PU EUROPE
EXCELLENCE IN INSULATION
FEDERATION OF EUROPEAN RIGID POLYURETHANE FOAM ASSOCIATIONS

Factsheet n° 2

Assessment of the Fire Behaviour of Insulated Steel Deck Flat Roofs

EXECUTIVE SUMMARY

No test standard designed to simulate the performance of an insulated steel deck flat roof above a developing internal fire, regardless of whether used for regulatory or insurance purposes, currently exists in Europe. Nor does one exist in its Member States or from ISO. External fire performance and small-scale fire tests on the components of a roof appear to be the only concern in Europe. Often the regulatory or insurance restrictions are made on the basis of calorific value and not on the basis of fire performance.

A test program was therefore initiated with the objective of developing a small room scale test method. The test method was required to be capable of assessing the performance of insulated steel deck flat roof assemblies above a developing internal fire.

In order to use the test method as a basis for a classification system for steel deck flat roof assemblies insulated with different insulation materials, clear pass/fail criteria were developed.

This factsheet describes the test method and details the outcome of its application to flat roof assemblies with different insulation materials.

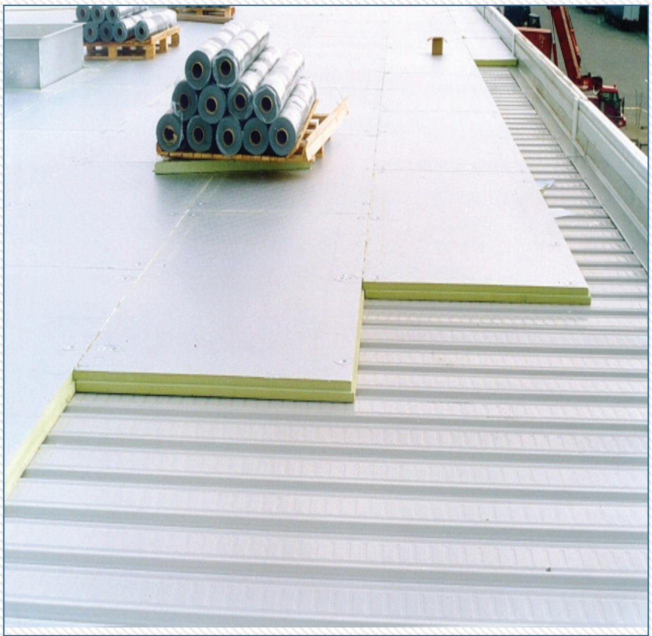


Figure 1: Example of a roof construction containing a steel deck support, PIR insulation and a roof covering

WORK PROGRAM

The work program contained the following steps:

1. indicative fire tests;
2. establishment of the final test procedure; and
3. comparison of different insulation materials under the final test conditions.

FINAL TEST CONFIGURATION

The geometry of the test apparatus is the same as for the ISO 9705 room corner test. The floors and walls are made of lightweight concrete, while the roof is constructed and tested simulating the end use application (**Figure 2**).

ISO 9705 as Basis for the New Test:
The ISO 9705 Room Corner Test was used in the development of the Euro-classification system, which classifies construction products for reaction to fire. However, the ISO 9705 Room Corner Test was developed by ISO specifically for the assessment of the fire behaviour of internal linings and it is not directly suitable for assessing the performance an insulated steel deck flat roof above a developing internal fire. Insulated steel deck flat roofs could be considered a special case, since production of pyrolysis gases within the roof assembly can lead to fire propagation and flashover.

The test is performed according to the fire scenario described in the ISO 9705 standard, with modifications to the burner programme and duration. During the first 5 minutes the burner is set to 100 kW and for the remaining 25 minutes it is set to 300 kW. The burner is stopped after 30 minutes or just after flashover.

The tests are performed under a 6 metre diameter calorimeter hood (**Figure 2**). This is used to measure the heat release rate (HRR). Thermocouples, placed between the insulation and the waterproofing membrane, are used to monitor temperature development and insulating performance. Thermographic images are recorded from above the roof with an Infra-red (IR) camera. These can provide a good visual representation of heat emission from the roof, and can measure the temperature of the upper roof surface. The temperature measured by the IR camera is different from the thermocouple measurements taken from between the insulation and the waterproofing membrane.

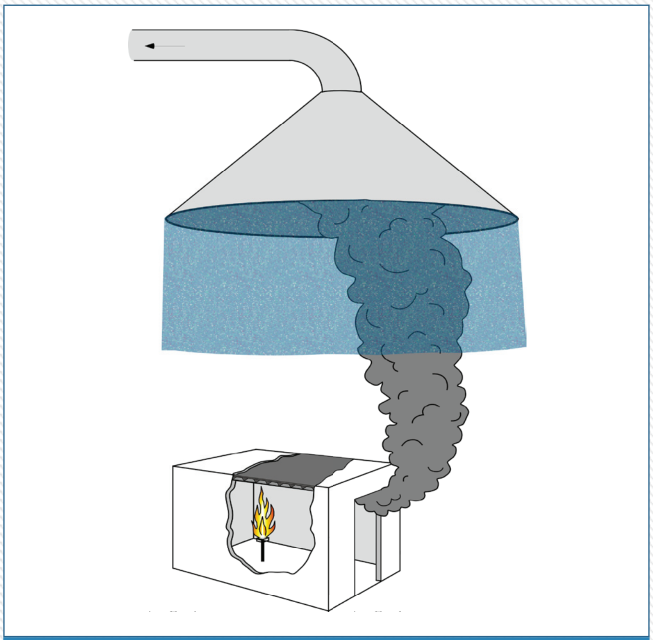


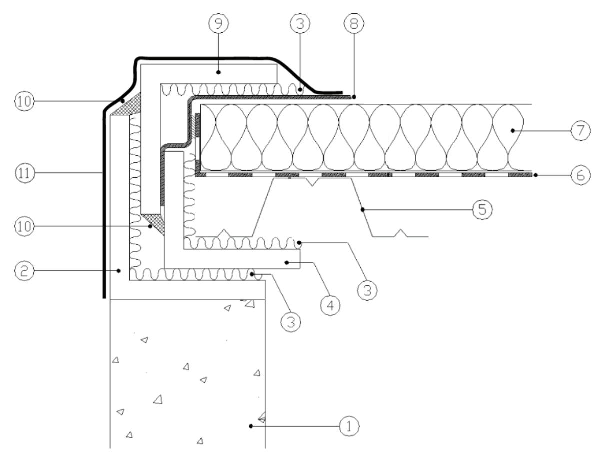
Figure 2: Schematic drawing of the test set-up under a large calorimeter hood

MOUNTING

Figure 3: Substantial smoke release through the roof

In the final test configuration, the complete roof assembly is mounted in a closed frame on top of the test room. The frame is set at a slope of 2%, with the lower side above the back wall. The channels in the steel deck are laid parallel to the length of the building. The thickness of insulation material is varied according to its declared thermal conductivity so as to achieve the same R-value.

The most critical part of the roof assembly is the edge detail. It is very important to ensure that combustible gases and smoke can not escape through the roof assembly or its edges, so called 'venting' (**Figure 3**). Tests carried out during the development of this test method showed that when 'venting' occurs the heat release measurement is unreliably low and flashover is inhibited. The test is thus no longer representative of reality and repeatability is lost. The edge detail is constructed as below (**Figure 4**).



1. non-combustible lightweight concrete wall
2. frame permanently attached to the room
3. ceramic wool
4. bottom frame
5. steel deck
6. vapour control layer
7. thermal insulation
8. waterproofing membrane
9. top frame
10. welds, at two points on each side
11. bituminous waterproofing membrane strip to seal the deck

Figure 4: Schematic of the edge detail

REPEATABILITY OF THE TEST

In order to prove that the test method is repeatable, two tests with expanded polystyrene (EPS) insulation were performed during the development of the final test conditions. Flashover was observed in both tests [Reference 1]. The repeatability of the test method is therefore good.

CLASSIFICATION CRITERIA

This newly developed reference scenario intends to assess the full-scale behaviour of insulated steel deck flat roof assemblies and can be used for testing in end-use configuration. However, in order to use the test method as a classification system, clear pass/fail criteria are required.

The following failure criteria are proposed and have been used for the results shown in this report.

- When flashover occurs during the test or during the observation period after the burner is stopped (**Figure 5**).

Figure 5: Illustration of flashover during the test

- When the temperature recorded by the thermocouples between the insulation and the waterproofing membrane exceeds 200 °C – signifying loss of insulation.

- When the insulation has disappeared completely in the roof above the doorway. (The doorway is the furthest away from the burner and the roof there is not in direct contact with the flames, which means that the fire has spread beyond the direct vicinity of the burner.)

COMPARISON OF TESTS OF FLAT ROOFS INSULATED WITH DIFFERENT INSULATION MATERIALS

A group of flat roofs containing different insulation materials was tested under the final test conditions and the results are given below.

Applying the proposed pass/fail criteria to the data for the different insulation materials, rock mineral fibre and rigid polyisocyanurate (PIR) passed the test whilst EPS failed the test.

EPS caused flashover. At flashover, the fire continued until all the material was burned. It did not self-extinguish. A back-flash occurred, on several occasions, after manual extinction. The integrity of the roof was completely destroyed.

Flat roofs insulated with rock mineral fibre and PIR did not exhibit flashover and the heat release rate was limited. The temperature on the outside of the insulation stayed well below 200 °C and there was no venting. The insulation remained in place over the entire roof. The thermocouple temperatures from between the insulation and the waterproofing membrane stayed low during the entire test.

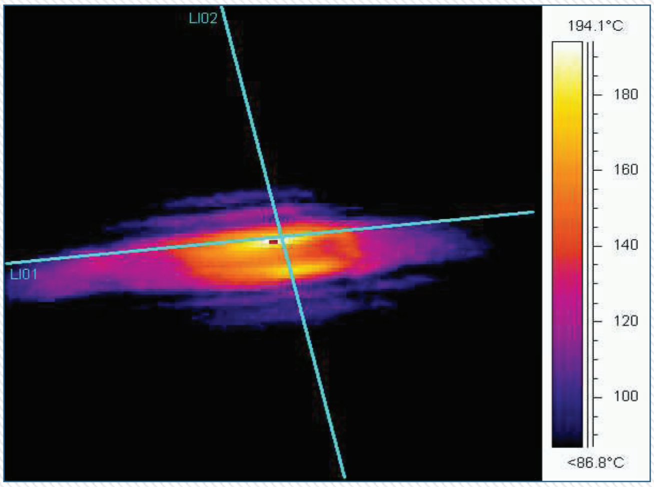
For the roof insulated with PIR, the insulation was charred over the whole surface, above the burner to about 75 % of the thickness, but with the degree of char decreasing with increasing distance from the burner. The flames self-extinguished soon after the burner had stopped.

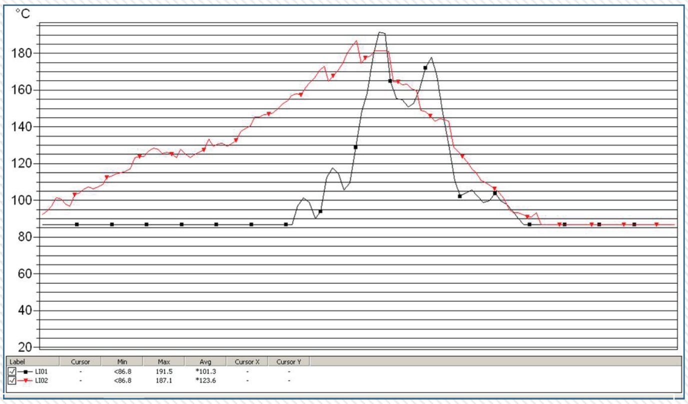
The rock mineral fibre insulation was visibly heat damaged to about 30 % of its thickness.

Figure 6 shows thermographic images taken towards the end of the tests. The graphs show upper surface temperature profiles on the lines plotted on the thermographic images. For both rock mineral fibre and PIR, the upper surface temperature of the roof was still low at the end of the test, while for EPS the roof temperature at 22 minutes reached 200 °C at which point thermographic imaging was interrupted.

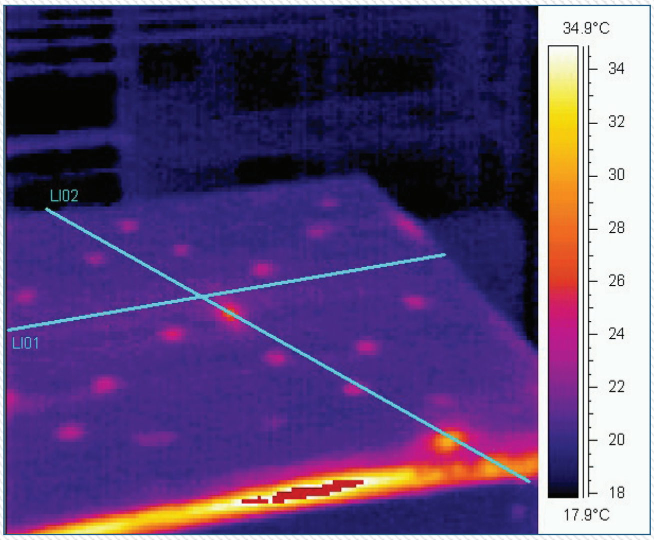
The PIR insulation material used in the tests also achieves FM 4450 class I, whilst neither of EPS test samples reach this benchmark. The rock mineral fibre appeared not to have been tested to FM 4450 but it is assumed that it would pass. This indicates a promising correlation between this test method and FM4450.

Correlation with FM 4450:
Combustible insulation materials can, by regulation, be applied directly to a steel deck in the USA, if the assembly meets the requirements of the Factory Mutual standard, FM4450. Part of this FM standard is a fire test, which is performed on a complete roof assembly, designed so as to simulate the end use application.

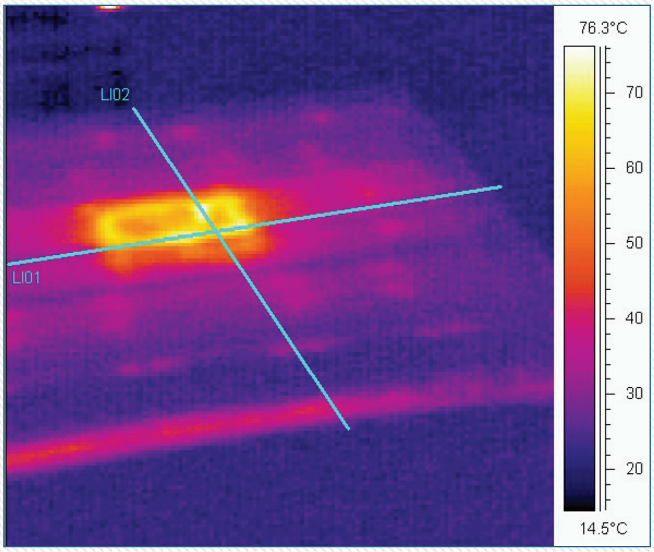


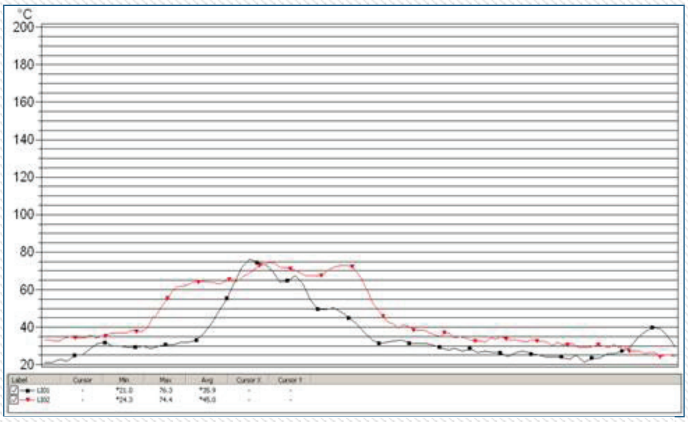


Flat Roof Insulated with EPS
Elapsed time = 22:00 minutes



Flat Roof Insulated with Rock Mineral Fibre
Elapsed time = 30:00 minutes



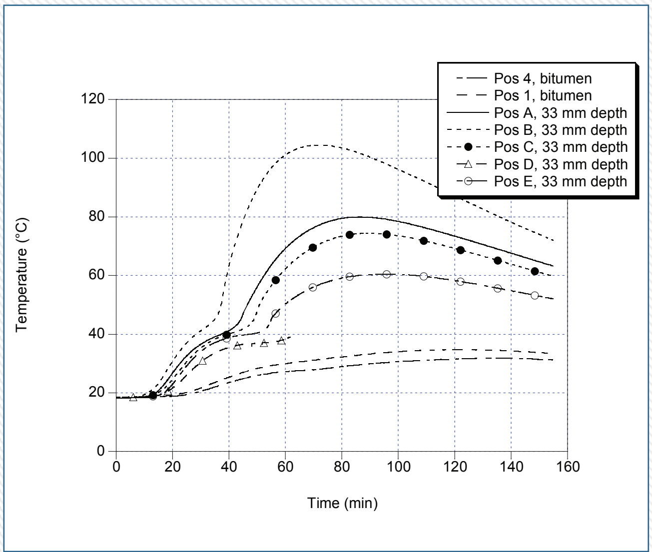


Flat Roof Insulated with PIR
Elapsed time = 29:30 minutes

Figure 6: Thermographic images recorded from above the upper surface of the roof assembly and graphs of the surface temperature profiles along the latitudinal and longitudinal lines L01 and L02

PUNKING

Figure 7 shows a temperature increase in the rock mineral fibre insulation after the burner had been shut off. This is interpreted as some onset of punking after the burner was extinguished. The cellular plastic insulation materials tested did not exhibit punking.



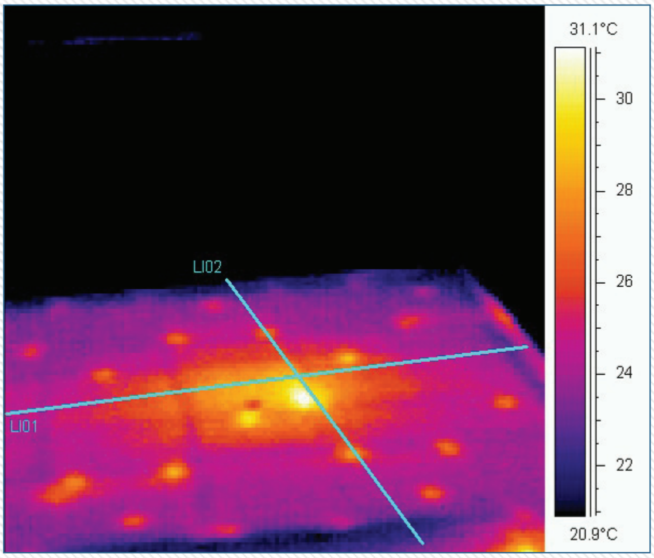


Figure 7: Temperatures within the insulation (0-160 minutes) in roof assembly insulated with rock mineral fibre. Thermocouples in positions 1 and 4 are at the interface between the insulation and the waterproofing membrane. Those at positions A to E are buried 33 mm below the top surface of the insulation material. Thermographic image recorded from above the upper surface of the roof assembly insulated with rock mineral fibre after 1 hour and 40 minutes

CONCLUSIONS

A project was undertaken to develop a test method for the assessment of the fire behaviour of insulated steel deck flat roof assemblies above a developing internal fire. The test method was derived from the ISO 9705 test with a minimum of modifications.

An extensive research program demonstrated that this newly developed test method can give repeatable results, which makes it suitable for the assessment of the full-scale fire behaviour of steel deck flat roof assemblies. The experience from this research program has made it possible to propose pass/fail criteria.

The results obtained with rock mineral fibre and PIR insulation materials show acceptable performance. Flashover is not observed. PIR insulation gave some contribution to the rate of heat release while rock mineral fibre showed some onset of punking after the test.

For EPS materials, flashover occurs and damage of the insulation material is complete.

Promising correlation was found with the results of testing to the FM4450 standard.

The test allows the evaluation of the risk of punking.

References

[1] *Assessment of the Fire Behaviour of Insulated Steel Deck Flat Roofs. Test Method Based on the ISO 9705 Room Corner Test*, Reference document based on Bestrahlung mit einer Infrarotlampe, Untersuchungsbericht, 2004