Specific building-physical properties of ETICS on mineral-wool basis

IBP report HTB-20/2009 made on behalf of Rockwool

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Abstract: According to the report HTB-20/2009 of the Fraunhofer Institut "Specific building physical properties of ETICS based on mineral wool", stone wool contributes to the durability of ETICS systems due to its physical properties such us moisture, mechanical and fire behaviour.

The moisture behaviour has been tested in practice by means of natural weathering in the worst orientation in Germany (west oriented with driving rain).

In addition the hygrothermal stress of different ETICS systems with different surface layers and brightness have been compared to traditional brick based walls, considering the elongation of materials due to radiation, exterior temperature, specific heat capacity and moisture content.

Mechanical properties such as tensile strength and shear strength have been tested that demonstrate the benefits of the use of stone wool in ETICS systems.

1. Introduction

In Central Europe, thermal insulation composite systems (ETICS) have for many years been a conventional and well-preserved possibility of insulation of exterior walls for new buildings and for refurbishment. A major advantage of ETICS is that with such system thermal insulation and weather protection of construction components can simultaneously be assured.

This report summary first provides an overview of the studies conducted by Fraunhofer IBP in Holzkirchen since the 70s on hygrothermal performance and durability of exterior insulation with mineral wool in different installation situations, showing the favourable behaviour of mineral wool based ETICS systems due to its permeability.

2. Summary of previous investigations by IBP

Mineral wool is a non-combustible mineral wool thermal insulation material with thermal conductivities dependent on the density of λ = 0.035 to 0.04 W/m2K. The special feature compared to other insulating materials is the high water permeability, which is specified in DIN 4108-4, with μ = 1, i.e. mathematically equivalent to a layer of air. This has advantages and disadvantages and must in a construction of an insulated wall be considered individually: external mineral-wool insulation makes rapid release of housing humidity to the exterior possible, whereas inside insulation by mineral wool would require vapour barrier on the room side. With core insulation with mineral wool such considerations do not need to be taken.

3. Investigations of moisture behaviour and weather resistance of mineral fibres

Mineral wool insulation products which are on the outside of the construction directly or in different ways well-protected against free weathering have in many cases proved to be unexpectedly durable and weatherproof. As already stated, mineral-wool insulation slabs are not capillary-absorbent, i.e. they cannot absorb any water when they are put into contact with water on one side. This property is practically independent of the degree of hydrophobicity. If hydrophobised mineral-wool slabs are sprinkled on one side, as is the case when it rains, then the water can ‘sink into’ the fibre structure, depending on the compactness of the fibre structure, i.e. the density and the hydrophobic effect. It is the same when mineral-wool slabs are completely immersed in water (see Figure 2 and Figure 3). That there is practically no difference between non-hydrophobic and hydrophobised mineral-wool slabs as to capillary water absorption means that in studies of sandwich walls with core insulation of the two types of insulation, no difference in the insulating material humidity could be detected according to reference [6].

In reference [2], experiments conducted on the weathering of mineral-fibre insulation behind facades with open joints in west and east orientation (see Figure 1) on the IBP test site in the years 1985 to 1989, are described. Extreme structural conditions with 20 mm thick pads and also 20 mm wide joints were selected that allow the entry of radiation, rain and even hailstones up to the insulation surface. The insulation boards have densities of 45, 65 and 100 kg/m³. The results show minimum thickness losses of the entire slabs, with somewhat greater material removal in the joint area itself, which after four years on the west side, dependent on density of the material, is at 3 (100 kg/m³) to 6 mm (45 kg/m³) and on the east side at 0.3 to 3 mm. Given the extreme test conditions, the loss of substance for this application is considered to be safe in practice and in view of the overall slab thickness negligible in terms of energy.

In reference [1], mineral-fibre insulation products are examined in terms of their hygrothermal behaviour, in particular liquid water absorption and thermal conductivity. It is noted that the often criticised strong humidity-dependency of the thermal conductivity is based on faulty measurements or misinterpretations of the results and that the conductivity of hydrophobic fibres only increases slightly with their water content – thus, there is no separate treatment of the insulation material. Since a capillary water absorption does not occur in practice, as previously described, the authors of reference [1] conclude that nothing stands in the way of using hydrophobic fibres in the inverted roof or as perimeter insulation (excluding groundwater) from a building physical point of view.

Figure 1: Surfaces of stone-wool fibre slabs after 4 years of weathering in western orientation with driving rain load (top) and east (bottom)

When sprinkling unprotected mineral wool slabs, the immediate affected fibres on the surface in the direction of flow of water are “straightened” over time which causes a certain mechanical "diversion" of the water, as is for example the case with straight straws in thatched roofs. This was found in a comparison of free weathered thatched roof and mineral-wool samples. At the 37.5 cm thick thatched roof a max. permeation of rain humidity of 50 mm was measured within a period of a year, compared to a permeation of max. 10 mm at a 10 cm thick mineral-wool slab. This could be described as "thatched-roof effect” as in reference [6]. This effect has a practical significance in view of mineral-wool insulation behind a façade clothing of factory stone plates with open joints. The resulting weathering in the joint area depends on the density of the insulation slabs. The weathering at 65 kg/m3 after 4 years of weather exposure shows Figure 1. A measurable decrease in the hydrophobic effect was demonstrated only in the outermost 5-10 mm.

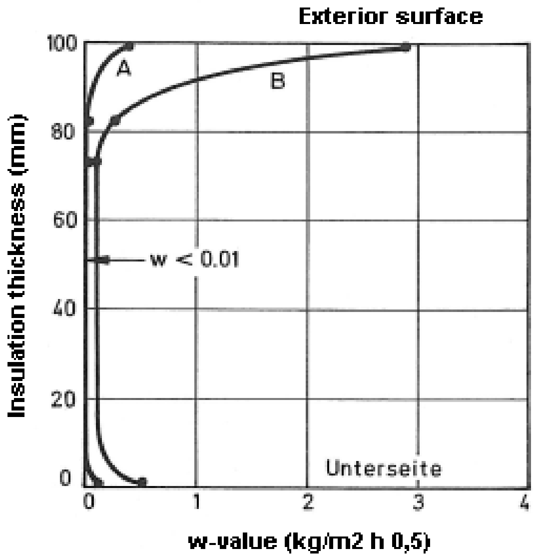

Figure) in the 6 years when the UK Roof Insulation weathered mineral wool insulation slabs of 100 mm thickness and 150 kg/m3.

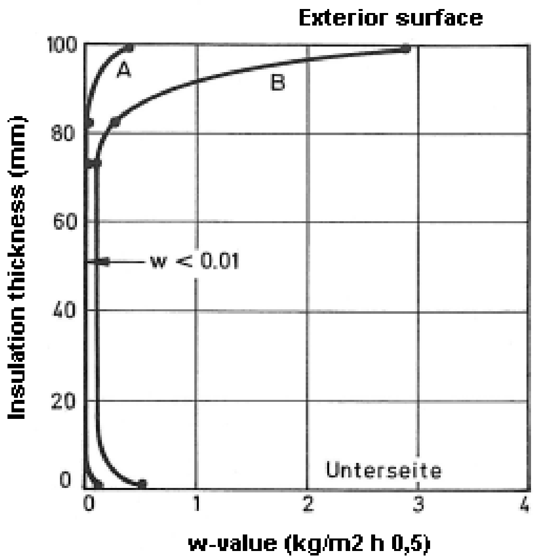

Figure 3: w_{24}-value (water permeability rate or water mass in kg absorbed within 24 hours in 1m2 test surface) profile of weathered mineral-fibre slabs from inverted roofs after 3.5 years of weathering of a slab with a density of 175 kg/m³ (A) and 6 years of weathering of a slab with 150 kg/m³.

In reference [3], the long-term behaviour of the Rockwool thermal blocks (compressed, hydrophobized mineral-fibre slabs) with natural weathering is tested. These were placed on the west wall of a test house on open land by the Fraunhofer Institute for Building Physics in Holzkirchen and freely weathered over a period of five years, and part was provided only with factory-made coating, the other part also painted with white emulsion paint. The investigations have shown that the thermal blocks are not only weather-resistant and dimensionally stable, but can also with a moisture content below 2 M. -% guarantee thermal protection on a long term.

Already in 1998, it is found in reference [8] that the artificial aging, as it is e.g. in the UEAtc test required and tested, in comparison with outdoor measurements lead to unrealistic unfavourable rating results. Other publications in the following years have further proved and confirmed these critical views.

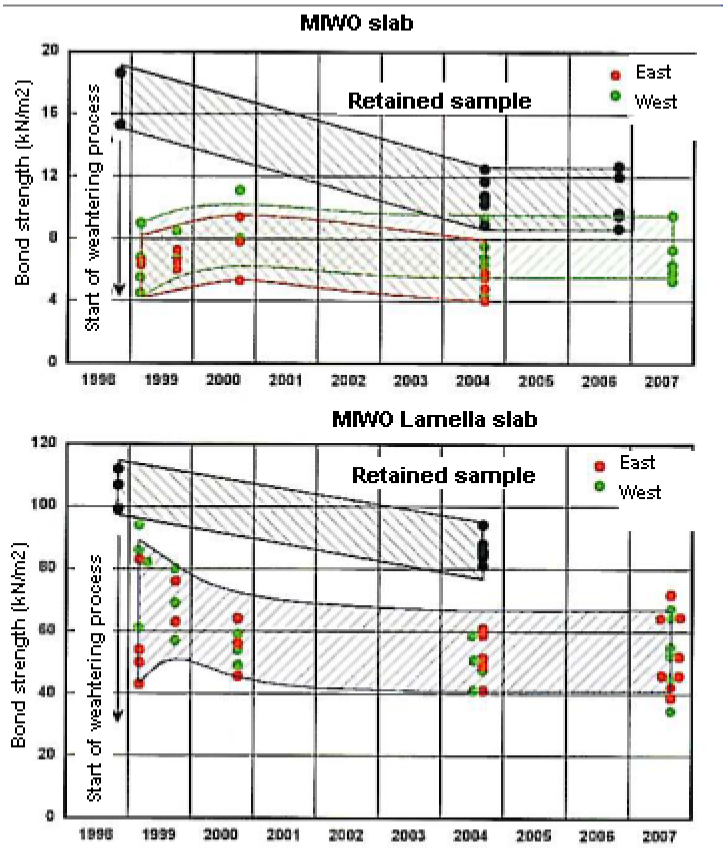

Figure 4: Time course of the delamination strength of mineral-wool insulation measured in situ on the test walls and in the laboratory on reference samples

As part of a thorough analysis and evaluation of long-term studies to examine the delamination strength of various systems after field tests and weathering in laboratory it is demonstrated that the current requirements related in particular to a required relative tensile strength as regards strength value of the new material, are neither justified nor seem reasonable. Alternatively, an absolutely proven laboratory value of the cross strength of 80 kN/m² and on the object of 40 kN/m² is proposed, based on the measuring results (see Figure 4) and taking into account a safety margin of 100% and in line with the requirements for thermal insulation render and for the base to be insulated.

4. Advantages and durability of ETICS

Reference [3] deals with the hygrothermal stress and durability of mineral render and mineral-fibre slabs on ETICS. Against this, from different sides there were doubts as only foam plastic systems with a synthetic resin render were considered flexible enough to tolerate the hygrothermal strains in the thin thermally divided layer of render, while mineral renders or slabs appeared to be too rigid. The investigations show that the thermal stresses in surface layers with bright colours for ETICS only increase approx. 10-30% compared with solid walls – i.e. much less than previously partly assumed. On the contrary, the hygric stresses increase for the examined systems with rigid foam insulation against a brick base by 300%, which could lead to problems particularly for multi-layer render systems with different hydric elongation properties.

Figure 5: View of the west facade of a renovated building with ETICS in Munich in 1989 (top), three years after refurbishment, and in 2004 (below) with the growth of algae (arrow below)

Here, as regards damage to the render, the mineral systems are rather advantageous. It also shows that in mineral systems even with fine cracks (up to max. 0.2 mm) there are no changes in the moisture content in the entire construction. The minimal capillarity in the mineral wool, both the hydrophobic and non-hydrophobic fibres, ensures protection of the basic construction against driving rain, even in case of cracked render. Overall, the mineral-wool ETICS with mineral renders as well as the foam systems prove good durability, based on 82 reference objects.

26 of the 82 already mentioned objects in reference [3] were once more investigated in 1991 and somewhat more differentiated described in reference [4] – in particular as regards formation of cracks in render. The previously indicated positive evaluation can be confirmed. Most systems have remained in that period without optically visible cracks - in

some cases fine cracks have occurred distributed in an area, which have no consequences for the moisture absorption of the construction, therefore, are regarded as unproblematic. A further inspection of 12 of the now between 18 and 35 years old systems was performed in 2004 (see Figure 5). The results and an overview of the general benefits of ETICS are presented in reference [6]. To estimate the positive experiences over the long period of investigation and as compared to conventional masonry render facades the rather better conditions of the render surfaces may estimate the durability of the systems with minor maintenance to more than 60 years; this represents a doubling of the period, so far frequently referred to as 30 years.

References [9] and [11] discuss the ability of ETICS, in a harmless way to bridge cracks and movements in the substrate for the top coat and the new outer surface. This property was already in 1998 known from long experience, but was again doubted due to calculated investigations. The contributions show that the calculated investigations are flawed because they do not take sufficiently into account the relaxation property of the insulation materials. This should be approx. 20%. In reference [9] a simplified laboratory test on small specimens with an expansion joint of 2.5 mm is presented, and the results coincide well with the practical experience. The low shear stiffness of the tested insulation materials (mineral wool and foam) and irreversible structural changes (relaxation) result in a significant decoupling of the substrate and render layer which enable the proven harmless bridging of gaps, even up to 4 mm in diameter.

5. Specific building-physical properties of mineral-wool-based ETICS

The building-physical benefits of mineral-fibre insulation in thermal insulation composite systems in Central Europe arise mainly from the diffusion openness of the material. In reference [10], the drying of wall structures with different ETICS is considered. When using rigid foam insulation the temperature level increases compared to a monolithic wall, but the diffusion current which is important for the drying to the outside is impeded by the diffusion resistance of the insulation.

With an EPS insulation compared to the monolithic wall, there is thus an equally long or longer drying time, which is shorter with mineral wool. Depending on the moisture sensitivity of the wall construction, ETICS based on mineral wool would thus be preferable. However, it should be noted that only permeable renders are used in order to avoid accumulation of moisture on the outside of the mineral wool underneath the render in case of heavy drying currents.

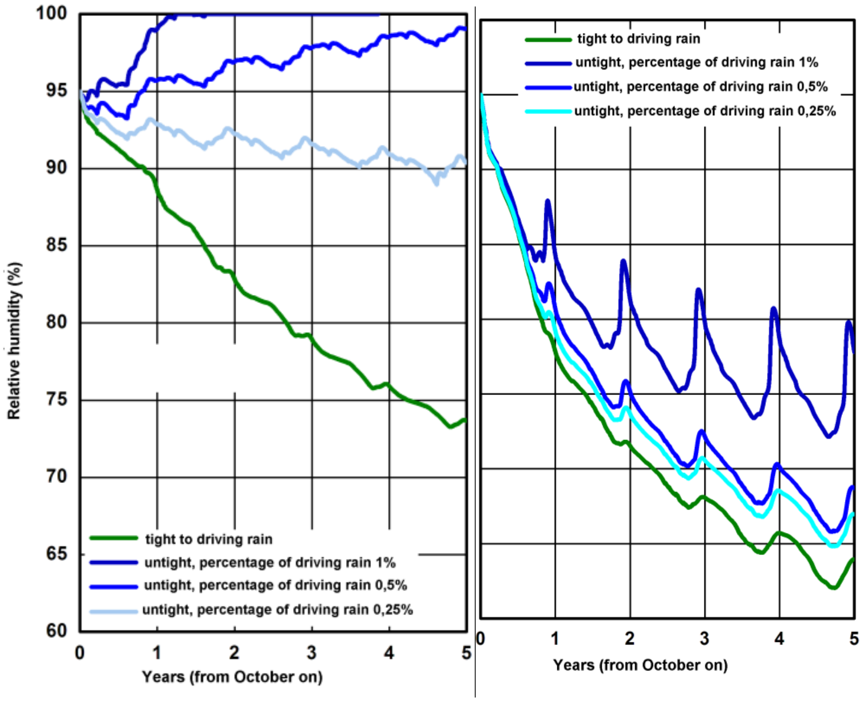

Figure 6: Calculated course of relative humidity in the area of reinforcement in concrete, depending on the amount of penetrating driving rain after installation of ETICS with EPS (to the left) and mineral-wool insulation (to the right) respectively, assuming a mean humidity in the freely weathered weather shell (climate location Holzkirchen).

Reference [7] deals with the suitability of ETICS for the refurbishment of prefabricated buildings. The reason for the refurbishment is often the incipient corrosion of the weather-shell reinforcement. While massive substructures tend to be moisture-proof, the relative humidity in this case should remain permanently low. The results of computational analysis reveal a rapid drying within six months in the uncritical humidity range when using mineral wool ETICS, compared to a drying period of about two years with polystyrene insulation.

6. Conclusion

The diffusion openness of mineral wool based ETICS systems favours the drying process of the inside wall and render if the top coat has a similar diffusion resistance than the mineral wool. Weathering tests in extreme test conditions with open joints on painted mineral wool samples have demonstrated that mineral wool is weather-resistant and dimensionally stable and guarantee thermal protection on a long term. Bond strength measurements of 20 year old samples demonstrate that mineral wool fulfils ETA requirements.

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