thermal insulation material made from expanded polysterene (EPS)

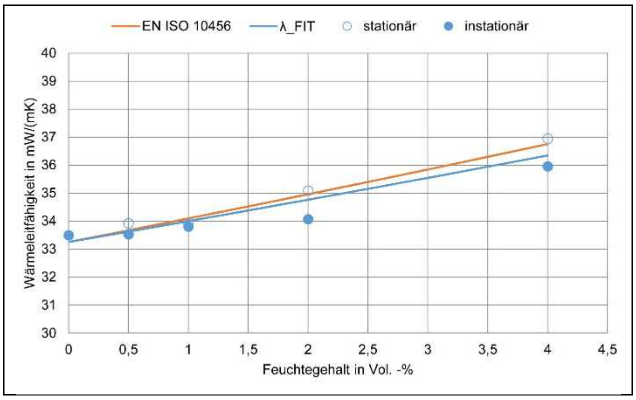

Fig. 13:
Thermal conductivty as a function of the moisture content for thermal insulation material made from extruded polysterene (XPS)

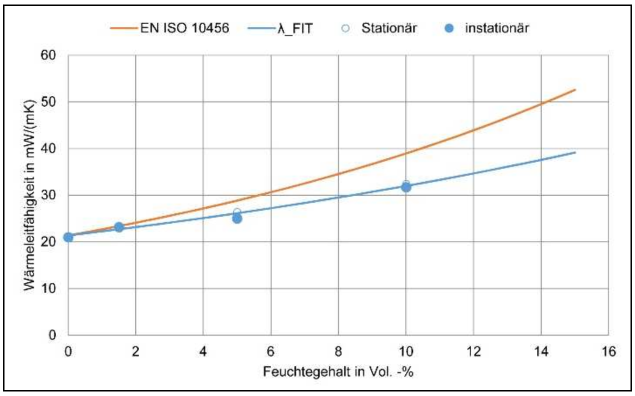

Fig. 14:
Thermal conductivty as a function of the moisture content for thermal insulation material made from polyurethane (PUR)

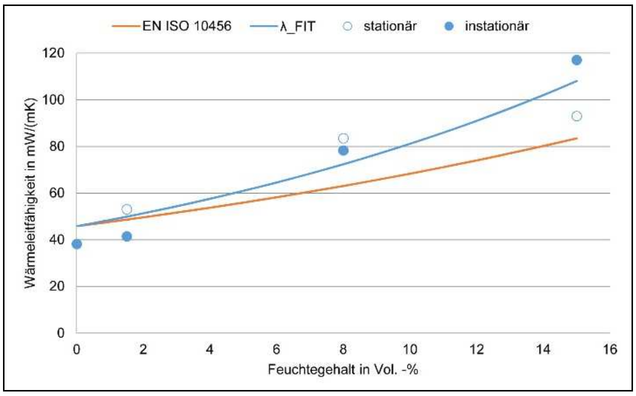

Fig. 15:
Thermal conductivty as a function of the moisture content for thermal insulation material made from mineral wool (MW)

Fig 12 to 15:
Measurement values of thermal conductivity and regression curve of thermal conductivity as a function of the moisutre content based on the measured values (blue curve) and according to the moisture conversion coefficients as given in the standard DIN EN ISO 10456

5 Legal aspects

If insulation materials are found to contain increased levels of humidity, and if, in spite of that, the decision is taken after careful consideration to leave them in the interior of the roof structure, there may arise a number of legal problems.

The obvious questions are discussed in the report. They are dealt with under the following categories:

1. New buildings: humidity in insulating materials before or during acceptance inspection („Abnahme“)
2. Humidity occurring after formal inspection within the warranty period
3. Maintenance of the sealing layer after warranty time has expired
4. Measures to increase thermal protection

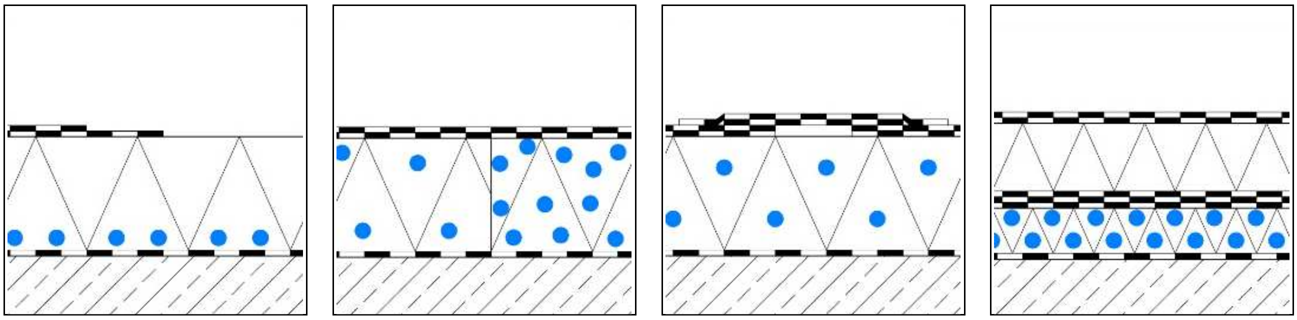

Fig. 16:
Four different situations in which leaving humid insulation materials in the roof structure is open to dispute

6 Practical recommendations

Recommendations to keep humid insulation materials within the roof structure are based on the analysis of individual cases of damage and on laboratory tests of thermal conductivity.

These recommendations are dealt with in the following chapters:
Measuring and documenting moisture content – Increasing the weight of loads – Evaluation of vapour barriers – Regulations of the Energy Savings Directive („EnEV") – Sucking off water from low points of the roof structure – Drying out – Bonded roof structures – Mechanical fastening – Perforation of the sealing membrane – Additional insulation and water-proofing measures – Drainage – Further criteria for decision-making

7 Conclusions

Humid insulating materials can remain in the interior of the roof structure if there are no moisture-sensitive materials in the sealing-layer or immediately adjoining it, such as timber, cork, jute, possibly mineral wool, or mechanical fastening elements susceptible to corrosion. The research report describes appropriate conditions and suggests practical solutions.

As far as foam plastics are concerned, the analysis of heat flows, both under steady and non-steady conditions, shows that the moisture conversion coefficients of DIN EN ISO 10456, which can be used to assess the change in thermal conductivity in relation to moisture content, correspond fairly well with measurement results and are thus on the safe side. The results for mineral wool should be checked and differentiated by further tests because of the considerable fluctuation of density in raw mineral wool.

Apart from that, some effects of heat flows measured in humid insulation materials cannot be explained in the light of current scientific knowledge. Obviously, comprehensive research into moisture transport processes within insulation materials is still lacking, and these processes cannot at present be adequately expressed by mathematical formulas. Describing moisture transport based only on the constant vapour stream density - expressed by the s_d-value – does not adequately explain the heat flows measured in tests.

So further research will be necessary, although the results established so far may already offer practical assistance.