Effects of humidity penetration on the condition of mineral wool insulation materials installed in non-ventilated flat roofs

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The responsibility for the content of the research study lies with the authors.

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Summary Account

1. Aims of the research study

The research study aimed to develop reliable methods to assess the effects of humidity in mineral wool insulation layers of non-ventilated flat roofs. This involves the effect of humidity on durability („strength“) and thermal conductivity. The study only considered such insulation layers that are placed above the load-bearing construction and are exposed to pressure caused by use. As the insulation of intermediate rafters on wooden roof constructions does not need to fulfill the same requirements, it was not included in the research project.

The investigation tried to assess, which factors (such as the degree of humidity content, the duration of moisture storage, or the composition of the mineral wool) are likely to cause damage to the insulation material, under which conditions it will dry out (due to the natural climate or by forced drying out), and in which cases, from a technical point of view, it will be necessary to replace the insulation layer. The intention was to determine limit values, which will allow a more objective assessment in legal disputes. Lastly, it is also a question of sustainability and economic efficiency, if humid mineral wool insulation can still function adequately.

2. Investigations and surveys

2.1 Inspection of existing buildings

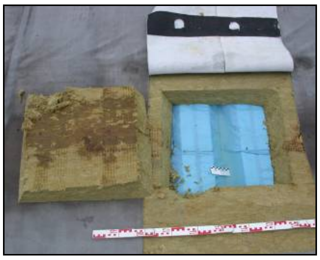
From the number of flat roofs insulated with mineral wool which were specified by building experts in the survey, five examples were chosen and the relating data closely analysed. Then the degree and the distribution of humidity and its effects on the proper functioning of the roof were documented.

There are mainly two conclusions to be drawn from the inspection of the buildings:

Firstly, the amount of humidity penetrated into the mineral wool cannot usually be the only criterion to install a new insulation layer. Scientific data about the immediate effects of humidity on the insulation or its long-term consequences are not available at the moment. (How does humidity affect the structure of the material? In what way do compressive strength and thermal conductivity change? Does the degree of humidity affect the technical lifespan of the insulation?)

Secondly, the characteristic compressive strength of the installed mineral wool insulation is considerably changed depending on the intensity of mechanical stress to which it is exposed, e.g. when a roof surface not constructed for use is nevertheless exposed to the impact of heavy weights. Limit values for the extent to which these changes are normal and technically acceptable have not yet been defined, nor is it clear when the insulation must be regarded as defective.

Roof surface with central row of light fittings and photovoltaic installation on the sides



Insulation material with a high degree of humidity above a fold filled with water

Sample with considerably reduced resistance to pressure

Measuring distortion under typical stress

2.2 Survey among building experts

Based on a survey among 1,978 officially appointed experts, the study compiled practical examples of the performance of humid mineral wool insulation materials. The questionnaire was addressed to 1,114 experts on building damage, 485 experts on roofing and 410 experts on building insulation, some of them appointed in several fields. Almost 10% (185) replied to the questions in great detail, describing several cases of damage, and agreed to answer any further questions on the phone.

So it was possible to evaluate the data of 566 buildings with damp mineral wool, focussing on such cases of damage that occurred during the last ten years.

2.3 Results of the survey

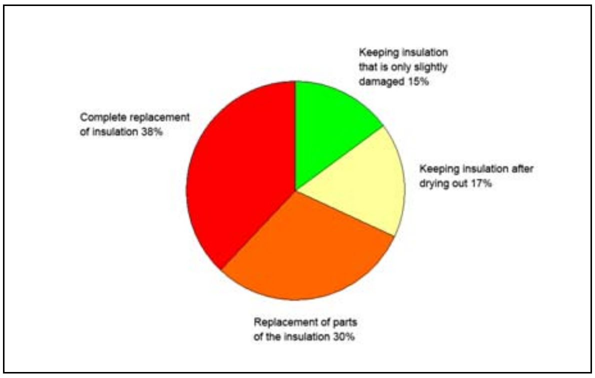
In general, experts recommend the replacement of insulation, if, apart from the degree of humidity, there are other reasons for installing a new insulation, e.g. if damage has occurred on the base below, or if the structure as a whole is showing signs of deterioration.

Renewal is also advised if there is a high degree of moisture with water collecting in the interior of the structure, or if there are visible defects to the insulation.

In the case of warranty claims, experts frequently consider it necessary to replace the whole of the humid insulation material because this will be the only way to create the conditions owed under contract. This estimation is supported by producers' recommendations, which do not specify any limit values for the humidity content of their products.

Frequent compressive stress on the surface is also described as problematic. Areas that are walked on regularly, often show diminished resistance to pressure.

The drying out of the insulation layer is generally not regarded as a suitable remedy.



Percentage of recommendations for the replacement or keeping of mineral wool insulation

3. Thermal conductivity of mineral wool containing moisture

As cases of damage have shown in practice, even water-repellent mineral wool can absorb a considerable quantity of moisture. Since the process of humidity migration in mineral wool insulation has not been systematically examined yet, the conclusion must be drawn that older measurements of the change in thermal conductivity, in relation to moisture content, are no longer valid. The conductivity of the insulation material has to be distinguished from the energy flow which is caused by moisture passage. At present, it is to be assumed that the insulation material's thermal conductivity itself will not be changed by humidity. Scientific studies of heat transport by locked-in, diffusing humidity with changing aggregate phases have only recently been initiated at an international level. But if the insulation material is damaged by diminished thickness, the thermal resistance value will, of course be reduced by at least the same degree.

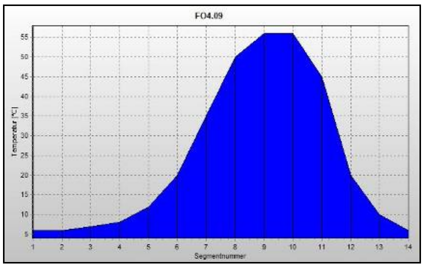
4. Tests of compressive strength that is affected by humidification and storage at changing temperatures

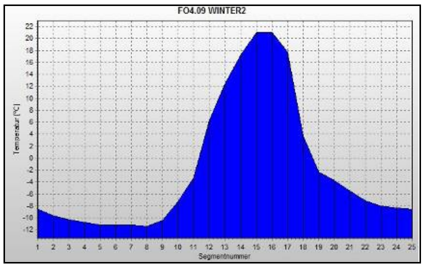
In cooperation with the FIW Munich, the research study developed laboratory tests, in which samples with a high degree of humidity were exposed to changing temperatures. Then the compressive strength of materials diminished in thickness by 10% was measured by methods similar to the standard tests. The aim was to determine the number of temperature cycles and the degree of moisture content that would lead to substantial changes in the material's resistance to pressure. These tests were the first to simulate a realistic interrelation between the humidity degrees measured in practice and the changes in the state of the insulation material.

Based on temperatures recorded at flat roofs, the typical process of temperature changes in the external climate was specified. From these data, two typical days (in summer and in winter) were chosen and entered as reference values for the control program.

The typical summer section comprised temperatures between +5° C and + 55° C, the winter section between -11° C and + 21° C. For the purpose of subsequent tests, the samples were cut into pieces of a size of 200 mm by 200 mm. Those pieces were wrapped in plastic bags and, depending on the test series, filled with water. Their humidity content was determined at 1.5 mass-percent, 5 mass-percent and 50 mass-percent.

Samples prepared for storage at changing temperatures



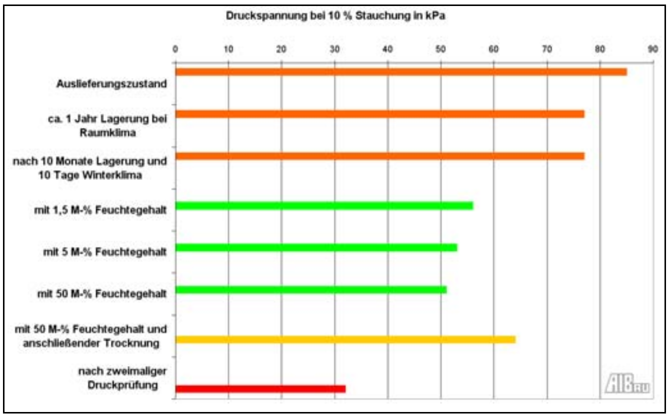


Temperature cycles during storage in summer (left) and in winter (right)

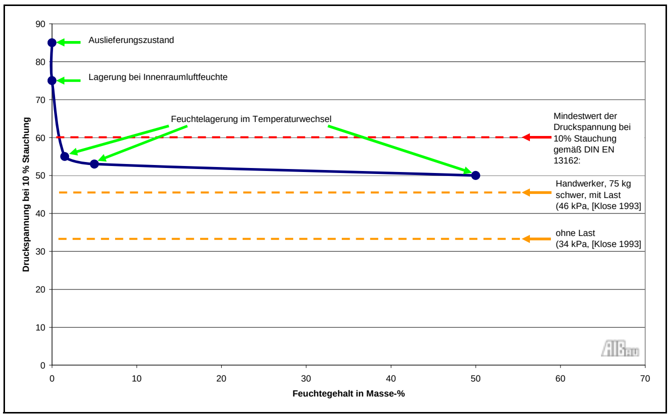
The tests show that there is no direct correlation between the quantity of water in the material and its loss of compressive strength. Neither does it make any noticeable difference if the material is exposed to the stresses of summer or winter climate, nor does the strength of the samples seem to be influenced by the length of exposure, e.g. over a period of ten or of twenty days.

On the other hand, any further increase in humidity will diminish compressive strength only to a comparatively slight extent. That means, a high degree of humidity itself cannot necessarily be regarded as an indication of serious damage, because moisture can never be completely prevented from penetrating into the material.

It is clear that even small amounts of humidity will considerably diminish the material's resistance to pressure and reduce compressive strength below the limit standard value of 60 kPa, though it will still be above the critical limit in relation to reference strength, which, according to producers, should not be lower than 35 kPa, the typical standard of non-usable roofs.



Summary of measurements (medium values), compressive strength at 10% loss of thickness in kPa and various conditions of storage



Compressive strength at 10% loss of thickness in relation to humidity content

5. Conclusion

1. Humidity in mineral wool insulation material will diminish ist compressive strength, the degree of moisture content being of secondary importance.

Mineral wool insulation with a high degree of humidity may still show great resistance to pressure. The degree of humidity itself is not a sufficient criterion for a substantial reduction in the resistance to strenght of the insulation material.

2. The changes in heat transfer occurring in humid mineral wool insulation cannot be exactly quantified at present.

The findings of earlier scientific studies, which quantify heat transport in humid mineral wool, are at dispute today. More recent calculations and validations are currently not available.

3. Soft insulation materials primarily result from too many and/or too frequent compression stresses.

The reduction of the compressive strength of mineral wool insulation is not predominantly caused by humidity, but by increased mechanical stress, for example by transport works on the finished roof surface.

4. The permissible compression of installed insulation materials should not be determined by the standard test for 10 % compressio

From a certain degree of softness, insulation material will considerably damage the proper function of the roof. But to decide when the replacement of insulation layers becomes necessary, there are no generally valid limit values, which could be applied to all cases of damage.

5. Whether the proper performance of the insulation is diminished or not depends on the conditions of the individual case.

Thermal insulation layers have to be replaced if the defects of the insulation, caused by softened materials or by permanently high humidity levels, is likely to damage the structural components of the roof insulation or the roof construction, or if the loss of thickness alone has greatly reduced thermal protection.

6. Exposure to mechanical stress should be avoided to the greatest possible extent.

When installing mineral wool insulation layers, measures must be taken to reduce mechanical stress, especially if works of other trades are executed on the finished roof surface. Clearly defined access areas (permanently fitted access ladders, doors leading from parts of the building onto the roof, delivery floors) must under all circumstances be protected by load-distributing layers, too.

7. When inspecting the roof for acceptance, and before the beginning of other works which involve foot traffic on the roof, the depth of imprints should be measured and documented.

During inspection, and before the beginning of subsequent work that involves foot traffic on the roof, the state of the mineral wool insulation beneath single-layer plastic sheets should be documented by assessing the distortion of the insulation surface caused by normal stress (foot traffic).

8. Recommendations for the evaluation of roofs containing humidity

When evaluating humid insulation materials, a difference must be made between cases of warranty and cases of renovation.

In cases of warranty claims, the replacement of the insulation materials should depend on whether the producing firm can ensure the proper function of the mineral wool insulation at the degree of humidity it was found to contain.

In the case of renovation, it should be noted that higher degrees of humidity do not generally diminish the performance of the insulation materials examined in this study. Taking into account the conditions mentioned in concluxions 5 and 6, they can often remain in place.

9. Developing improved insulation materials

The producers of mineral wool should optimize the qualities of their materials so that

- load-bearing capacity will not be reduced already by small degrees of humidity,
- long-term performance will be guaranteed even at higher degrees of humidity,
- the break-down products of binding-agents will not cause annoying smells if the material becomes humid.

10. Conclusions for building regulations

Regarding flat roofs insulated with mineral wool, building regulations should give clear recommendations to install load-distributing layers in the areas of the roof surface exposed to frequent or increased mechanical stress. Such layers should either be installed permanently (e.g. in access areas which are regularly walked on for maintenance work), or at least temporarily when there is assembly work by other contractors (e.g. fitting glazed roofs, air-conditioning, solar panels). Specific information should be formulated especially in the following building directives:

- DIN 4108 -10 and DIN18531
- Regulations for Flat Roofs („Flachdachrichtlinien“) and Directive for Roof and Wall Solar Systems („Merkblatt Solartechnik für Dach und Wand“)

Future Prospects

Further scientific studies will be required to determine the long-term effects of humidity on mineral wool insulation materials installed on non-ventilated flat roofs which are exposed to compressive stress, and to describe how heat flows are changed by diffusing humidity content.

The aim is to improve the practical performance of flat roofs insulated with mineral wool, so that they will be able to cope with the effects of humidity in confined spaces and with periods of peak pressure. In this way it will be possible to avoid the economical and ecological disadvantages of demolishing the insulation before its expected lifespan has expired.