Durability of polyurethane insulation products

Executive summary

The need for better research data on the durability of construction products has significantly increased over the past years mainly because of life cycle cost and life cycle analysis considerations. This is particularly true for insulation products which are designed to minimise the heat transfer through the building envelope. They not only play a crucial role in determining the use phase costs of buildings (energy consumption), but are often integrated in the building envelope and hence difficult to replace.

With a view to responding to these market needs and building trust in the supply chain, PU Europe asked the Forschungsinstitut für Wärmeschutz e.V. (FIW, Munich) to evaluate decades-old PU specimens from existing buildings according to the following characteristics:

- Thermal conductivity
- Compressive strength
- Moisture content
- Dimensional changes and product integrity of the insulation board

The tests demonstrated that, after decades in application, these PU insulation boards were fully functional and still reached all originally declared values and performances. The specimens showed no damages or defects. This provides planners, specifiers and owners with valuable guarantees as to the long term performance of PU (PUR/PIR) insulation products in buildings and permits a more thorough estimation of the future energy demand of buildings.

The PU insulation industry will undertake to test more samples to underpin these results. Other insulation products should follow this example.

What is Durability?

Guidance Paper F concerning the Construction Products Directive defines durability as follows:

> **Durability of a product** - the ability of a product to maintain its required performance over a given or long time, under the influence of foreseeable actions. Subject to normal maintenance, a product shall enable a properly designed and executed works to fulfil the Essential Requirements for an economically reasonable period of time (working life of the product).
>
> Durability is thus dependent on the intended use of the product and its service conditions. The assessment of durability can relate to the product as a whole or to its performance characteristics, insofar as these play a significant part with respect to the fulfilment of the Essential Requirements. In either case, the underlying assumption is that the performance of the product will be maintained at an acceptable level, in relation to its initial performance, throughout its working life.[1]

The durability of a product and its product characteristics is an essential planning element for developers, specifiers and owners to estimate the long-term performance of buildings in terms of costs and impact on the environment. It is therefore covered by the construction product standards (EN 13165 for PU insulation boards).

The estimated working life of insulation products can be anywhere between 30 and 80 years depending on the material and the end-use application. However, very few practical test results are available to confirm these assumptions.

Durability and Life Cycle Costs

The durability of insulation products has a significant impact on the life cycle costs of a building. About 70 % of these costs are related to the building's use phase[2] with the lion's share spent on heating and cooling. If the insulation product does not maintain its performance characteristics over time and the heat transfer through the building envelop increases, energy cost can grow substantially.

Repair or replacement of the insulation product before the end of the estimated working life will entail significant additional costs as the insulation layer is often not easily accessible.

Durability and Environmental Product Performance

The environmental performance of construction products can be subdivided into impacts from production, use and end-of-life. The building's use phase accounts for approximately 80 % of its overall environmental impact[3]. The period during which the insulation can maintain its declared performance levels affects the overall environmental performance of a building.

If the life time of a building is estimated at 50 years, but the insulant must be replaced after 30 years, then the life time environmental impact of the insulation doubles for that building. Alternatively, if the insulation is not replaced, the building's energy demand will increase and comfort levels will fall. Obviously, this would also affect the overall environmental performance.

PU Europe is committed to providing third-party verified test results regarding the durability of PU insulation products. With this in mind, PU Europe asked chartered building experts to take samples from existing buildings and send them to the FIW to measure all relevant performance characteristics.

Test 1: test of a 28 year old PU insulation sample

Test sample:
Sample 1 was taken in April 2010. The specimen (ca. 600 x 600 mm, thickness: 100 mm) belonged to a PU board forming part of the insulation layer installed in 1982 above the rafters in a pitched roof of a small detached house (pictures 1 and 2).

The chartered building expert noted in his report that the PU insulation boards were found tightly installed against one another with no gaps between them (pictures 1 and 3).

Picture 1: Inside of the pitched roof with the rafters and the insulation layer

Picture 2: Sampling of the test specimen

Picture 3: Insulation boards tightly installed against one another

The FIW evaluated the following characteristics:

- Type and condition of the facing
- Homogeneity, holes, cavities, bubbles in the foam
- Thickness according to DIN EN 823
- Moisture content after drying at 70°
- Thermal conductivity in the state of delivery according to DIN EN 12667
- Compressive strength according to DIN EN 826
- Reaction to fire (small burner) according to DIN 4102-1-B2

Test results:

Property	Initially declared characteristics	Measured value after 28 years
Facing: Aluminium multilayer facing on both sides, one side perforated		
Thickness	100 mm	101.08 mm
Moisture content	Not declared	0.05 Vol.%
Compressive strength	150 kPa	208 kPa
Thermal conductivity	0.030 W/(m·K)	0.0292 W/(m·K) (10°C mean temperature)
Reaction to fire	Class B2 (normally ignitable) in accordance with DIN 4102-1 No flaming droplets / particles	Class B2 (normally ignitable)[4] in accordance with DIN 4102-1 No flaming droplets / particles

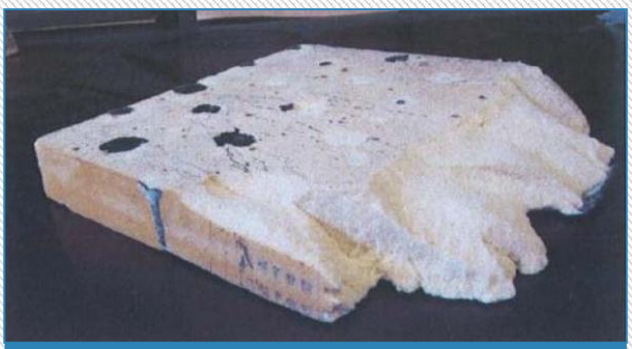
Picture 4: PU specimen before the tests

The tests demonstrated that the specimen showed no damages, no holes, bubbles, cavities or other inhomogeneities. One side of the facings showed some dust and traces of humidity. The FIW confirmed that, after 28 years in application, this PU insulation board was still fully fit for use and still reached all declared values and performances.

Test 2: test of a 33 year old PU insulation sample

Test sample:

Sample 2 was taken in September 2011 from the flat roof of a school which was being renovated. The insulation layer was installed under the membrane. As the mounting with the bitumen layer was still very good, no complete insulation boards but only larger pieces could be removed (pictures 4 and 5).



Picture 4: PU specimen removed from the flat roof

The FIW evaluated the following characteristics:

- Homogeneity, holes, cavities, bubbles in the foam
- Thickness according to DIN EN 823
- Moisture content after drying at 70°
- Density
- Thermal conductivity in the state of delivery according to DIN EN 12667
- Compressive strength according to DIN EN 826 (10 % deformation)

Test results:

Property	Initially declared characteristics	Measured value after 33 years
Thickness	60 mm	59.05 mm
Moisture content	Not declared	0.07 Vol.%
Overall density	Not declared	30.7 kg/m^3
Compressive strength	150 kPa	226 kPa
Thermal conductivity	0.030 W/(m·K)	0.0272 W/(m·K) (10°C mean temperature)

Picture 5: PU specimen removed from the flat roof

The FIW confirmed that the PU foam "has no worth mentioning damages" and "was still without defects". Furthermore, "the PUR insulation boards, after 33 years in application, are fully functional and still reach all declared values and performances."

Conclusions

The following conclusions can be drawn from this initiative:

- The tests provided practical evidence of the excellent long-term performance of PU insulation. This should increase trust in energy demand calculations for buildings over their whole life cycle.
- On the other hand, more product samples need to be evaluated to underpin the results of these tests. PU Europe is committed to providing additional samples in the near future.
- Other insulation products should be encouraged to provide similar information.

Notes

[1] Guidance Paper F (concerning the CPD - 89/106/EEC), Durability and the CPD (Revision December 2004)

[2] This share can be as high as 80%: "Life Cycle Costs in Construction" (2003) endorsed by the Tripartite Meeting Group (Member States/Industry/Commission) on the Competitiveness of the Construction Industry.

[3] Environmental Improvement Potentials of Residential Buildings (IMPRO-Building), JRC 2008

[4] The German class B2 is close to Euroclass E.