White Paper

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Large scale investigation of PV roof assemblies and the role of a mitigation layer

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Background

The implementation of the European Union's Energy Performance of Buildings Directive (EPBD) is expected to drive a substantial expansion of building-applied photovoltaic (BAPV) installations on European rooftops. In this context, the insurance sector plays a pivotal role in overseeing and mitigating fire risk through its underwriting practices and risk-engineering requirements.

The addition of BAPV introduces additional combustible elements on the roof, creating new structures that significantly alter flame spread mechanisms, heat flux distribution, and overall fire dynamics on flat roofs[1]. These effects, however, can be effectively mitigated when the roof is assessed and designed as a complete system rather than focusing on individual materials.

To assess the fire performance of flat roofs with EPS insulation equipped with BAPV systems, IVH and EUMEPS commissioned several large-scale fire tests at the Twente Safety Campus facility in the Netherlands. The tests reflect typical European commercial and industrial flat-roof configurations. The tests were performed by KIWA BDA Testing with DBI (The Danish Institute of Fire and Security Technology), witnessing all tests and analysing the outcomes based on visual inspection and temperature measurements.

Objectives

The goal of the testing campaign was to determine the effectiveness of different protective layers in preventing ignition and damage of flat roofs in combination with PV panels, with a focus on EPS insulation. In detail, the horizontal flame-spread behaviour beneath an East/West-oriented PV array was evaluated, as well as the vertical fire penetration into the building.

Test Configurations and Instrumentation

Test design

All tests were performed with a consistent ignition scenario by using a 15-kW gas burner operated for 10 minutes under the edge of a PV module in an East/West-oriented PV array on a 7m×7m roof build-up. The 12-module PV array was mounted directly on the roofing membrane. A Broof(t1) membrane was used in all roof built-ups. The square burner, as defined in CLC/TR 50670[2], was installed at the midpoint of the long edge below a PV module at the corner of the array. Further information and a detailed description of the individual roof built-ups specified in KIWA BDA reports[3].

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[1] J. S. Kristensen, 'Fire risk associated with photovoltaic installations on flat roof constructions – Experimental analysis of fire spread in semi-enclosures', Doctor of Philosophy, The University of Edinburgh, Edinburgh, 2022.
[2] European Committee for Electrotechnical Standardization, 'CLC/TR 50670:2016 External fire exposure to roofs in combination with photovoltaic (PV) arrays - Test method(s)', CENELEC, 2016.
[3] KIWA BDA Test report 25L0198/1 Large-scale fire test on a flat roof system with EPS insulation and a cement-bonded particle board fire barrier, with a PVC roof waterproofing sheet.

Test instrumentation

To support visual observations during and after the tests, a large number of thermocouples (TCs) were installed below the waterproofing membrane, on the top of the insulation and on the top of the trapezoidal steel deck in each test.

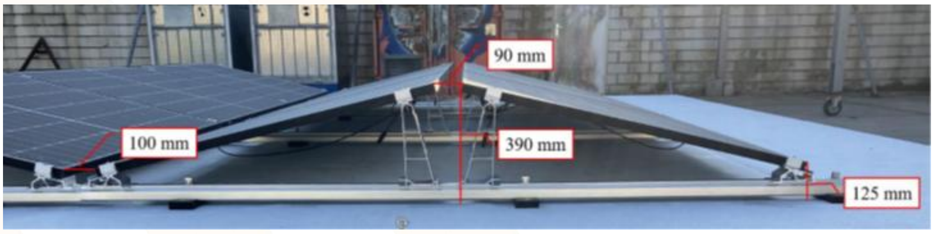

Fig. 1: Side view of the East/West-oriented PV array.

Test build-ups

All described test results in this white paper used a (BROOF(t1)) PVC Roofing membrane and a trapezoidal steel supporting deck. Two different roof insulations were considered:

- Expanded Polystyrene (EPS)-based combustible insulation, Euroclass E (DAA, 100 mm to 260 mm);
- Mineral wool insulation: 120 mm, Euroclass A1.6.

Three different mitigation layers options were tested:

- Cement-Bonded Particle Board (A2-s1,d0): 12 mm3, and 8 mm4;
- Cement Board (A1-s1,d0): 6 mm 5.

Key Findings

Horizontal Fire Spread

All tests were analysed and evaluated by DBI, with detailed information in the reference reports[4]. In none of the tests where class E insulation material was used in combination with a cement

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KIWA BDA Test report 25L0271/1 Large-scale fire test on a flat roof system with EPS insulation and a cement-bonded particle board fire barrier, with a PVC roof waterproofing sheet

KIWA BDA Test report 25L0271/2 Large-scale fire test on a flat roof system with EPS insulation and a cement-bonded board, with a PVC roof waterproofing sheet.

KIWA BDA Test report 25L0198/2 Large-scale fire test on a flat roof system with MWR insulation and PVC roof waterproofing sheet.

[4] Large-scale tests of flame spread on roof build-ups with PV systems: Phase I', DBI - The Danish Institute of Fire and Security Technology, SIEC21006-001, Nov. 2025.

Large-scale tests of flame spread on roof build-ups with PV systems: Phase II', DBI - The Danish Institute of Fire and Security Technology, SIEC21006-002, Nov. 2025.

board-particleboard, significant self-sustained flame spread outside the PV arrays was observed (Fig. 2).

The horizontal fire spread on the roof was efficiently limited by the cement particle board, which absorbed the energy and prevented self-sustained ignition. The fire self- extinguished within a short time and only one PV module was damaged in the test with the cement-fibre board used as a mitigation layer. A similar trend was observed for the 12 mm board (Fig. 2a) and for the thinner cement board options, with 8 mm board (Fig.2b) and 6 mm board (Fig. 2c).

Fig. 2: After fire damage BAPV on roof with a 12 mm cement board (left), 8 mm board (middle) 6 mm board (right).

For comparison purposes, the performance of an unprotected non-combustible insulation roof (Fig.3) was analysed. Once ignited, the roof showed intense and uncontrolled horizontal fire propagation: the gas burner had to be removed after *ca.* 5 min to avoid an explosion of the gas line. The fire was extinguished because of safety and environmental concerns after 12 minutes.

Fig. 3: Fire behaviour of BAPV on a flat roof with A1-insulation, during and after extinguishment.

Performance of Mitigation Layers

The fire-mitigation mechanism of the cement-bonded particle board is primarily associated with its pronounced heat-sink capacity, which reduces the energy available for ignition, limits the development of self-sustained flame spread, and prevents ignition of the underlying EPS layer (Fig. 4). Slight retraction and shrinkage of the EPS were observed exclusively in the area directly beneath the burner placement.

Fig. 4: Fire damage on a roof built-up with a 12 mm Cement board (A2) mitigation layer.

The thinner cement-bonded particle board exhibited a comparable effect in limiting horizontal flame spread, with fire propagation confined to a single PV module.

The EPS insulation retracted under heat exposure, shrank, and did not contribute further to flame spread. The trapezoidal steel deck remained undamaged (Fig. 5). Similar performance was identified with the thinnest 6 mm A1-board (Fig. 6).

Fig. 5: Fire damage on the roof built-up with an 8 mm Cement board (A2) mitigation layer.

Fig. 6: Fire damage on the roof built up with a 6 mm cement board mitigation layer.

Even under large-scale roof fire conditions, experimental results demonstrated that the mitigation layer effectively protects the roof insulation. Large-scale fire tests performed on a bitumen[5] waterproofing membrane system showed that, even in a fully developed fire scenario

[5] KIWA BDA Test report 25L0053/1 Large-scale fire test on a flat roof system with EPS insulation and a cement-bonded particle board fire barrier, with a bitumen waterproofing sheet.

leading to the complete loss of the photovoltaic (PV) modules, the cement board effectively prevents fire penetration into the insulation layer, as illustrated in Fig. 7 (right)

Fig. 7: Fire damage on the roof built-up with bitumen membrane.

Conclusions

Visual observation and temperature measurements of large-scale tests of roof construction built-ups with building-applied photovoltaic (BAPV) arrays, confirmed that the correct installation of a cement- bonded particle board on the top of the roof insulation:

- Significantly reduces the probability of self-sustained flame spread below the BAPV system (horizontal fire spread);
- Acts as a heat sink and prevents vertical fire spread into the roof system, including the insulation.

The use of non combustible insulation without any additional protective layer resulted in an uncontrolled fire development, with extensive horizontal and vertical damage. Due to safety and environmental concerns, the testing facility decided to terminate the test.

The use of these kinds of cement boards can be considered as a protective measure for roof assemblies where BAPV systems are installed. Its application provides an additional layer that limits the thermal impact on the underlying components, regardless of the insulation material used.

Disclaimer

All information is provided to the best of our knowledge and belief, without guarantee. Any liability arising from the use or interpretation of this information is excluded.

The results presented herein are limited to the specific roof construction build-ups tested, incorporating a comparable building-applied PV system. The findings indicate a potential reduction in fire-related consequences when cement-bonded particle board is introduced as a mitigation layer between the roof covering and the underlying EPS insulation.

Accordingly, these results should be regarded as a basis for further technical discussion on mitigating the consequences of PV-related fires, rather than as definitive solutions. These tests were not conducted in accordance with standardised methods, do not represent an approved system configuration, and have not been subject to formal fire classification.