PU EUROPE EXCELLENCE IN INSULATION

FEDERATION OF EUROPEAN RIGID POLYURETHANE FOAM ASSOCIATIONS

Factsheet n° 3

Repetitive loads on flat roofs

REQUIREMENTS FOR THE INSULATION LAYER

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EXECUTIVE SUMMARY

A flat roof is often exposed to dynamic mechanical loads, e.g. by pedestrian traffic or small vehicles during the construction or maintenance process. Increasing installation of solar elements on flat roofs is leading to more intensive walking on these roofs while wind loads on installed solar elements can create additional mechanical loadings.

As a consequence, more attention is drawn to cases of larger deformations observed in flat roofs due to damaged insulation material. This is mainly due to the cost of repairing damaged insulation layers and roof sealants and related liability issues.

Repetitive loadings can be the reason for the decrease in the compression strength and larger deformation of the insulation layer. The declaration of static compression behavior of thermal insulation products alone may therefore not be sufficient for certain building applications. There is increasing evidence that a new European testing procedure for consideration of cyclic compression loadings of thermal insulation products applied in buildings is needed.

This factsheet presents such a test method and outlines a simplified repetitive loading test for CE marking. Both the experience on the ground and the test results themselves indicate that the declared compressive strength/stress at 2 % deformation for CE marking of thermal insulation products should allow for the safe design of flat roofs exposed to repetitive loads.

INTRODUCTION

CE marking is related to properties such as compression strength/stress at 10 % deformation, point load capacity or long term compression resulting in creep deformations. These properties are determined under static load exposures. But in some specific applications, dynamic loadings can become relevant for the integrity of the thermal insulation.

Figure 1: Example of a damaged roof

A flat (or low slope) roof is often exposed to dynamic mechanical loads e.g. by pedestrian traffic or small vehicles. These loads occur during construction of the building or for regular maintenance of installations on the roof. After a few loads, some materials tend to lose their compressive strength, resulting in a deeper imprint of e.g. the foot on the waterproofing. This stress in the waterproofing may lead to cracks, or to the penetration of a mechanical fixer through the waterproofing if the imprint is close by. Therefore the insulation material and the waterproofing may be severely damaged, resulting in a leaking roof.

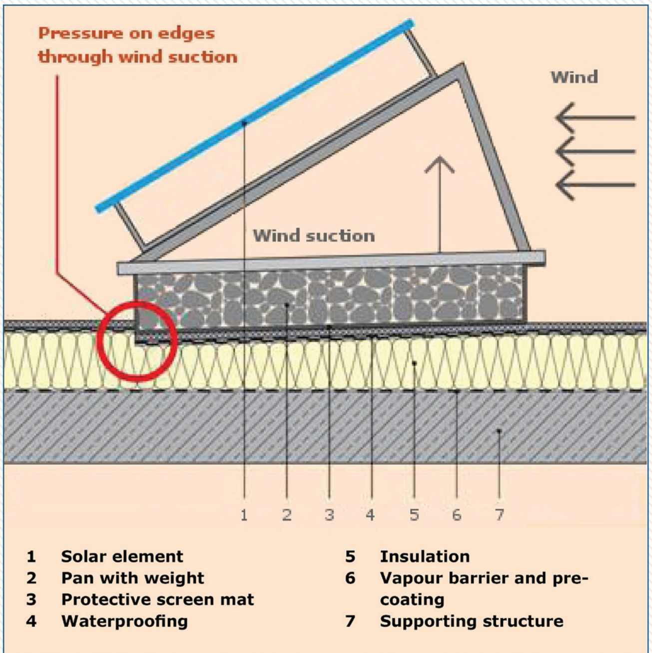

Figure 2: Pressure on edges through wind suction (source: IVPU)

Also the increasing installation of solar elements on flat roofs leads to more intensive walking on roofs during installation and maintenance (**figure 1**). More importantly, the projection of wind loads onto the mountain stands via weights means that the bearing structure, seal and insulation are subjected to the highest loads. Pressure on the sloping panels on the windward is relieved, while pressing on the leeward is increased. If the solar panel dips as a result of wind suction, the entire weight shifts to the edge of the stand. The pressure from the edge can cause damage to the roof's waterproof cladding when the insulation layer is soft (**figure 2**).

Figure 3: Solar panels on a flat root (source: IVPU)

This factsheet will summarise the conclusions of the following documents/ projects:

- Investigation of the Aachener Institute für Bauschadensforschung und angewandte Bauphysik (AIBau) **[1]**
- A new method for assessing the effect of repetitive loads **[2]**
- Compression testing with cyclic loading **[3]**

EXISTING TEST METHOD IS FAILING TO ADDRESS REPETITIVE LOADING

Today, a static test method is used for the determination of compression behavior of thermal insulation products applied in buildings. Compression strength/stress is measured at 10 % deformation.

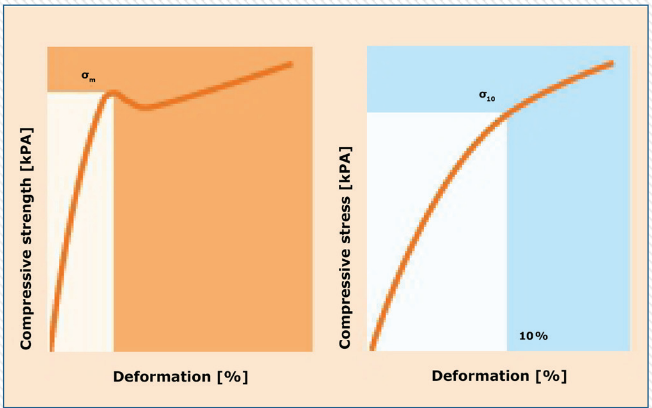

Figure 4: Compressive strength and compressive stress at 10 % deformation **[4]**

However, the experience from certain applications shows that declarations using a static test method and a limit level of 10 % deformation may not give sufficient information about the compression behaviour of thermal insulation products under cyclic loading scenarios, which may occur in flat roof applications. This is particularly true when repeated traffic of people and small vehicles can be expected for construction and maintenance works or when solar panels on stands are installed on the flat roof.

EXPERIENCE FROM FLAT ROOF APPLICATIONS [1]

The Aachener Institut für Bauschadensforschung und angewandte Bauphysik (AIBau) **[1]** reported that larger deformations were observed in flat roofs due to damaged insulation materials (**figure 5**). In the beginning, it seemed logical to link the loss of compressive strength (and hence increased deformation) of certain inorganic insulation products to the penetration of humidity.

Figure 5: Measurement of the deformation **[1]**

However, the institute's survey among experts came to the result that repetitive loading can be more problematic even if the insulation material is not humid. Areas which are frequently walked on often show decreased compressive strength.

It was investigated by AIBau **[1]** under which conditions (e. g. humidity content, duration of humidity penetration, composition of certain inorganic insulation products, load level) the insulation material is damaged, under which conditions drying is possible and when the insulation material needs to be replaced because of the damage.

The investigation came to the conclusion that

- The weakness of insulation materials can be caused by too high and/or repetitive loading.
- The allowed deformation of installed insulation materials should not be derived from the standard compressive test at 10 % deformation.

A METHOD FOR ASSESSING THE EFFECT OF REPETITIVE LOADS [2]

To predict potential damage due to repetitive loads, a new method was developed simulating pedestrian traffic on a roof. A machine was built, the so-called marathon man, simulating the repetitive walking of the foot (with a shoe) of a man of 75 kg with a roll of waterproofing of 25 kg. The number of load cycles can be adjusted, simulating the intensity of the repetitive loading of the roof (**figure 6**).

Figure 6: Marathon man test equipment

To perform the tests, a standard PU flat roof insulation board was used with a density of 35 kg/m³, faced on both sides with 50 μ aluminium foil (Ins 1). The material was compared with another commonly used organic insulation (Ins 2) and an inorganic insulation product (Ins 3).

Significant changes in compressive strength (CS) were observed (**figure 7**). For PU, the reduction in CS was limited to less than 20 %. For type 2, the reduction of CS was 8 %. Type 3 showed a much larger decrease. The remaining CS was about 50 % after 5 cycles, and after 30 cycles the remaining CS was less than 15 %.

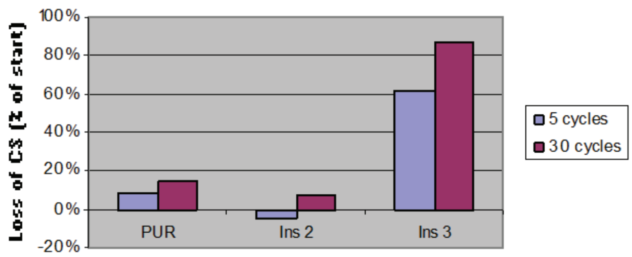

Figure 7: Loss of compressive strength after test

This work already caused a discussion in Holland on how to adapt building regulations by incorporating a test which truly reflects the performance of a material on a walked-on roof. The "marathon man" method is one of the options.

A classification system has been proposed by BDA in the Netherlands.

Class	Number of cycles	Meets criterion[1]	Type of walkability
0	5	no	not
1	5	yes	limited
2	10	yes	good
3	30	yes	intensive

[1] Criterion: compressive strength after testing not more than 15 % lower than initially

Table 1: Classification system proposed by BDA

COMPRESSION TEST WITH CYCLIC LOADING FOR CE MARKING [3]

The test equipment as described in chapter "A method for assessing the effect of repetitive loads" represents a realistic scenario for the insulation applied in flat roofs but is quite complicated for a product assessment to be used in CE marking. Therefore, the FIW (Munich) was asked to develop a test scenario for a regular compression test machine and to run tests on different insulation materials.

The load scenario was chosen with 5 cycles and increasing load levels:

- Load time 1 s
- Free time 60 s
- Test speed 180 mm/min
- Load at free time 2 kPa
- Sample size 100 mm x 100 mm

The test results clearly show the increasing non-linear deformations under the compression load cycles with increased loading levels.

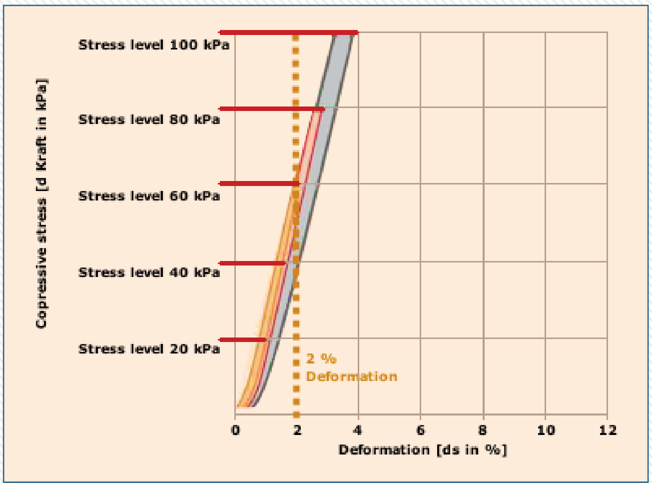

Figure 8: Deformation of PU rigid foam through cyclic compressive stress **[4]**

A linear deformation behaviour was observed up to the load level at 2 % deformation.

The FIW concluded the following from the tests **[3]**:

"There is a gap between measured values of compressive stress at 10 % deformation and a real exposure in a flat roof with dynamic loading. A set of test results after dynamic loading according to the described parameters was obtained. The compressive stress values at 2 % deformation seem to fit quite well to the obtained load levels after free time and a load level of ≤ 2.0 % deformation".

NEXT STEPS

Repetitive compression loading on flat roofs from foot traffic or wind suction on solar panels can influence the integrity and long-term mechanical performance of the thermal insulation layers. The declared compression strength/stress at 10 % deformation for CE marking of thermal insulation products may not give sufficient information for a safe design of the flat roof construction.

Research results and investigations on the ground highlight the need for insulation products to declare cyclic compression load performance at 2 % deformation with the CE mark. The test results described in this factsheet should contribute to the development of a new affordable European test procedure which reflects performance in end-use applications.

References

[1] Oswald, R.; Spilker, R.; Abel, R.; Wilmes, K.: *Zustandsänderungen von Mineralwolledämmstoffen in Warmdachaufbauten bei Flachdächern infolge Feuchteeintritt* (Changes of mineral wool insulation in warm roof build-ups of flat roofs due to infiltration of water), AIBau Aachener Institut für Bauschadensforschung und angewandte Bauphysik, Research Report Nr. F 2824, IRB-Verlag, Stuttgart 2012

[2] *The Effect of Moisture on the Compressive Strength and Walkability of Roofing Insulation*, Paper presented at the 5th Global Insulation Conference, London, 4-5 October 2010, Nico A. Hendriks, BDA

[3] *Determination of behaviour under cyclic loading ("walkability"),* Research report of Forschungsinstitut für Wärmeschutz e.V.-München (FIW), 2012

[4] IVPU-Merkblatt *Flachdächer mit Solarthermie- oder Photovoltaikanlagen – Anforderungen an die Wärmedämmung*