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Leipzig Institute for Materials Research and Testing

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Work Group 3.2
Fire Behaviour of Building Components and special Constructions

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# Test Report No. PB 3.2/21-120-1

25 July 2022
No. Copy 1

Translation from German

| | |
|---|---|
| Subject matter: | Tunnel fire test on two structural joints sealed with Tendonol®-FDS (Flexible Dry System) in a horizontal supporting structure with additional fire protection reinforcement of the reinforced concrete sample with a one-sided thermal load from below using an RWS fire curve over 180 minutes with a subsequent holding and cooling phase of 90 minutes in accordance with directive Efectis-R0695:2020. |
| Client: | VARIO Baustoffsysteme GmbH<br>Dielinger Str. 47<br>32351 Stemwede |
| Date of order: | 09 June 2021 |
| Samples received on: | 03 May 2022 |
| Sampling: | Not official |
| Date of testing: | 19 May 2022 |
| Person in charge: | S. Treutler, M.Sc.<br>C. Kramer, M.Eng. |

This test report consists of 9 pages and 4 enclosures.

## Table of contents

## 1 General matters and requirements

On 9 June 2021, the company VARIO Baustoffsysteme GmbH commissioned MFPA Leipzig GmbH with a tunnel fire test on two structural joints sealed with Tendonol®-FDS (Flexible Dry System) in a horizontal supporting structure. In addition, the reinforced concrete samples used for this purpose were reinforced with Aestuver TX or Promatect-T fire protection panels.

This test report describes the structural design including assembly procedure, the test conditions and the results obtained for the specific part described herein which was tested in accordance with directive Efectis-R0695:2020. Any considerable material deviation from the tested construction in terms of the size, structural details, materials, loads, stress statuses, marginal conditions, or means of fastening is not covered by this test report.

The fire test was performed at the Fire Test Centre of MFPA Leipzig GmbH, MFPA-Allee 1, 04509 Laue bei Delitzsch, Germany.

## 2 Supporting structure

In coordination with the client, the supporting structure consisted of three reinforced concrete bars with individual dimensions of w x l x d = 430 mm x 1700 mm x 300 mm. The overall dimensions of the sample were w x l x t = 1350 mm x 1700 mm x 300 mm. The reinforced concrete samples were produced from concrete with stability class C30/37. Concreting was performed by MFPA Leipzig GmbH. After stripping, the samples were stored under dry ambient conditions. On the day of the test, the age of the concrete was 106 days. The compressive strengths determined can be found in the test report PB 1.1/22-043-1.

For the tunnel fire test on two structural joints sealed with Tendonol®-FDS (Flexible Dry System), a horizontal solid part construction consisted of reinforced steel bars with an element thickness of 300 mm and a joint distance of 20 mm and 40 mm. The joint seals with a length of l = 1400 mm which was exposed to the flames were subjected to thermal stress from below on one side using the Rijkswaterstaat (RWS) fire curve and therefore tested in experiments. For an overview of the test set-up, the positioning of the joint seals and the specified measuring points, please refer to Enclosure 1.

## 3 Sample and installation

### 3.1 Description of the joint seals in a horizontal installation

The horizontal supporting structure which is described in section 2 was constructed by experts of MFPA Leipzig GmbH. Then, the structural joints were sealed with Tendonol®-FDS (Flexible Dry System) by the client. For this purpose, strands of Tendonol®-FDS (Flexible Dry System) were glued into the joints using Tendonol® Fire Protection Sealing Compound. The strands had a diameter of 45 mm for joint 1 and 55 mm for joint 2. The two outer reinforced concrete bars were then lined with Aestuver TX fire protection panels with a thickness of 25 mm. The centre bar was lined with a Promatect-T fire protection panel with a thickness of 25 mm. The cladding panels with a length of 1500 mm were fastened with ten drop-in anchors of type MKT N-K 6-20/59 and suitable washers in the reinforced concrete bars at a distance of a ≤ 600 mm. The edge distance of the means of fastening was approx. 50 mm. The fire protection panels were approx. 100 mm shorter than the reinforced concrete bars at the longitudinal sides in order to allow for stressless placement of the sample.

The installation position of the joint material is also summarised in Table 1.

*Table 1 Installation position of the joint material*

| Joint designation | Joint system | Joint width | Joint filling depth | Protrusion | Adhesion[1)] |
|---|---|---|---|---|---|
| Joint 1 horizontal alignment | Joint strands of Tendonol®-FDS (Flexible Dry System) (2.5 layers) l x w = 1000 mm x 20 mm Strand diameter 45 mm | 20 mm | 45 mm | 15 mm (side facing the fire) | glued on both sides in the joint face using Tendonol® Fire Protection Sealing Compound |
| Joint 2 horizontal alignment | Joint strands of Tendonol®-FDS (Flexible Dry System) (3 layers) l x w = 1000 mm x 40 mm Strand diameter 55 mm | 40 mm | 50 mm | 20 mm (side facing the fire) | glued on both sides in the joint face using Tendonol® Fire Protection Sealing Compound |

1) An element joint was positioned in the joint element. For this purpose, two strands were connected using a Tendonol®-FDS (Flexible Dry System) plug with a length of approx. 150 mm and sealed externally with Tendonol® Fire Protection Sealing Compound.

The entire sample was placed on the tunnel oven of MFPA Leipzig GmbH as a horizontal ceiling. In addition, the structural joints on the side facing away from the fire with cellular concrete blocks were covered, stuffed laterally and extended by 250 mm.

## 3.2 Building material characteristic values

At the time of the test, the stability and the humidity content of all building materials used corresponded roughly to the condition which is to be expected in common use. The building materials used for the tested construction with the given material parameters, building material classes, bulk densities and humidity contents are indicated in Table 2.

*Table 2 Building material characteristic values of the materials used to create the test construction*

| Building material designation | Thickness [mm] | Bulk density[1)] [kg/m³] | Humidity content [Weight %] | Building material classification |
|---|---|---|---|---|
| Aestuver TX fire protection panel | 25 | 884.1 | 2.82 | A1 acc. to EN 13501-1 |
| Promatect-T fire protection panel | 25 | 845.2 | 3.74 | A1 acc. to EN 13501-1 |
| Tendonol®-FDS (Flexible Dry System) | - | -[2)] | -[2)] | E acc. to EN 13501-1 |
| Tendonol® Fire Protection Sealing Compound | - | -[2)] | -[2)] | B-s1, d0 according to EN 13501-1 |

1) Bulk density in mounted state
2) not determined

# 4 Test set-up and performance

## 4.1 General information and test set-up

The fire test was performed at the tunnel oven of MFPA Leipzig GmbH. The sample was placed on the opening of the tunnel oven as a horizontal ceiling. The unilateral flame exposure of the sample was realised from the underside by eight diesel burners in total which are arranged at both longitudinal sides of the tunnel oven. For an overview of the test set-up, please refer to the Figure 1 below.

The installation of the sample on the tunnel oven of MFPA Leipzig GmbH is shown in Figure 1 below. The area of the sample which was directly exposed to the flames was approx.
l x w = 1400 mm x 1350 mm.

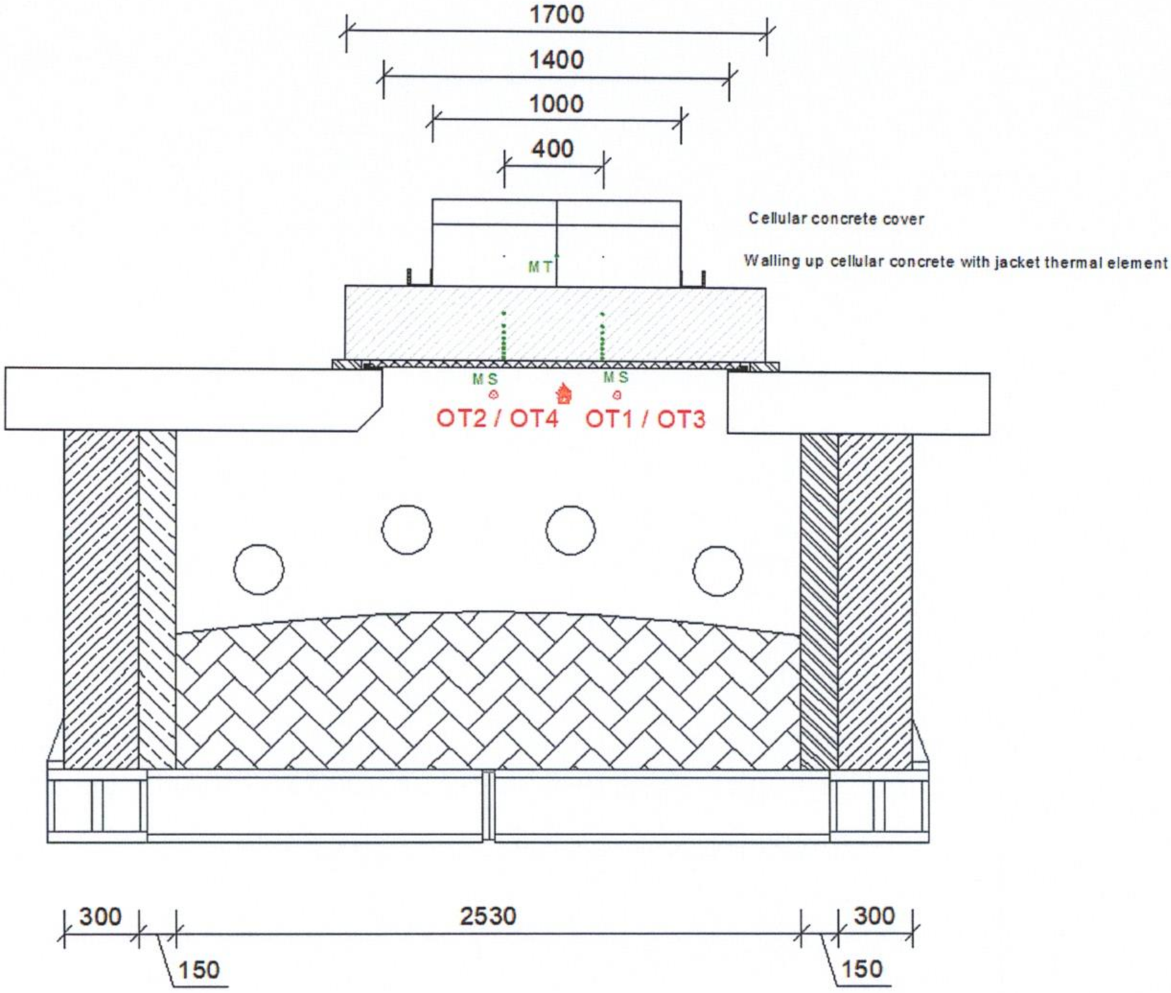


*Figure 1 Schematic representation of the test set-up (longitudinal section), incl. position of the sample on the tunnel test stand of MFPA Leipzig GmbH*

## 4.2 Thermal load

As unilateral thermal load from below, the RWS fire curve (cf. Table 3) was selected according to the coordination with the client.

*Table 3 Temperature/time development of the RWS fire curve*

| Time [min] | 0 | 3 | 5 | 10 | 30 | 60 | 90 | 120 | 180 | 190 | 210 | 240 | 270 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature [°C] | 20 | 890 | 1140 | 1200 | 1300 | 1350 | 1300 | 1200 | 1200 | 600 | 300 | 225 | 150 |

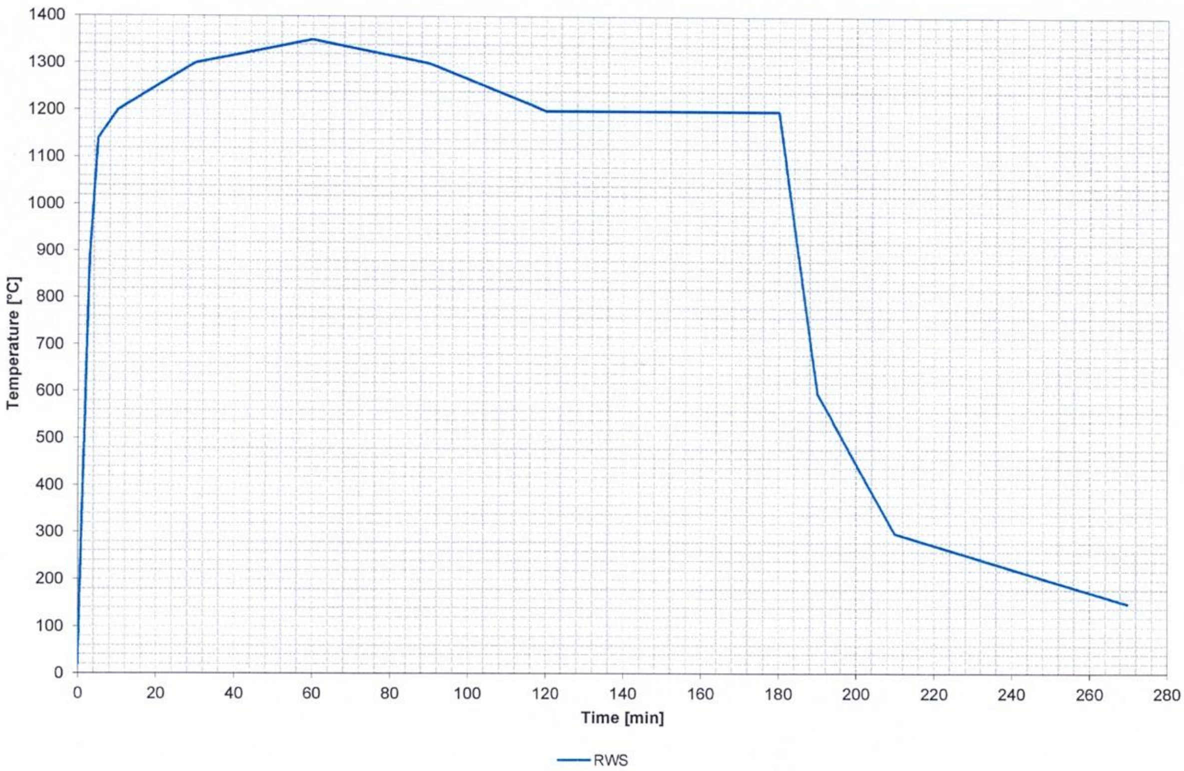


*Figure 2 Graphical representation of the RWS fire curve*

## 4.3 Measurement technology

The temperatures in the fire area were monitored and controlled using four jacket thermal elements of type K with a short-term measuring range of up to 1300 °C as well as four jacket thermal elements of type S with a maximum measuring range of up to 1600 °C. The thermal elements were positioned in the fire area so that the fire area temperatures were in each case measured approx. 100 mm below the sample surface and with a clearance of approx. 450 mm to the side walls.

Thermal elements at the edges of the reinforced concrete bars were set in concrete in nine different measurement levels (20 mm, 40 mm, 60 mm, 80 mm, 100 mm, 125 mm, 150 mm, 200 mm, 250 mm) to monitor the temperatures in the structural joints. The fastening of the spacers at the individual thermal elements of type NiCr-Ni was affected at the structural reinforcement of the sample.

The air temperature in the centre of the extended structural joints were also measured using jacket thermal elements of type NiCr-Ni. In addition, the temperature between the reinforced concrete bars and the fire protection panels was measured.

Enclosure 1 of this test report show the structure and the exact positions of the measuring points of the test construction.

The pressure in the fire area was measured in accordance with directive Efectis-R0695:2020 using differential pressure measuring transducers PU ± 500 Pa at a distance a = 100 mm to the furnace wall and to the test construction.

All fire area temperatures, the pressure in the fire area and the surface temperatures were measured and recorded every 6 seconds.

## 5 Test observations

The sample temperatures determined during the tunnel fire test, the fire area temperature and the pressure in the fire area can be found in Enclosure 4. The observations during the fire test are summarised in Table 4 and in a photo documentation in Enclosure 3.

*Table 4 Observations during the fire test on 19 May 2022*

| Testing time [min:s] | Observations during the test | Observation side [1) ] |
|---|---|---|
| 00:00 | Start of the test | - |
| 02:00 | Slight soot deposits on the fire protection panel | F |
| 04:00 | Some smoke escapes from the side of the joints at the joint material | FA |
| 06:30 | Formation of a white layer of ash on the joint material | F |
| 14:30 | Slight foaming of the joint material | F |
| 24:30 | Some smoke escapes from the side of joint 2, no further smoke escapes from joint 1 | FA |
| 35:00 | Escape of smoke from joint 2 increases slightly | FA |
| 106:00 | Slight brownish discolouration at the side of joint 2 | FA |
| 270:00 | Completion of the test in agreement with the client | - |

[1)] F = Side facing the fire FA = Side facing away from the fire

## 6 Test results

On 19 May 2022, MFPA Leipzig GmbH was commissioned by VARIO Baustoffsysteme GmbH to perform a fire tunnel test on the sample described in sections 2 and 3 in accordance with directive Efectis-R0695:2020 according to the RWS fire curve for a test period of 180 minutes.

The horizontally positioned joint seals were tested in a horizontal ceiling construction with an element thickness of the reinforced concrete bar of t = 300 mm.

The fire protection panels did not fall off during the entire fire tunnel test. However, cracks were visible after the fire test which presumably appeared due to the shrinkage of the panels in the cooling phase. Furthermore, there was no spalling on the reinforced concrete bars or an escape of fire during the test. Some smoke escaped from the side surfaces of the joints.

Test observations also show that the joint strands from Tendonol®-FDS (Flexible Dry System) remained stuck in the joints during the entire fire test. Therefore, a direct thermal load of the protected reinforced concrete bars was prevented.

After the tunnel fire test, the joint material was removed and the length of the joint material that was not used was determined. The residual lengths were still 20 mm at joint 1 and 25 mm at joint 2.

The mean and maximum temperature values of the two joints as well as behind the fire protection cladding at selected times are indicated Table 5 below. All measured values are indicated the graphical analysis of the measurement results in Enclosure 4.

*Table 5 Mean and maximum values of the temperatures*

| Sample | | Mean temperature value at time | | | | | | Maximum tempera-ture | At time |
|---|---|---|---|---|---|---|---|---|---|
| Designa tion | Measure ment level | 30 min | 60 min | 90 min | 120 min | 180 min | 270 min | | |
| Joint 1 (20 mm) | 1 | 93 °C | 186 °C | 275 °C | 310 °C | 422 °C | 221 °C | 510 °C | 186 min |
| | 2 | 63 °C | 117 °C | 169 °C | 152 °C | 286 °C | 209 °C | 351 °C | 195 min |
| | 3 | 43 °C | 83 °C | 119 °C | 118 °C | 196 °C | 191 °C | 255 °C | 209 min |
| | 4 | 33 °C | 62 °C | 95 °C | 103 °C | 136 °C | 172 °C | 198 °C | 223 min |
| | 5 | 27 °C | 48 °C | 77 °C | 94 °C | 109 °C | 152 °C | 162 °C | 245 min |
| | 6 | 24 °C | 37 °C | 58 °C | 86 °C | 101 °C | 131 °C | 135 °C | 270 min |
| | 7 | 22 °C | 31 °C | 46 °C | 78 °C | 99 °C | 116 °C | 118 °C | 271 min |
| | 8 | 21 °C | 26 °C | 36 °C | 67 °C | 95 °C | 100 °C | 100 °C | 271 min |
| | 9 | 21 °C | 25 °C | 33 °C | 63 °C | 93 °C | 95 °C | 98 °C | 200 min |
| | Air | 19 °C | 29 °C | 48 °C | 79 °C | 97 °C | 99 °C | 102 °C | 243 min |
| Joint 2 (40 mm) | 1 | 98 °C | 224 °C | 349 °C | 392 °C | 471 °C | 237 °C | 534 °C | 182 min |
| | 2 | 67 °C | 126 °C | 192 °C | 192 °C | 276 °C | 225 °C | 361 °C | 189 min |
| | 3 | 48 °C | 89 °C | 130 °C | 131 °C | 187 °C | 203 °C | 258 °C | 202 min |
| | 4 | 37 °C | 67 °C | 101 °C | 108 °C | 136 °C | 180 °C | 199 °C | 236 min |
| | 5 | 31 °C | 47 °C | 68 °C | 82 °C | 92 °C | 128 °C | 169 °C | 256 min |
| | 6 | 27 °C | 42 °C | 62 °C | 90 °C | 105 °C | 134 °C | 140 °C | 271 min |
| | 7 | 25 °C | 35 °C | 51 °C | 81 °C | 102 °C | 118 °C | 120 °C | 271 min |
| | 8 | 24 °C | 29 °C | 41 °C | 72 °C | 98 °C | 102 °C | 104 °C | 271 min |
| | 9 | 23 °C | 28 °C | 40 °C | 71 °C | 95 °C | 94 °C | 101 °C | 191 min |
| | Air | 19 °C | 30 °C | 50 °C | 80 °C | 95 °C | 91 °C | 97 °C | 239 min |
| Aestuver | I1, I3, I4 | 97 °C | 188 °C | 295 °C | 340 °C | 425 °C | 229 °C | 519 °C | 180 min |
| Promat | I2 | 97 °C | 141 °C | 214 °C | 251 °C | 321 °C | 206 °C | 327 °C | 187 min |

The temperature at the individual measurement levels in the reinforced concrete sample and the maximum temperatures behind the fire protection cladding can be referred to as non-critical.

The results of the tests exclusively relate to the items tested. This document does not replace a certificate of conformity or suitability according to national and European building codes.

Leipzig, 25 July 2022

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*Testing Engineer*

## 7 List of Enclosures

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|---|---|
| Enclosure 1 | Structural design |
| Enclosure 2 | Measuring point plan |
| Enclosure 3 | Photo documentation of the fire test |
| Enclosure 4 | Graphical analysis of the measurement results |

Enclosure 1 Structural design

## Longitudinal section A-A - test setup

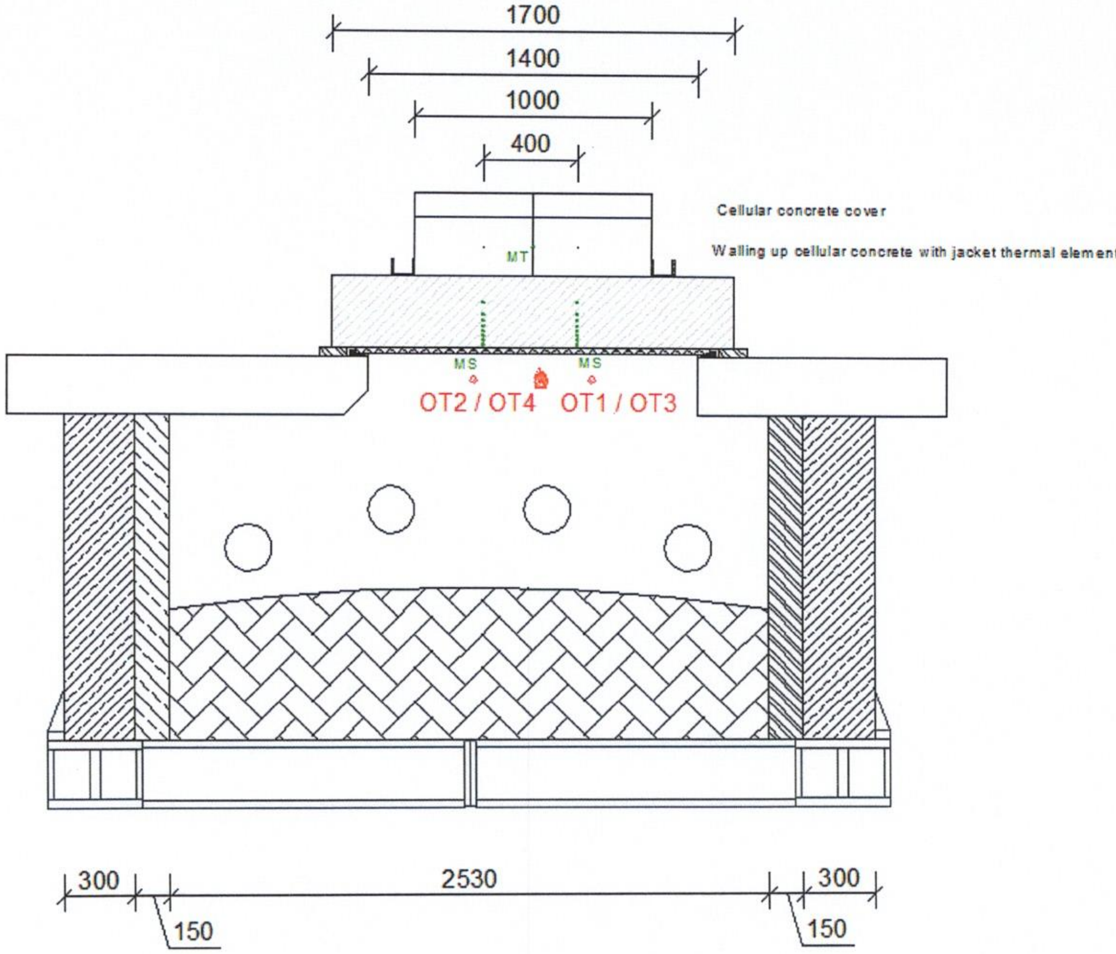



*Photo A1-1 Longitudinal section of the test set-up*

# Cross section - test setup

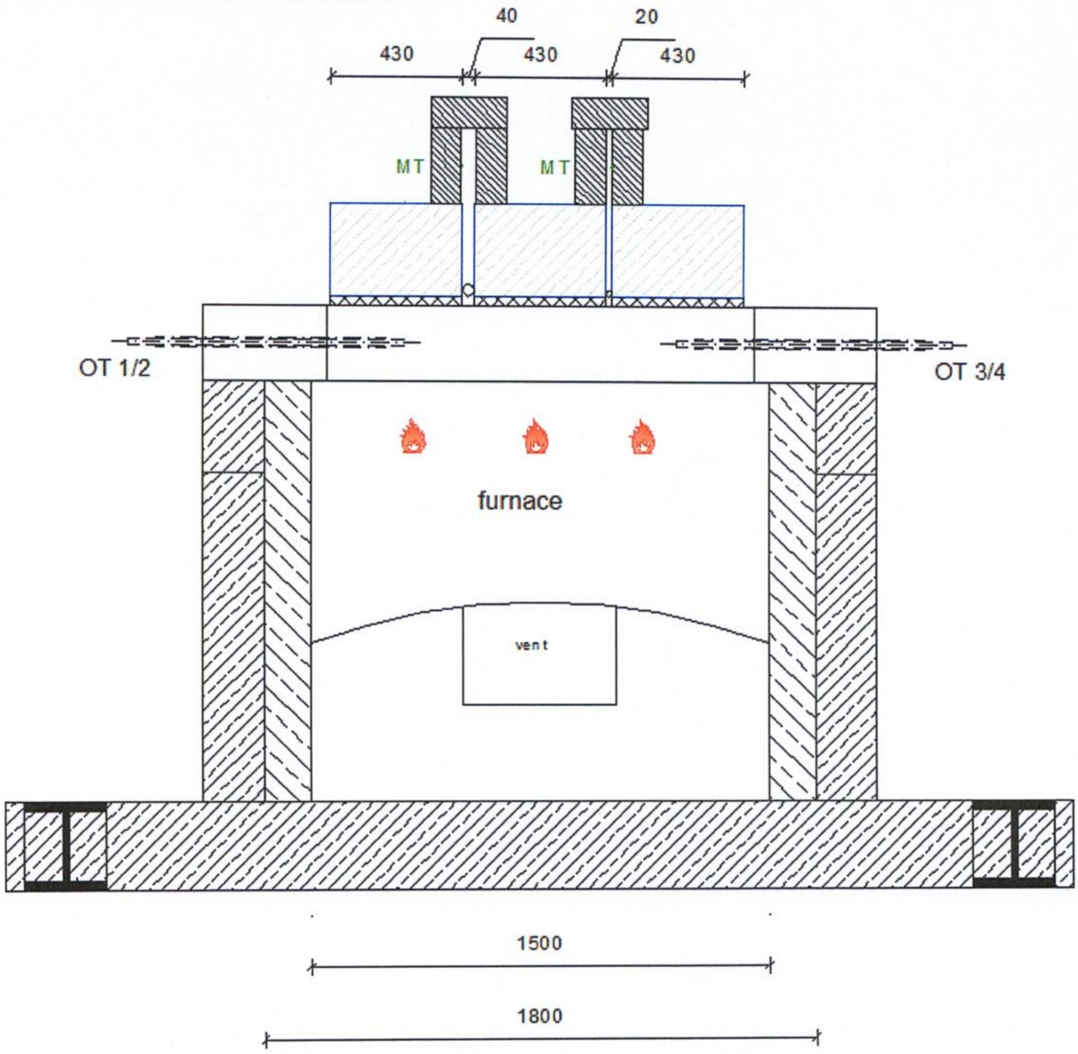



*Photo A1-2 Cross-section of the test set-up*

Enclosure 2 Measuring point plan

Outline

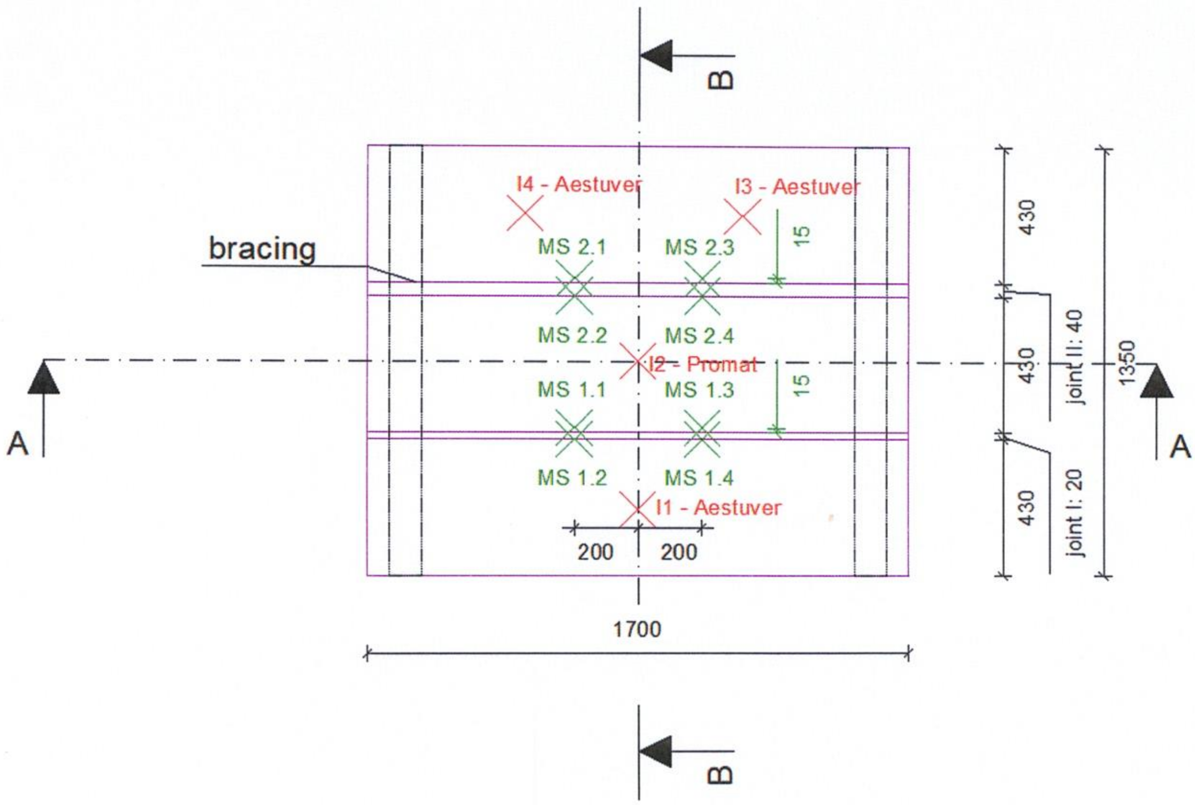



*Photo A2-1 Outline of the sample with the measuring points used in the sample*

section A-A

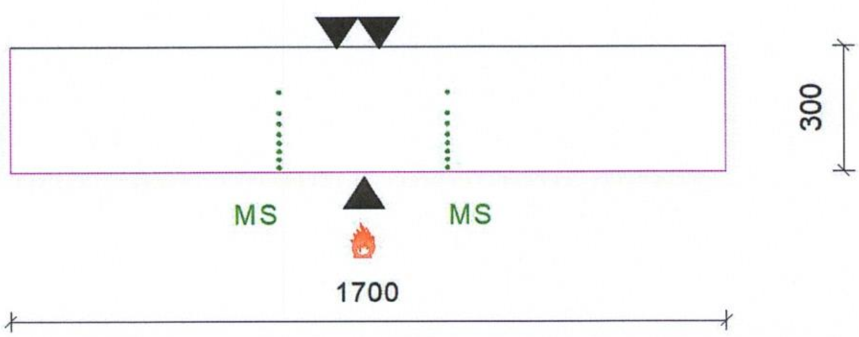



*Photo A2-2 Longitudinal section through the sample*

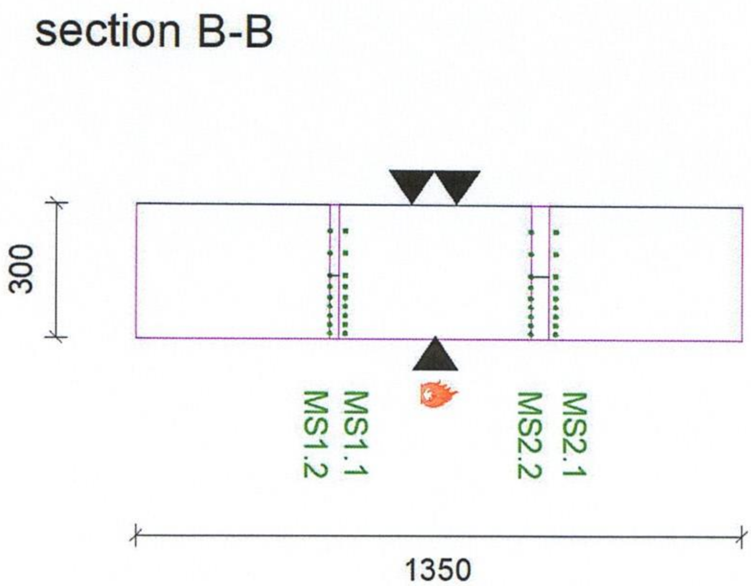



*Photo A2-3 Cross-section through the sample*

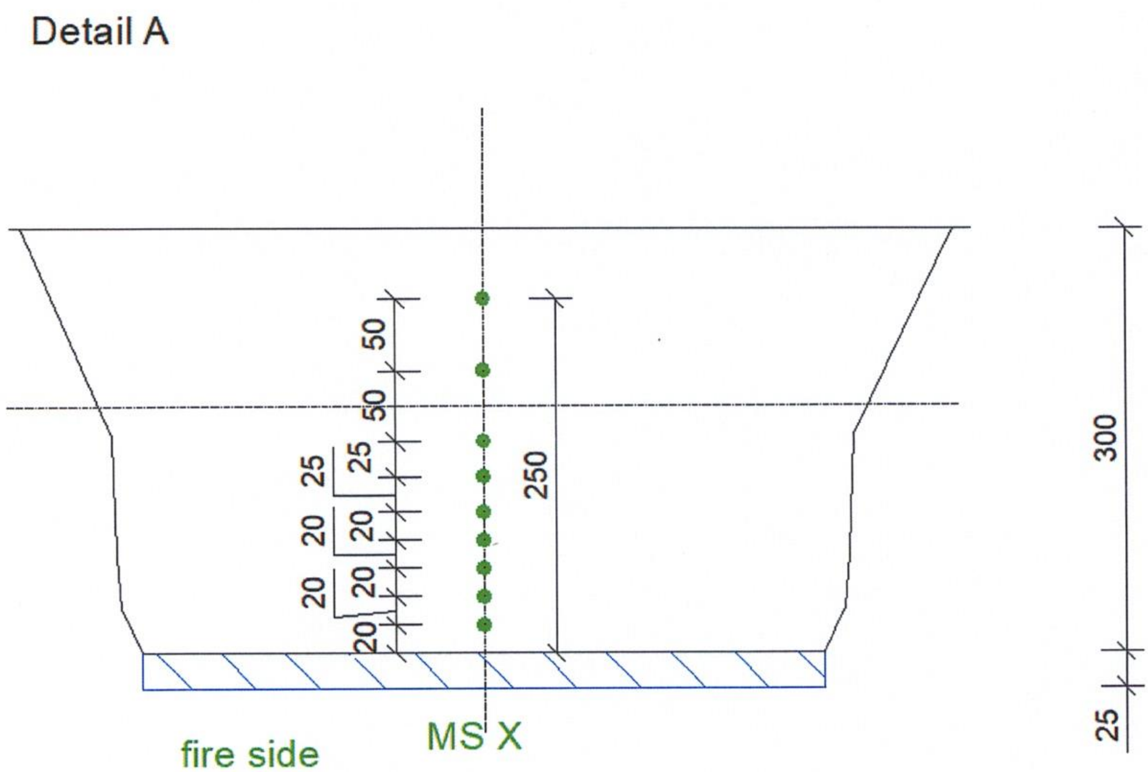



*Photo A2-4 Detailed representation of a "measuring ladder"*

## Enclosure 3 Photo documentation of the fire test

### Structure of the penetration seals

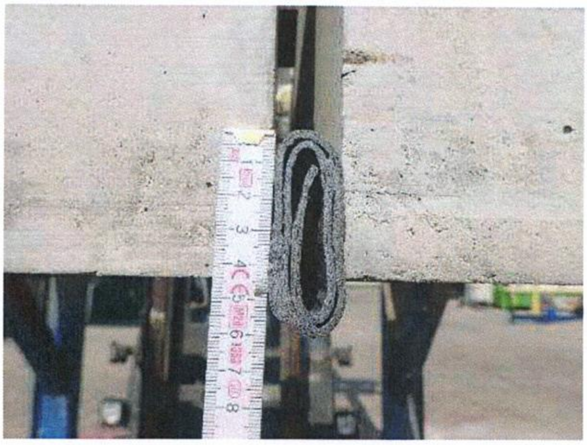


*Photo A3-1 Installation of joint material on joint 1*

*Photo A3-2 Installation of joint material on joint 2*

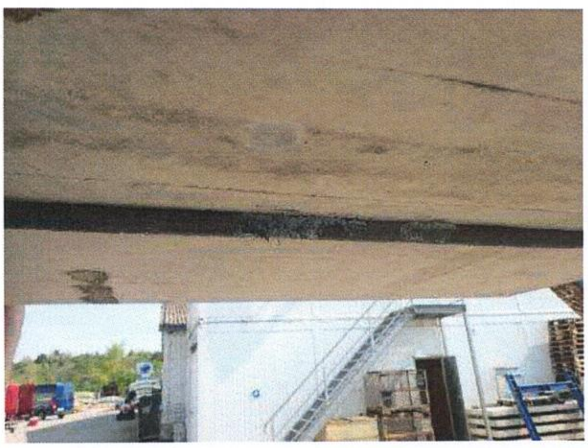


*Photo A3-3 Connection of the joint using a U shell made of the same material*

*Photo A3-4 Fastening of the Promatect-T fire protection panel*

*Photo A3-5 Sealing the panel edges with Tendonol® Fire Protection Sealing Compound*

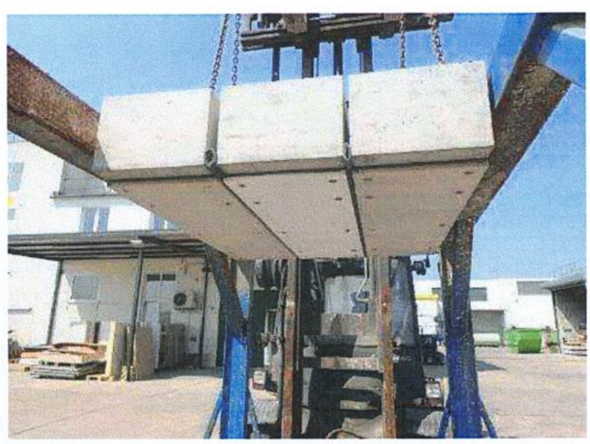


*Photo A3-6 Completed sample*

*Photo A3-7 View of the completely installed test construction from the side facing away from the fire*

Execution of the fire test

*Photo A3-8 View of the fire area – 2nd minute*

*Photo A3-9 Joint material starts sintering – 15th minute*

*Photo A3-10 Some smoke escapes from joint 2 – 36th minute*

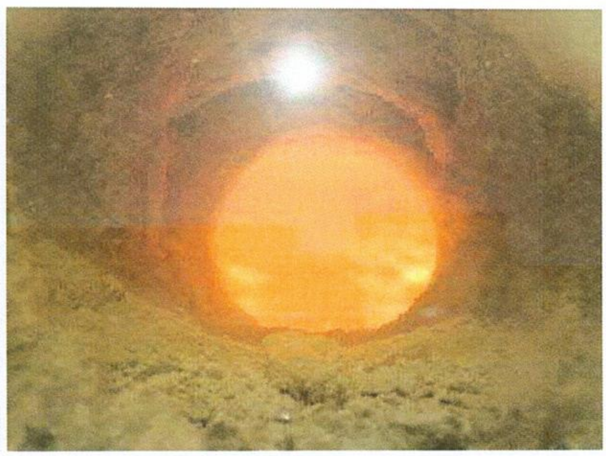


*Photo A3-11 View of the fire area – 62nd minute*

*Photo A3-12 Slight brownish discolouration at joint 2 – 106th minute*

*Photo A3-13 View of the fire area – 180th minute*

Pictures of the damage

*Photo A3-14 View of the side facing away from the fire directly after the fire test*

*Photo A3-15 View of cracked fire protection panels directly after the fire test*

*Photo A3-16 View of the joint material used (fire protectional panels were removed manually)*

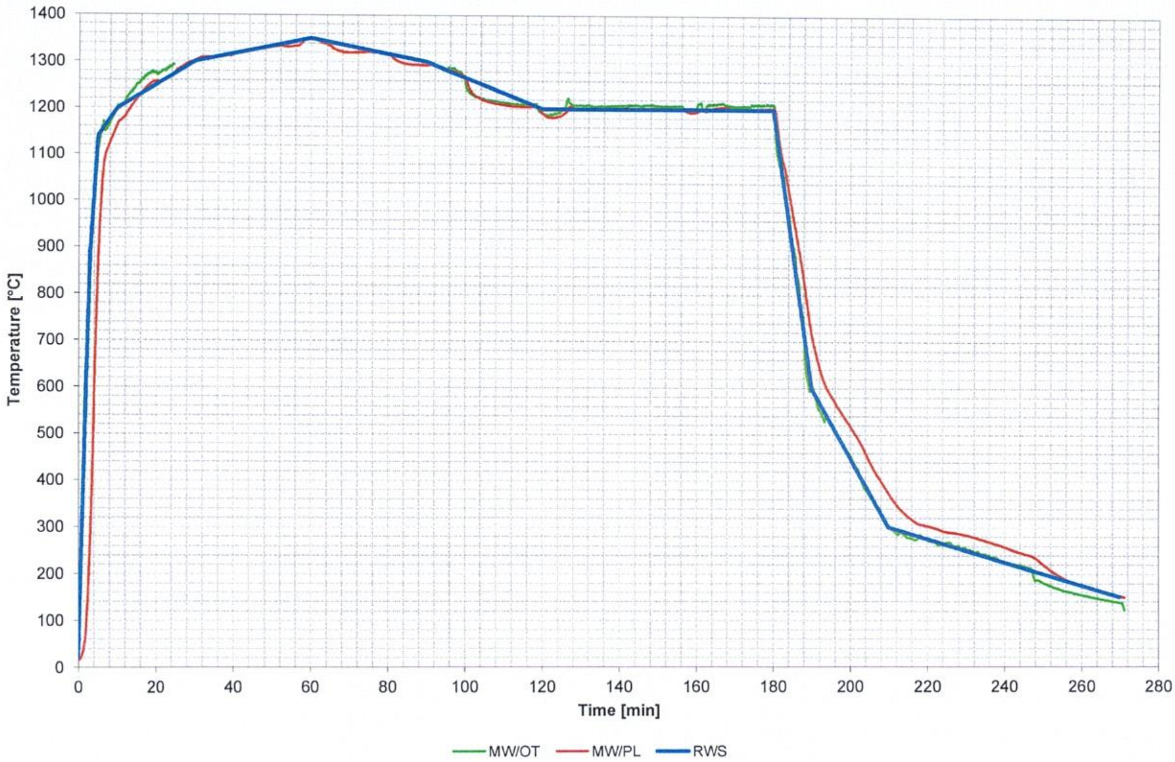
*Photo A3-17 View of the joint material removed (top: joint 2, bottom: joint 1)*

*Photo A3-18 Section of joint material from joint 2*

*Photo A3-19 View of no. 10 directly after the 120-minute fire test*

# Enclosure 4 Graphical analysis of the measurement results

## Diagram A4.1 Mean fire area temperature




## Diagram A4.2 Single values for fire area temperature

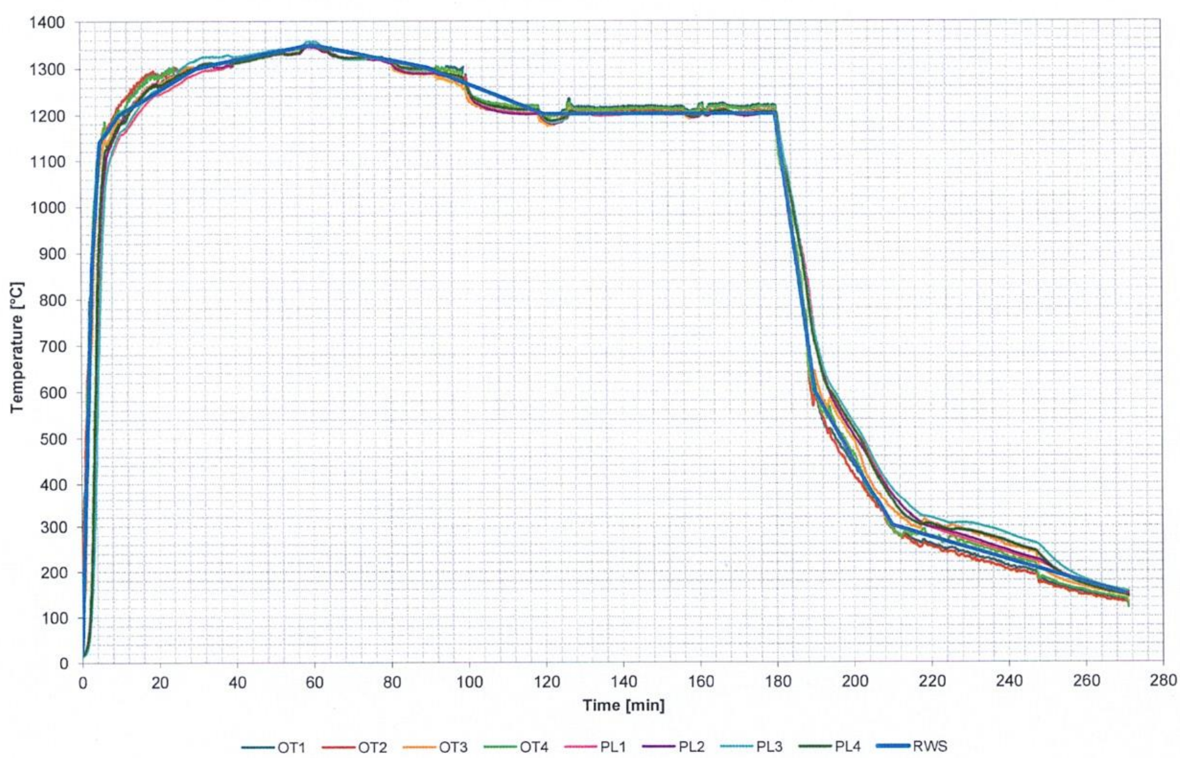


Diagram A4.3 Pressure in the fire area

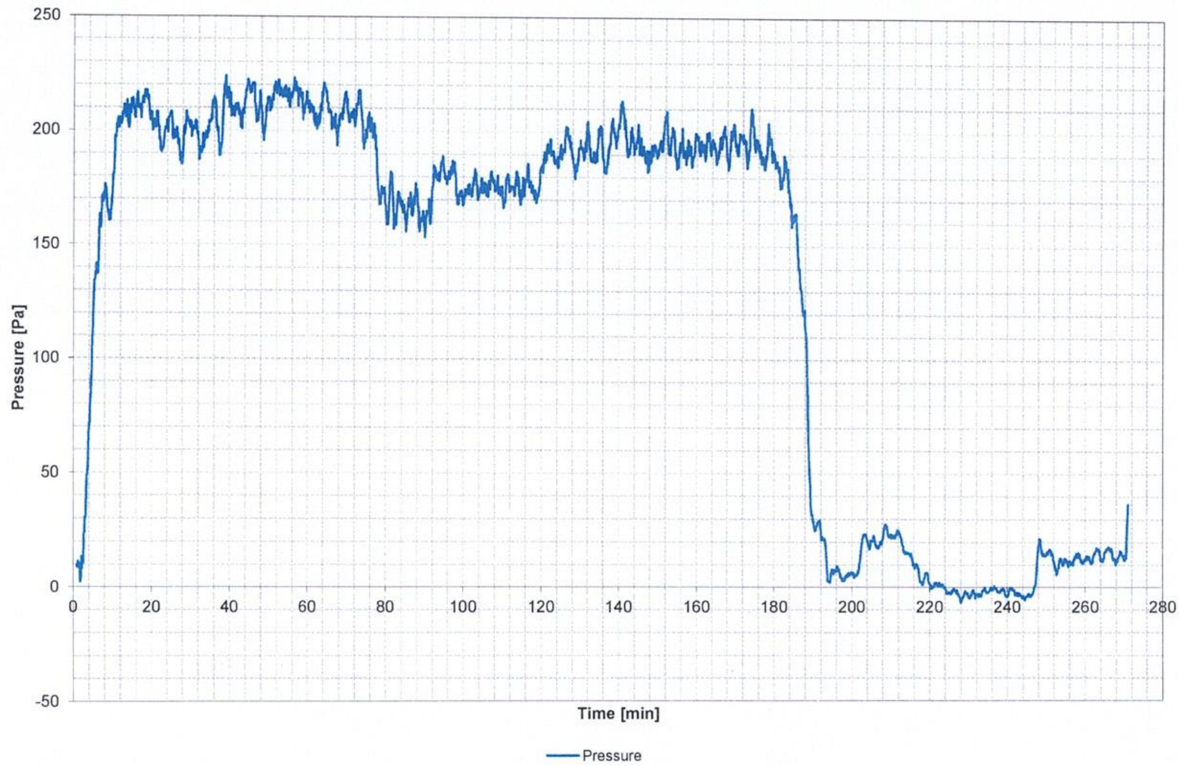



Diagram A4.4 Temperatures behind the fire protection panels

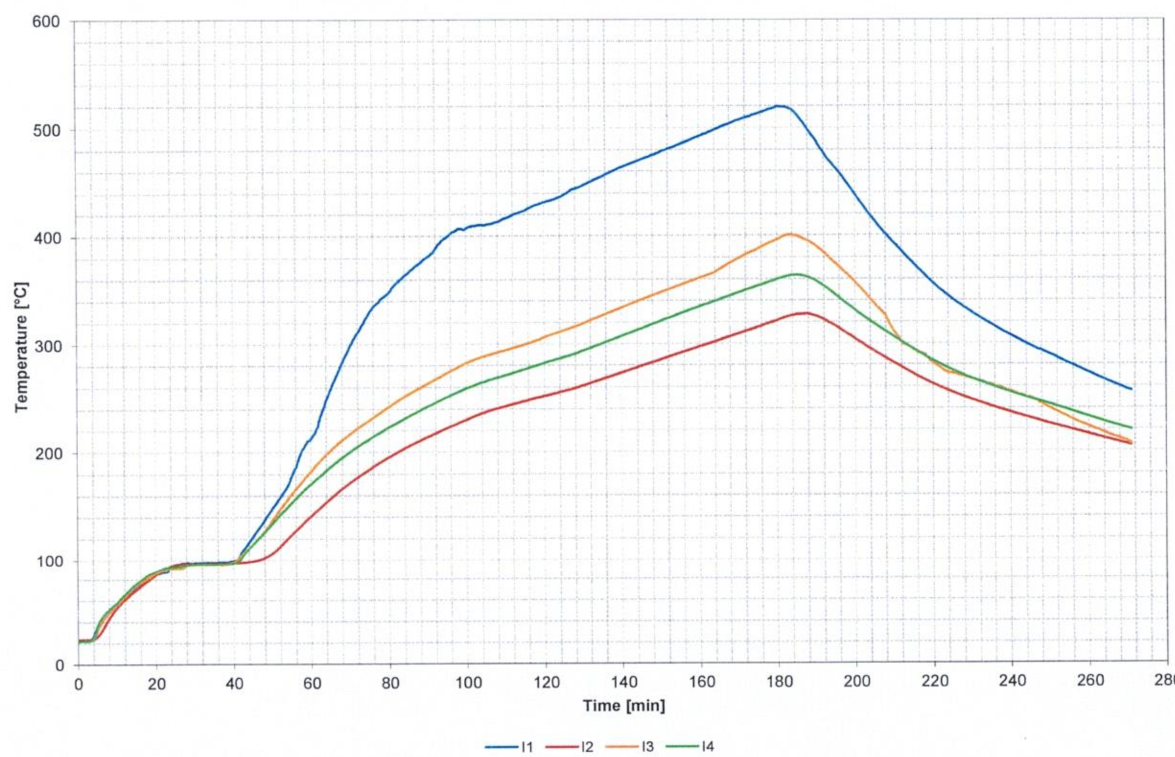


Diagram A4.5 Temperatures in joint 1 (with a concrete cover of 15 mm)

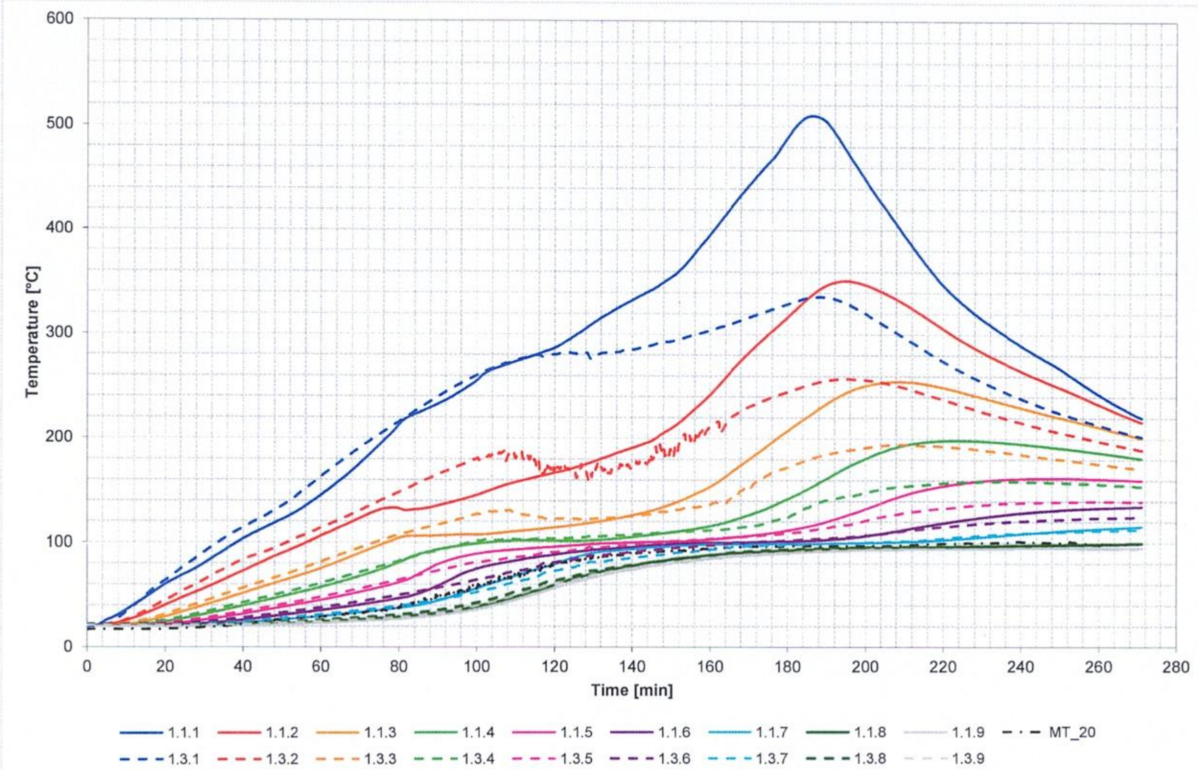



Diagram A4.6 Temperatures in joint 1 (at the concrete surface)

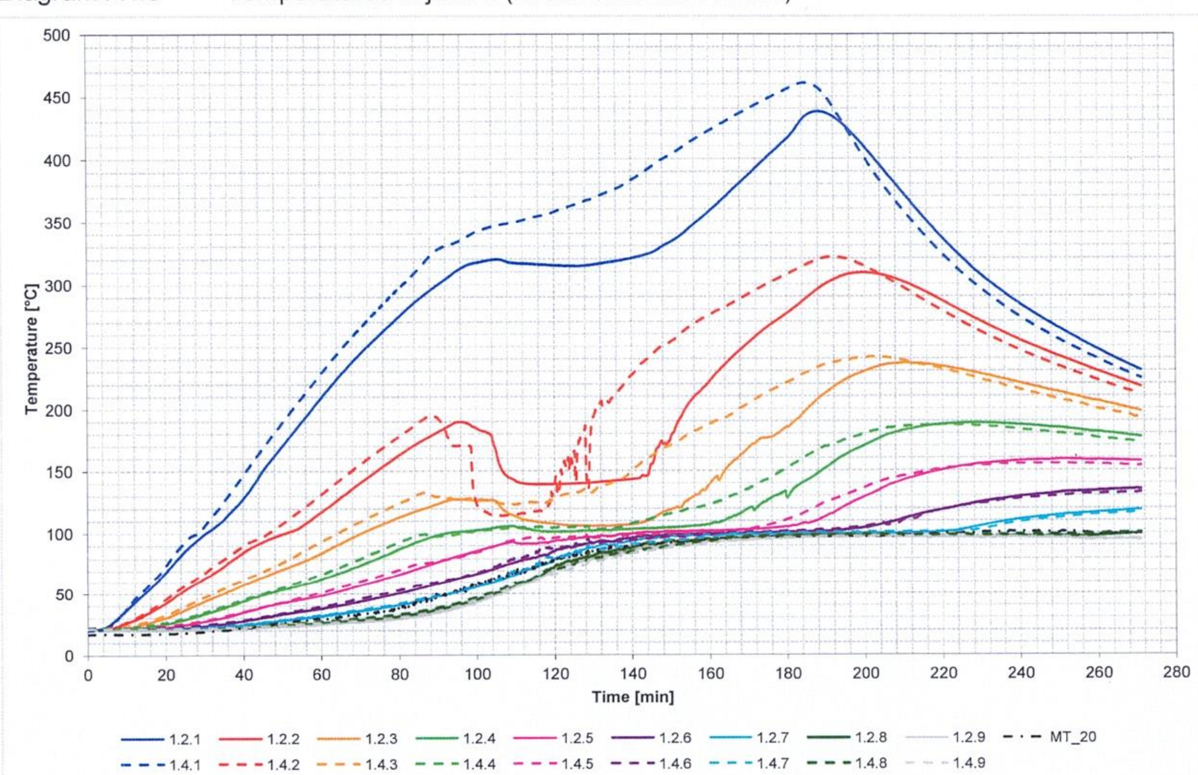


Diagram A4.7 Temperatures in joint 2 (with a concrete cover of 15 mm)

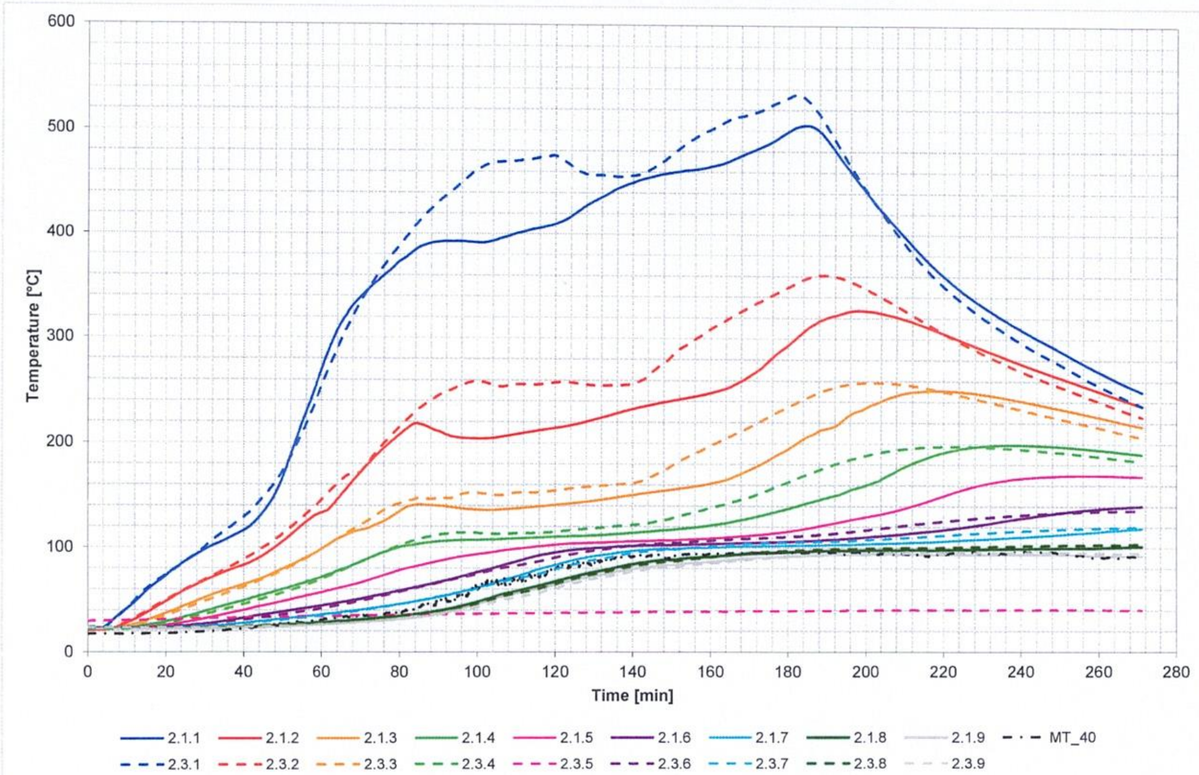



Diagram A4.8 Temperatures in joint 2 (at the concrete surface)