PU Europe FIRE SAFETY HANDBOOK

COMBUSTIBILITY BEHAVIOUR OF INSULATION PRODUCTS

SMOULDERING AND CONTINUOUS GLOWING

Smouldering and continuous glowing are slow internal combustion processes that can lead to fires breaking out some distance and time away from the original source of ignition.

There is no evidence that rigid PU insulation smoulders or shows continuous glowing. For this to occur an open porous material is necessary, which is not the case for PU insulation, but it is for many natural and synthetic materials, e.g. wood shavings, cotton, wool, etc. and a number of mineral wool products.

A new European test has been developed and published as EN 16733. Some countries, e.g. Germany, Italy and Austria, consider this criterion relevant for fire safety. PU insulation products do not need to be tested against European or national tests as they have not been shown to smoulder and so are not included in the smouldering product list. In reality, no incidents involving PU have been observed.

SMOKE AND SMOKE TOXICITY

Smoke density (obscuration) is an additional classification to each of the fire classes A2 to D in the Euroclassification system for reaction to fire. PU insulation products with CE mark carry a fire and a smoke class (see Reaction to fire classification in the section European fire standards and national legislation). PU insulation products meet the smoke requirements set by regulations for the applications they are used in.

In addition, it is possible to obtain wider approvals based on risk assessment [1].

Smoke toxicity is not part of the Euroclassification system, but it was part of the FSE assessments for special approvals, mentioned in the above paragraph (see also section: Fire safety in buildings).

There can be some further national limited smoke toxicity requirements. In Germany, non-combustible products for escape ways were, because of the nature of this application, subject to toxicity testing, as long as they were classified according to the national standard DIN 4102. With the introduction of the European classifications according to EN 13501, this requirement has disappeared because authorities have accepted that, with a very strict limitation of contribution to fire and smoke development, also the risk caused by toxic combustion gases is very limited. In France, in publicly accessible buildings a requirement asks for synthetic materials and products (construction or decorative) to have a limited nitrogen and chlorine content. For thermal insulation behind a 15 minutes fire resistant thermal barrier, no specific requirement applies.

[1] ISOPA Factsheet: *Risk assessment of smoke in buildings: Fire Safety Engineering and PU Insulation products* (January 2008)

PERFORMANCE IN APPLICATION-RELATED TESTS

COMBUSTIBILITY BEHAVIOUR OF PU (PUR/PIR) INSULATION

Structures insulated with PU products show excellent fire performance in real fire scenarios due to their thermosetting character and high thermal stability. PU insulation neither melts nor drips when heated. The char emerging on the surface of the insulation protects the core from decomposition, so the integrity of the structure is maintained for a long time even if heavily attacked by the fire. Structures insulated with PU insulation can perform better than or give performance equivalent to structures insulated with other mainstream non-combustible insulation materials.

Although PUR products can perform well in a fire, the PIR insulation products offer reduced combustibility, greater working temperature ranges, increased char formation and increased heat stability, and are therefore generally more suitable for higher risk applications.

Figure 1: Build up according to prDIN 4102 p20

Figure 2: Damage of the test sample: render finishing

EXAMPLE 1: FAÇADE FIRE TEST ON PU EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM (ETICS) [2]

An ETICS system was tested in 2002 in accordance with the German standard, prDIN 4102-20 'Besonderer Nachweis für das Brandverhalten von Außenwandbekleidungen'. This is now a full standard (DIN 4102-20) and has been proposed to be used as part of the future harmonised European test procedure.

EXECUTION OF TESTS:

FMPA Leipzig (Germany)

The test façade was arranged in a corner configuration with an opening (simulating a window) at the bottom. The flames from a wooden crib located in the opening attacked the cladding of the façade. A crib of 25 kg was used as the fire load.

Temperature measurements were carried out at the surface and behind the rendering and within the PUR boards in different levels of height of the façade. The test and observation time were a total of 60 minutes.

After ignition of the wooden crib the flames impinged on the surface of the PU ETICS system. The wooden crib was almost totally consumed after 14 minutes. However, further fire exposure was generated by the burning wooden window frame and the burning rolling shutter box. After 50 minutes the fire had extinguished totally and all flaming had stopped by self-extinguishment.

The temperatures reached 1 000 °C in the opening and even 800-600 °C between 1 m to 3 m above the opening. At the 4-5 m level the temperatures decreased to 200 °C, which corresponded to the maximum observed flame height which reached almost to the top of the façade at 5 m level. However, the measured temperatures within the PU foam (75 mm to 150 mm from the outside surface) remained quite low and did

[2] Isopa Factsheet: *Façade fire test on PUR External Thermal Insulation Composite System (ETICS)*

Figure 3: Damage of the test sample: PU insulation layer

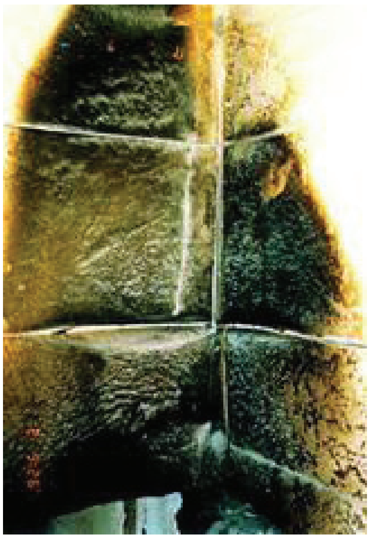


Figure 4: Damage of the test sample: fire room

not exceed 25 °C to 60 °C compared to the temperatures at the outside surface of 600 °C to 800 °C.

After the test the rendering was removed from the PU. No breaking of the rendering had occurred. The foam was only discoloured and partially destroyed within the surface layer and in a limited area, where the temperature from the fire exposure exceeded 200 °C. There was no spread of fire within the PU itself or outside the region of direct flame exposure.

DISCUSSION OF RESULTS:

The fire exposure was increased by the installation of a wooden window frame and a combustible rolling shutter box. Despite this increased fire loading, the PU ETICS façade showed very limited response to the fire exposure and then only where a high enough flame temperature occurred. No further flame spread was initiated by the PU rigid foam itself. All the flaming stopped by self-extinguishment.

MORE DETAILS:

Isopa Factsheet: *Façade fire test on PU External Thermal Insulation Composite System (ETICS)*. http://www.isopa.org/media/1090/facade61.pdf

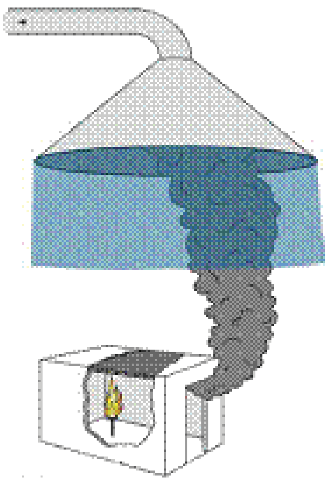


Figure 5: Schematic drawing of the test set-up under a large calorimeter hood

EXAMPLE 2: ASSESSMENT OF THE FIRE BEHAVIOUR OF INSULATED STEEL DECK FLAT ROOFS

Europe has no harmonised test standard designed to simulate the performance of an insulated steel deck flat roof above a developing internal fire, neither for regulatory nor insurance purposes.

A test programme was therefore initiated in 2004 with the objective of developing a small room scale test method for this purpose.

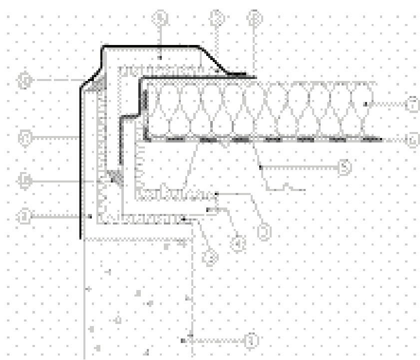
In order to use the test method as a basis for a classification system for steel deck flat roof assemblies insulated with different insulation materials, clear pass/fail criteria were developed.

EXECUTION OF TESTS:

SP (Sweden)

Test Configuration

The geometry of the test apparatus is the same as for the 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 5).



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 6: Schematic of the edge detail

The complete roof assembly was 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.

DISCUSSION OF RESULTS:

The research programme demonstrated the repeatability of results, which makes it suitable for the assessment of the full-scale fire behaviour of steel deck flat roof assemblies.

The results obtained with the non-combustible fibrous product and PIR insulation show acceptable performance. Flashover is not observed, the temperature on the outside of the insulation stayed well below 20 °C and there was no venting. The insulation remained in place over the entire roof. PIR insulation gave some contribution to the rate of heat release while the non-combustible fibrous product showed some onset of glowing after the test. Some other insulation products failed.

The PIR insulation product used in the tests also achieves FM 4450 class I. This is an indication of a possible correlation between this test method and FM 4450.

MORE DETAILS:

PU Europe factsheet: *Assessment of the fire behaviour of Insulated steel deck flat roofs*. https://www.pu-europe.eu/fileadmin/documents/Factsheets_public/Factsheet_2_Assessment_of_the_Fire_Behaviour_of_Insulated_Steel_Deck_Flat_Roofs.pdf

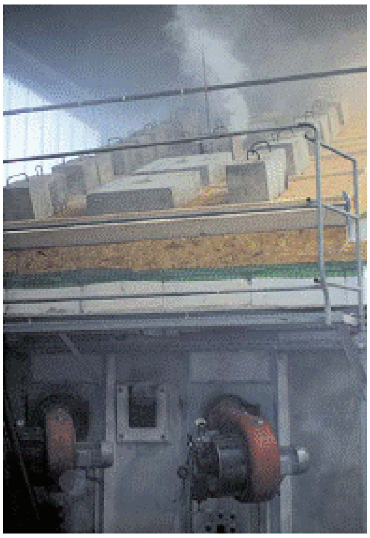


Figure 7: Test rig at the end of the test

EXAMPLE 3: FIRE RESISTANCE TEST ACCORDING TO EN 1365-2 OF A PITCHED ROOF INSULATED FOR PU BOARDS

A pitched roof structure insulated with PU insulation was tested in 2004 in accordance with the European Standard EN 1365-2: 1999 (Fire resistance tests for load bearing elements, Part 2: floors, roofs).

The tested assembly consisted of rafters, 19 mm thick tongue and groove timber boards above the rafters, bituminous felt, 100 mm PU insulation boards covered with 22 mm oriented strand board (OSB).

EXECUTION OF TESTS:

FMPA Leipzig (Germany)

Observations during the test:

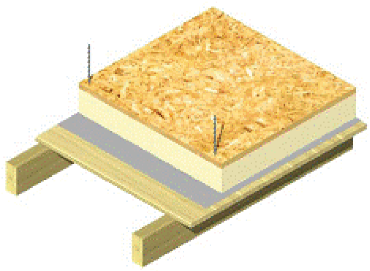


Figure 8: Test assembly

- 21 minutes after the start of the test, the timber boarding burned through and the PU insulation boards were exposed to the fire.
- Only after 37 minutes a slight increase in temperature was observed on the upper surface of the test rig but the limiting temperature rise of 180 K was never reached during the duration of the test.
- After 41 minutes some smoke was released through a joint but the structure was still not visibly damaged.
- In the 46th minute the test had to be stopped to prevent the structure from collapsing because the

rafters had been weakened by the fire.

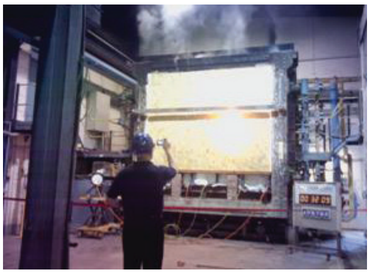
- At the end of the test, the PU insulation boards were partially charred but had prevented the fire from reaching the upper layers of the test rig.

DISCUSSION OF RESULTS:

The roof structure was classified REI 45. This means that three critical criteria were met for a minimum of 45 minutes: stability or mechanical resistance (R), room enclosure (E) and thermal insulation (I). Pitched roof constructions containing non-combustible non-cellular insulation materials hold REI 30 and REI 45 certification. Pitched roof constructions containing PU insulation boards can therefore demonstrate equivalent performance to, or better performance than, similar constructions containing non-combustible non-cellular insulation materials.

MORE DETAILS:

PU Europe factsheet: *The primacy of fire resistance as demonstrated by the behaviour of different insulation materials in pitched roofs and timber frame walls.* https://www.pu-europe.eu/fileadmin/documents/Factsheets_public/Factsheet_1_Fire_resistance_of_different_insulation_materials_in_pitched_roofs_and_timber_frame_walls.pdf



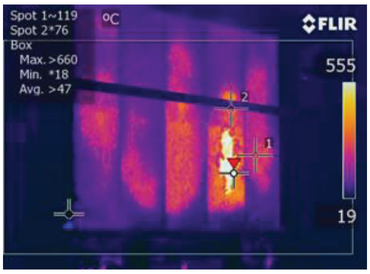


Figure 9: Test build-up according to EN 1365-1: the unexposed face of the specimen and thermographic image during test

EXAMPLE 4: FIRE RESISTANCE OF TIMBER FRAME CLOSED PANEL SYSTEMS USING POLYURETHANE AND MINERAL WOOL WITH EN 1365-1

This test was conducted in 2011 with a view to comparing typical timber frame closed panel systems using PU and mineral wool with EN 1365-1 (Fire resistance tests for load-bearing elements – Walls). The build-ups were agreed with the UKTFA (UK Timber Frame Association) and Exova (Warrington Fire UK) and used exactly the same materials and fixings. The internal exposed (to fire) face was covered by a 12.5 mm standard gypsum wallboard. For the unexposed face cladding, a 11 mm OSB (Orientated Strand Board) was used. Both build-ups used C16 grade softwood 140 x 38 mm studs (at 600 mm ctrs), headbinder and soleplate. The insulation was fitted between the studs.

- (Test 1) 140 mm FrameTherm Slab 35 (mineral wool)
- (Test 2) 80 mm foil faced PIR

Both tests were loaded to 11 kN per metre.

EXECUTION OF TESTS:

Exova (Warrington Fire UK): WF Report N° 306703

Test 1 (140 mm FrameTherm 35 Mineral Wool)
The load-bearing capacity was maintained for 32 minutes (test stopped at 32 minutes). The insulation lost its integrity after 31 minutes.

Test 2 (80 mm foil faced PIR)
The load-bearing capacity was maintained for 39 minutes (test stopped at 39 minutes). The insulation lost its integrity after 38 minutes.

DISCUSSION OF RESULTS:

All external timber frame walls in the UK require a minimum of 30 minutes fire resistance. The mineral wool build-up (T1) achieved 32 minutes and met this requirement. Test 2 (PIR build-up) used the same materials, same fixings, same U-value (0.27) with 60 % of the insulation thickness thanks to a lower thermal conductivity. With 39 minutes, the level of fire resistance was approximately the same and the regulatory requirements were also clearly met.

MORE DETAILS:

PU Europe factsheet: *Fire Resistance of timber frame wall constructions.* https://www.pu-europe.eu/fileadmin/documents/Factsheets_public/Factsheet_20_Fire_resistance_of_timber_frame_wall_constructions.pdf

EXAMPLE 5: COMPARATIVE TESTS OF FULLY FURNISHED ROOMS, INSULATED WITH NON-COMBUSTIBLE MINERAL WOOL AND WITH PU FOAM

Tests were done in 2016 in order to find out whether the contribution of the building envelope to smoke toxicity in a building fire starting in a furnished room is relevant.

The tests were performed in two identically furnished rooms with a different envelope construction: insulated with non-combustible mineral wool and with PU foam.

EXECUTION OF TESTS:

Exova (Warrington Fire Belgium)

A test room according to ISO 9705 with door opening was used. The wall build-up (insulation products and internal lining) was mounted inside this room. The wall of the test room was insulated with PIR in the first test and with mineral wool in the second test. Details for the insulation products are given in Table 1. In order to achieve a fair comparison, the insulation thicknesses differed (80 m vs.140 mm) so that the walls U-values in both tests were the same, however leaving the inner volume of the room identical. The insulation layer was lined with 12.5 mm plasterboard. A power socket was placed near to the main fire-load, to create a realistic weak spot in the plasterboard lining.

	Test 1 PIR	Test 2 MW
Reaction to fire classification	E	A1
Thermal conductivity *(W/m·K)*	0.022	0.035
Thickness *(mm)*	80	140

Table 1: Insulation products in test 1 and test 2

Both rooms were identically furnished, with a curtain (fabric), an armchair, a small table, a TV cabinet, a TV and a bookcase.

The fire scenario was chosen in order to simulate a waste bin fire in a room. A gas burner was used to simulate a waste bin fire underneath the curtain and initiate the fire.

The time of ignition of the armchair was chosen to be the starting point of the analysis, to minimise variations in fire development in the early stages of the fire.

DISCUSSION OF RESULTS:

- In the early stage of a fire, when people still could escape, the contents of a room are far more important for fire development, smoke obscuration and toxicity than the contribution of the envelope ;

- Contribution of the building envelope to the development of heat and smoke starts only in a later phase of a fire and is not significant compared to the effects from burning building contents;
- Performance of the complete build-up is much more relevant compared to the individual construction products only;
- Toxicity is only to a certain degree a material property. It is strongly influenced by the environment, availability of oxygen, thermal attack, airflow and surfaces available for combustion;
- As smoke inhalation often contributes in case of occupant fatalities;
  - Early detection is key;
  - Other measures like early detection, extinction and safe egress are key for safety.

MORE DETAILS:

Contribution to toxicity of different construction products in a furnished room fire, Roy Weghorst and al., Fire and materials 2017

PU Europe factsheet: *Fire performance of thermal insulation products in end-use conditions – Building envelope vs building content*. https://www.pu-europe.eu/fileadmin/documents/Factsheets_public/Factsheet_24D_Fire_performance_of_thermal_insulation_products_in_end-use_conditions_-_Building_envelope_vs_building_content.pdf