UNIVERSITY of PATRAS
CIVIL ENGINEERING DEPARTMENT
Structural Materials Lab
Fire Testing Facility – Patras 26504

ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

Fire resistance test report for LAVAWALL® A9 & LAVAWALL® A25

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"ΛΑΒΑ ΜΕΤΑΛΛΕΥΤΙΚΗ ΚΑΙ ΛΑΤΟΜΙΚΗ ΑΕ"

May 2020

Fire resistance test report for LAVAWALL® A9
Test report

Name and address of the testing laboratory:

Fire Testing Facility of the Civil Engineering Department,
University of Patras. University of Patras, Rion Campus, Patras 26504, Greece.

Name and address of the assignor (sponsor):

“ΛΑΒΑ ΜΕΤΑΛΛΕΥΤΙΚΗ ΚΑΙ ΛΑΤΟΜΙΚΗ ΑΕ"
Δ. Σολωμού 32 , Τ.Κ. 14123, Λυκόβρυση Αττικής

Date of the test:

4 September 2019

Unique reference nomenclature of the test:

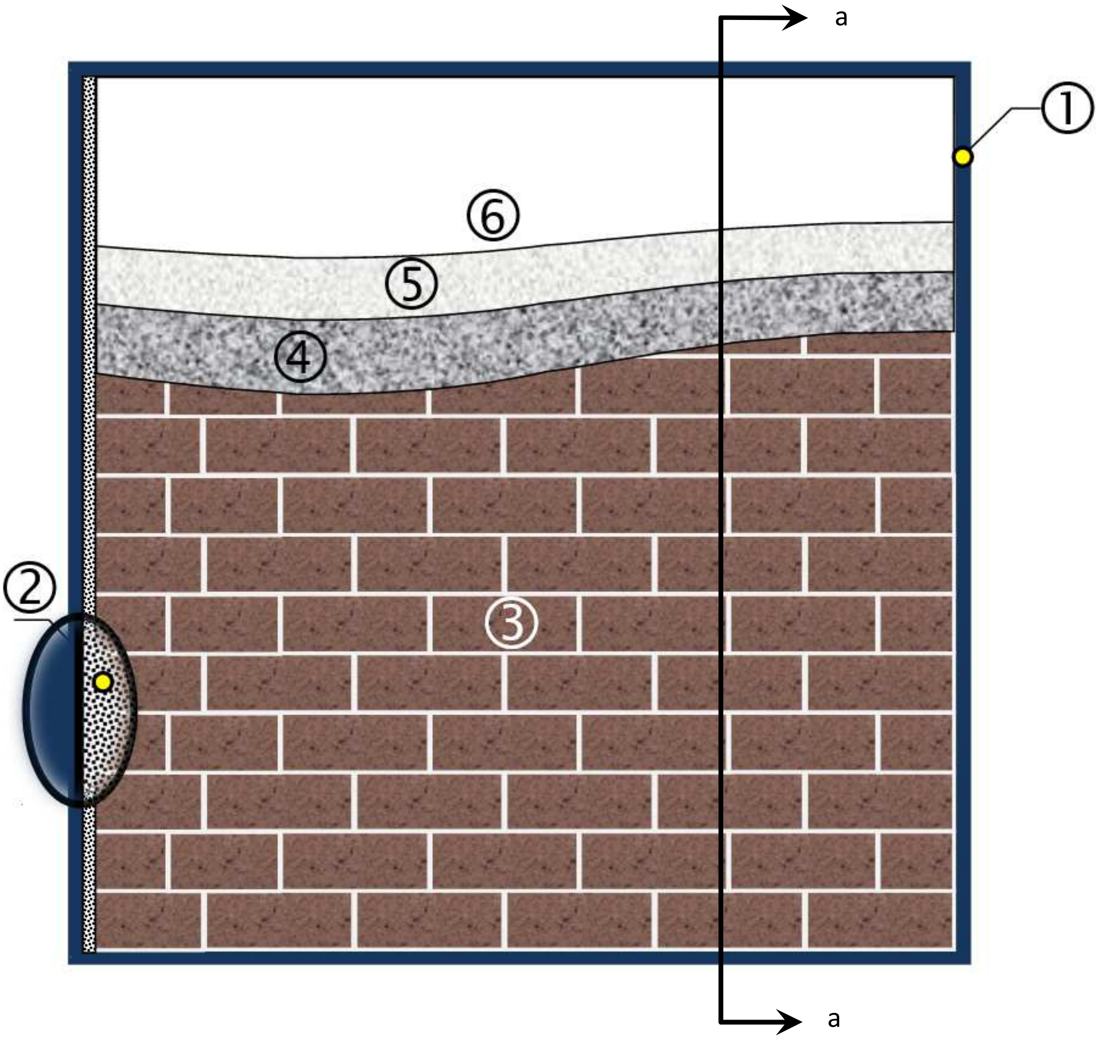
LAVAWALL_A9

Name of the manufacturer of the test specimen:

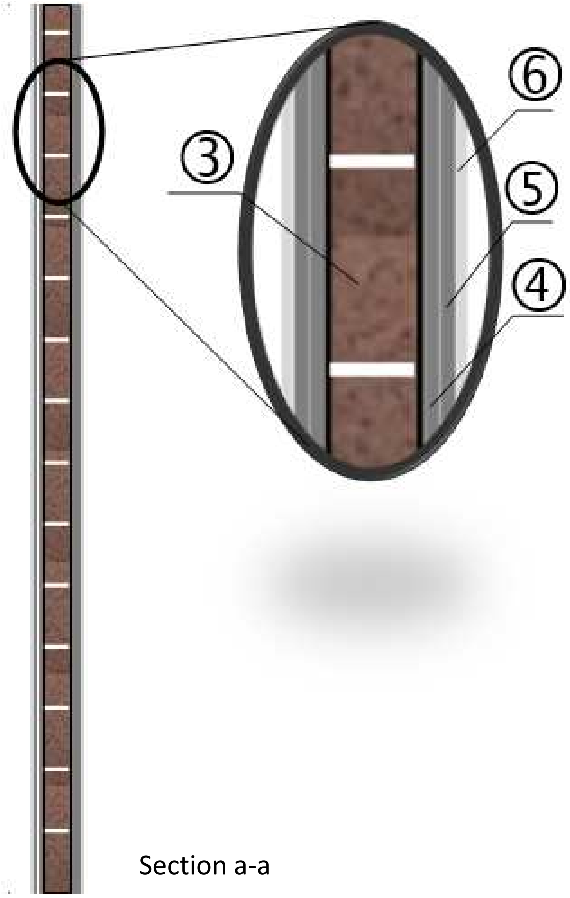
University of Patras – Structural Materials Lab staff (skilled mason)

Constructional details of the test specimen:

The test specimen comprised a single-wythe (leaf) wall installed (constructed and tested) in a rigid steel test frame, lined with refractory concrete blocks along all four sides (supporting construction, as per EN 1363-1). The wall comprised LAVAWALL® A9 building blocks (cavities left clear) in a running bond pattern bonded with a fit-for-purpose LAVAWALL adhesive and was fully representative of the construction intended for use in practice, including surface finishes. All constituent materials along with explicit instructions on handling the LAVAWALL products and constructing the wall were provided by the sponsor. The wall was rendered on both sides with the rendering layered in three sheets; from the wall surface outwards: a cement-based throw-on render, a cement-based troweled one and a fine marble mortar made from lime putty. Wall surface moistening preceded the application of the first layer of render on both sides. The total thickness of the render (on each wall face) and of the rendered wall was equal to 20 mm and 130 mm, respectively. The wall was symmetrical in respect to its mid-plane. The wall measured 3.00 m × 3.00 m (as in length × height). Since the height of the wall as constructed and used in practice is comparable to that of the test specimen the latter was restrained along its top edge (with the bottom and the vertical edge on the right also restrained). The vertical edge on the left (unexposed side) was left without restraint in order to allow wall dilatation lengthwise. The gap (expansion joint) was tightly packed with a fire resistant and compressible material (mineral wool) that provided a seal without restricting freedom of wall movement. Constructional details are depicted in **Fig. A9_1**.



① Rigid steel frame (lined with refractory concrete blocks) – 3.0 m × 3.0 m (clear)
② Expansion joint tightly packed with mineral wool (50 mm – thick)
③ LAVAWALL® A9 building block
④ cement-based throw-on render layer (8 mm – thick)
⑤ cement-based troweled render layer (8 mm – thick)
⑥ fine marble mortar made from lime putty (4 mm – thick)
Unexposed side view



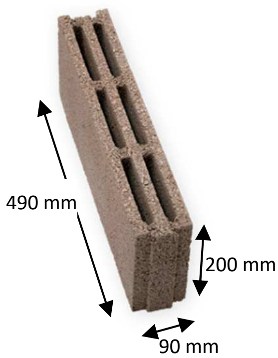


Fig. A9_1 Constructional details of the specimen

Pre-test conditioning of the test specimen:

At the time of the test the condition of the wall was similar to its strength and moisture content expected in normal service. Prior to testing the test specimen was stored for 28 days in an ambient atmosphere of 50% relative humidity at 23°C. The supporting construction born no influences on the behavior of the specimen.

Pre-test preparation:

Fig. A9_2 illustrates the layout of thermocouples on the unexposed side of the test specimen. **Table A9_1** lists the coordinates of the thermocouples' positions (bottom left corner being the origin). Thermocouples 2 to 6 were used for the determination of the average temperature of the wall's unexposed side. The rest of the thermocouples were used for the determination of the maximum temperature developed on the wall's unexposed side. Wall deflections were measured by a laser distance meter (range: 0.05 m to 100 m; measurement accuracy: 1.5 mm) placed on a fixed platform positioned 5 m away from the unexposed side of the specimen. The measurement point (laser target) is shown in **Fig. A9_2** (triangular point "W") and the general measurement principle is shown in **Fig. A9_3**.

The general layout of the specimen just prior to testing is given in **Fig. A9_4**. During handling operations of the wall-filled steel frame, a fine diagonal crack was formed at the bottom left corner of the specimen; the crack was located in the render coat of the unexposed side of the wall.

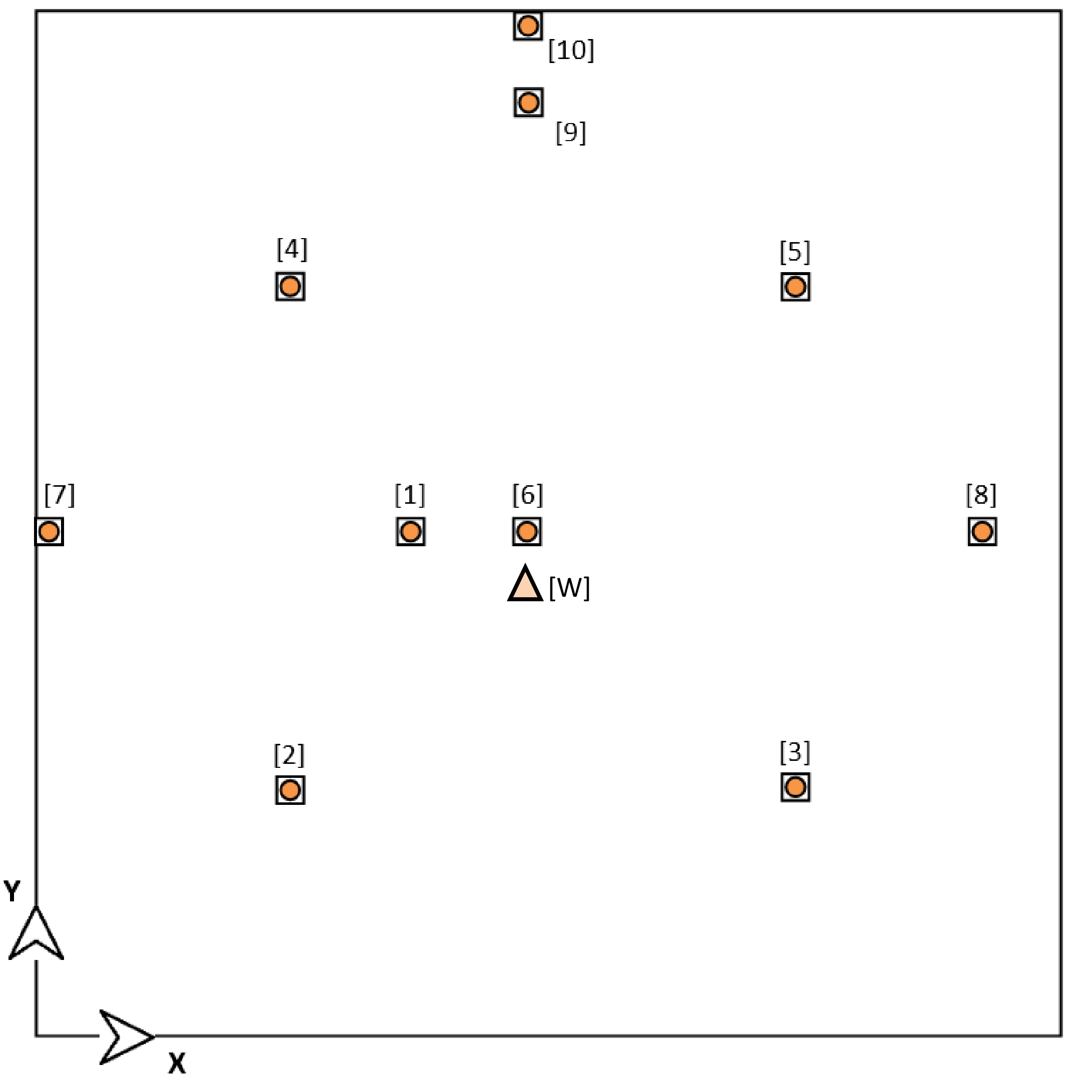


Fig. A9_2 Layout of the thermocouples' positions and deflection measurement point on the unexposed face of the test specimen.

Table A9_1 Positions of thermocouples (in mm)[1]

	Positions									
[mm]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
X	1160	790	2455	790	2455	1525	35	2920	1525	1525
Y	1490	775	775	2320	2320	1490	1490	1490	2885	2965

[1] Note (as per EN 1364-1): For uninsulated non-loadbearing walls, glazed or unglazed, the temperature of the unexposed face is not required to be measured and no thermocouples are therefore required to be attached.

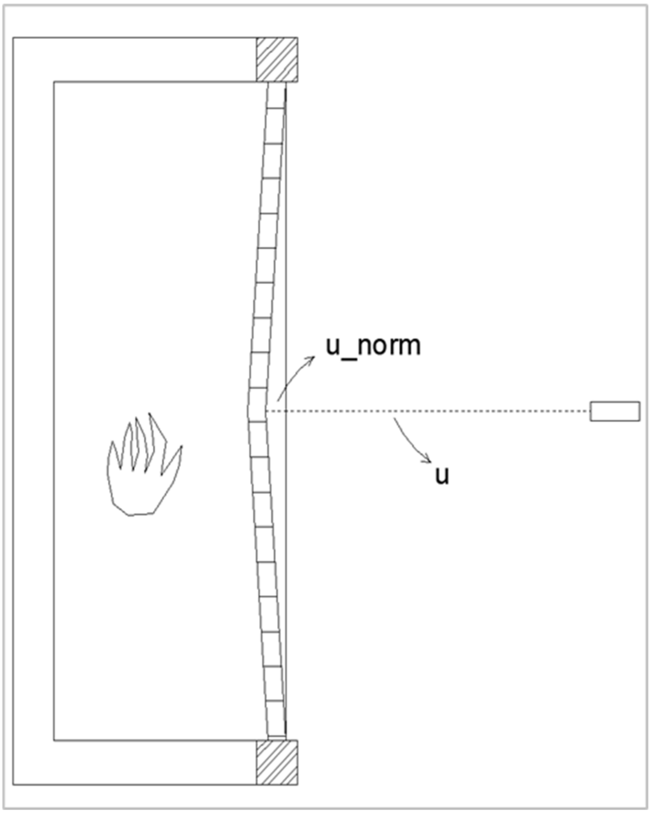


Fig. A9_3 Measuring the deflection of the wall at midpoint.

Fig. A9_4 General layout of the specimen during testing (00:14:38 post-test start).

Test procedure:

The test was carried out in accordance with EN1364-1:2015 Fire resistance tests for nonloadbearing elements Part 1: Walls.

The average temperature of the furnace was monitored and controlled such that it followed **Eq. (A9_1)**.

$$T = 345 \log_{10}(8t+1)+20 \qquad \textbf{Eq. (A9\_1)}$$

where,

T is the average furnace temperature, in °C;
t is the time, in min.

Ambient temperature was continuously recorded during testing and ranged between 30°C and 32°C (at the commencement of the test, ambient temperature was equal to 32°C [2]).

Test results:

The time versus (actual) furnace temperature curve (in comparison to the standard – i.e. target – time versus temperature one) is given in **Fig. A9_5a**. The time versus furnace pressure is given in **Fig. A9_5b**. The pressure (relative to the surrounding laboratory) remained fairly constant (11.09 Pa = 1.13×10^{-4} at; i.e. close to zero) after an initial transient that lasted approximately 15 minutes. The percentage deviation (d_c) in the area of the time versus actual furnace temperature curve from the area of the standard time/temperature curve is shown in **Fig. A9_6**; this deviation [abs(d_c)] is compared in **Fig. A9_6** to the maximum permissible one referenced in EN 1363-1 (tolerance; red line in **Fig. A9_6**). For the total duration of the test (excluding the first 5 min, as per EN 1363-1) d_c was lower than the tolerance. The rapid temperature increase in the first 5 min of the test was responsible for the exceedance of the tolerance (common to fire resistance tests – see EN 1363-1).

The temperature recorded by the furnace thermoplates (10 in number) versus time is shown in **Fig. A9_7**. At any time after the first 40 min of test, the temperature recorded by any thermoplate in the furnace did not differ from the corresponding temperature of the standard temperature/time curve by more than 100°C [3].

The deflection of the wall at midpoint (u_norm, in **Fig. A9_3**) as a function of time is given in **Fig. A9_8**.

<u>Fire integrity assessment</u>: Fire integrity is the ability of the wall, when exposed to fire on one side, to prevent the passage through it of flames and hot gases and to prevent the occurrence of flames on the unexposed side. The specimen continued to maintain its separating function **for more than 180 min** without either:

(a) causing the ignition of a cotton pad applied in accordance to clause 10.4.5.2 of EN 1363-1 (see in **Fig. A9_9** a snapshot of the application of the cotton pad at 75 min post-test start);
(b) permitting the penetration of a gap gauge as specified in clause 10.4.5.3 of EN 1363-1;
(c) resulting in sustained flaming.

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[2] EN 1363-1 specifies that the ambient air temperature should be (20±10)°C at the commencement of the test.

[3] Nevertheless, EN 1363-1 requires that at any time after the first 10 min of test, the temperature recorded by any thermoplate in the furnace does not differ from the corresponding temperature of the standard temperature/time curve by more than 100°C. Manual switching off of two burners at 18 min post-test start (in order to control the rapid increase of the furnace temperature) resulted in the non-compliance of two thermoplates with the aforementioned requirement up to 40 min post-test start.

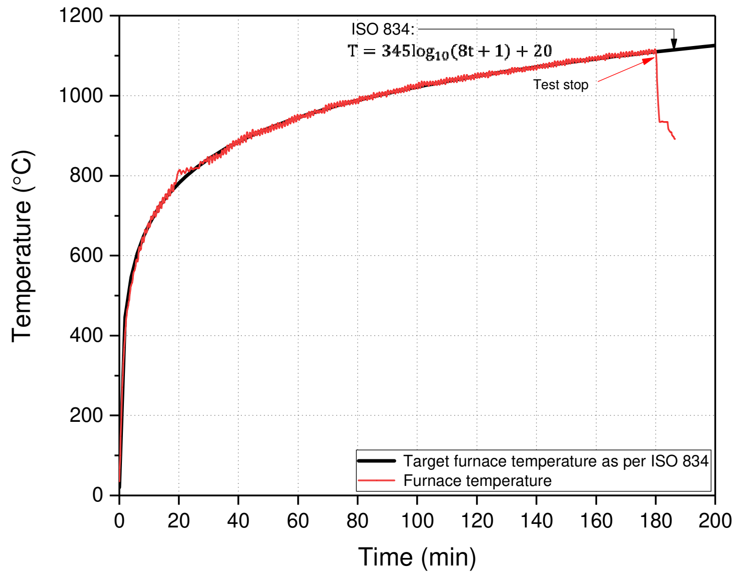
Fire insulation assessment: Fire insulation is the ability of the wall to withstand fire applied at only one side, without transferring the fire to the unexposed side as a result of significant heat transfer from the heated side to the unheated side. That is, fire insulation is the ability of the wall to restrict the temperature rise of the unexposed face to below specified levels. Fire insulation is the time completed in minutes for which the wall continues to maintain its separating function without developing temperatures on its unexposed surface which either:

i. increase the average temperature above the initial average temperature by more than 140°C,
ii. increase at any point of the unexposed wall surface above the initial temperature by more than 180°C.

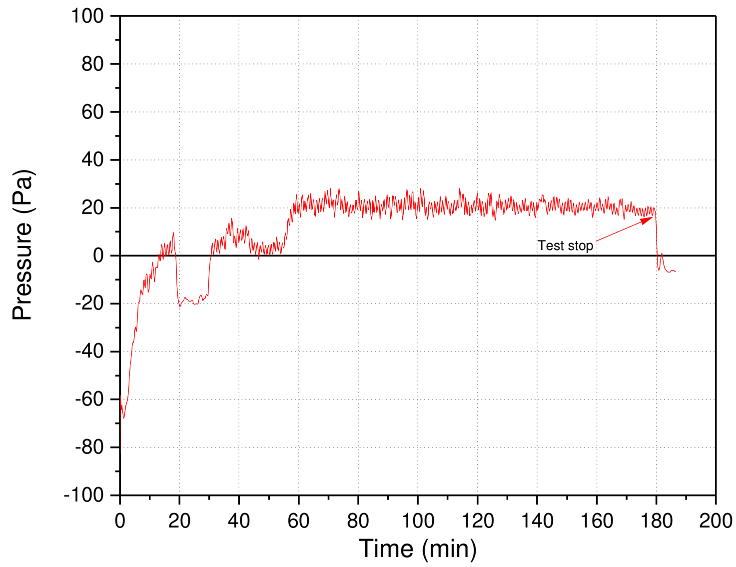
The assessment of point (i) and (ii) is shown in **Fig. A9_10** and in **Fig. A9_11**, respectively.

Thermal imaging was used in order to visualize the wall's temperature field on the unexposed side. Such a visualization is given in **Fig. A9_12**; the thermal image was taken 134 min post-test start. Maximum temperature in **Fig. A9_12** (112°C) corresponds to the diagonal crack in the render coat (bottom right corner). The width of the latter remained almost unchanged throughout the duration of the test (see **Fig. A9_13** – snapshot taken 180 min post-test start). Visual inspection of the exposed wall side - through a viewing port on the rear side of the furnace - revealed the development of another render crack (symmetrical to the one formed on the render of the unexposed wall side – see snapshot taken 180 min post-test start in **Fig. A9_14**). This crack – although not a (visibly) through one – can also be identified in **Fig. A9_13** (bottom left corner).

The test was terminated at 3 h 05 min.



(a)



(b)

Fig. A9_5 (a) Time versus (actual) furnace temperature curve (in comparison to the standard – i.e. target – time versus temperature curve); (b) Time versus furnace pressure

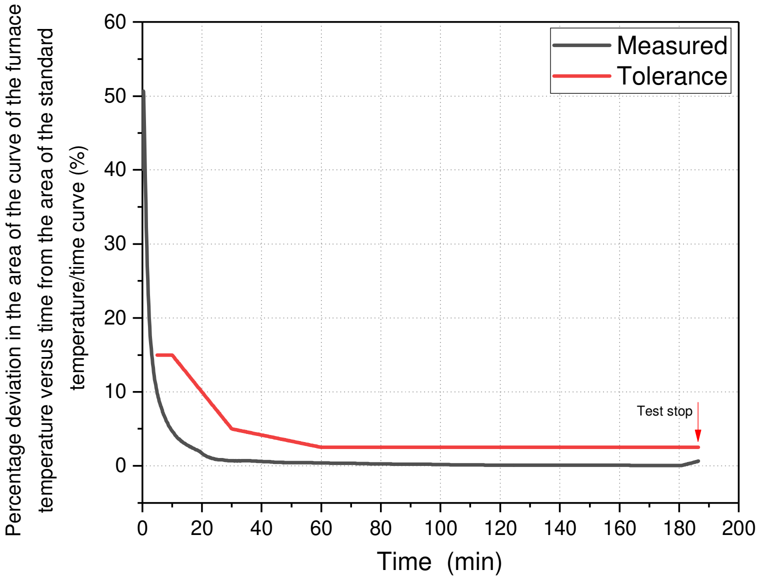


Fig. A9_6 Percentage deviation in the area of the time vs. actual furnace temperature curve from the area of the standard time/temperature curve and maximum permissible one as per EN 1363-1

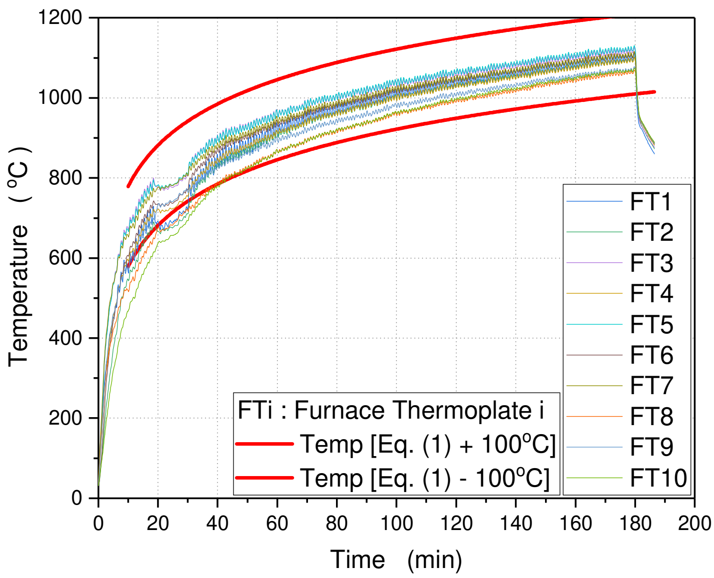


Fig. A9_7 Time records of temperature recorded by each thermoplate in the furnace in comparison to limit temperatures (standard temperature ±100°C)

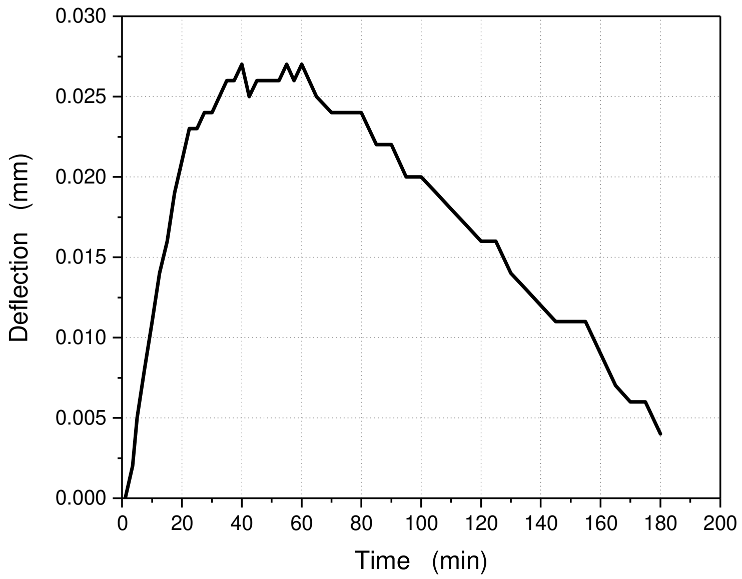


Fig. A9_8 Deflection of the wall at midpoint as a function of time

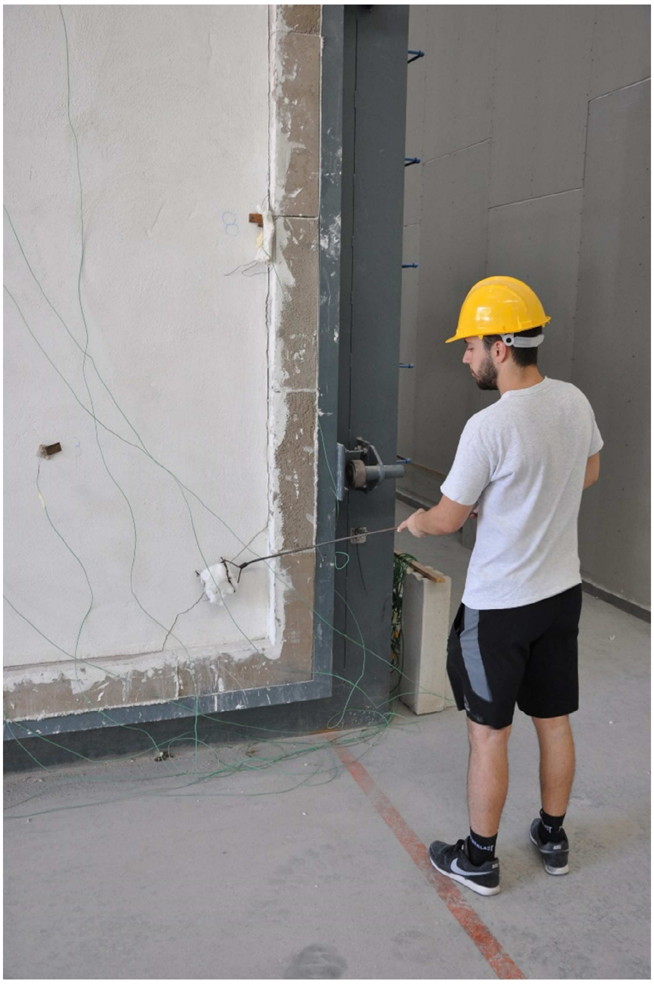


Fig. A9_9 Application of the cotton pad (75 min post-test start)

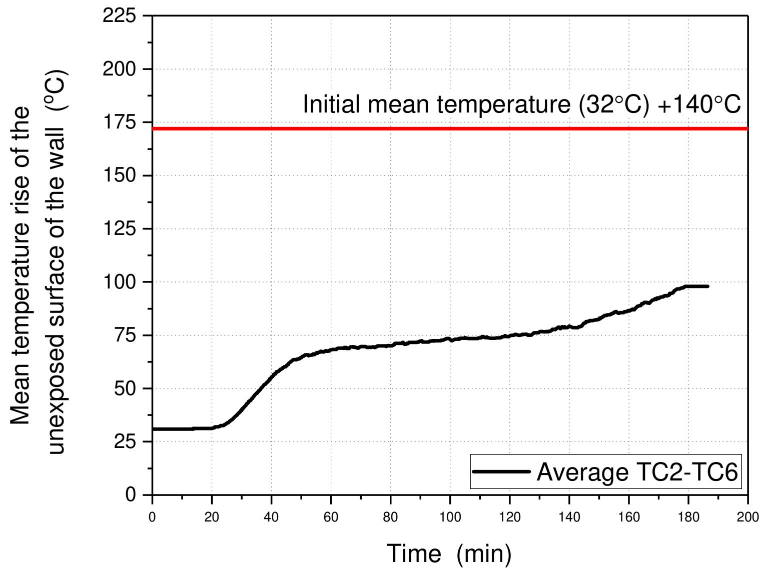


Fig. A9_10 Mean temperature rise of the unexposed surface of the wall versus time [fire insulation: assessment of point (i)]

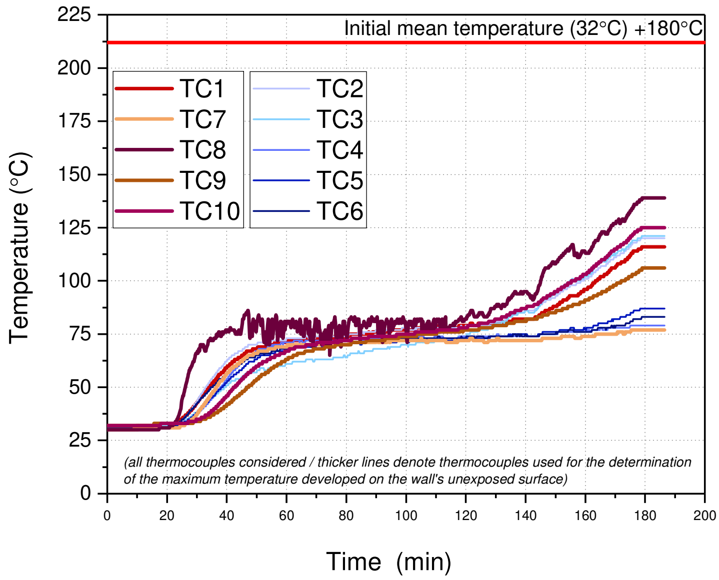


Fig. A9_11 Temperature rise at any point of the unexposed wall surface versus time [fire insulation: assessment of point (ii)]

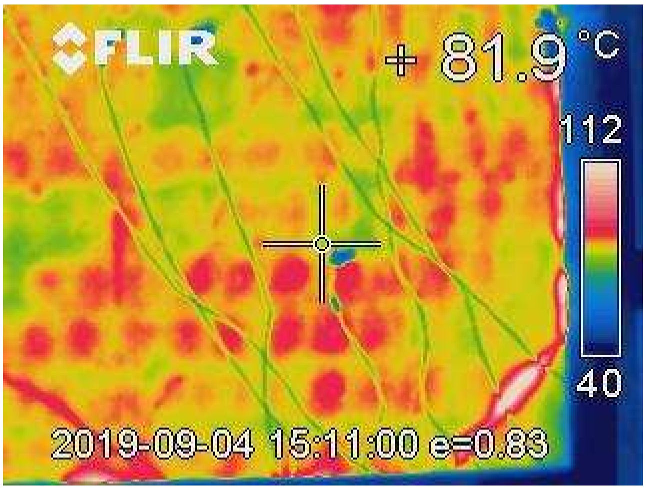


Fig. A9_12 Thermal image of the unexposed wall side at 134 min post-test start

Fig. A9_13 The wall at 180 min post-test start

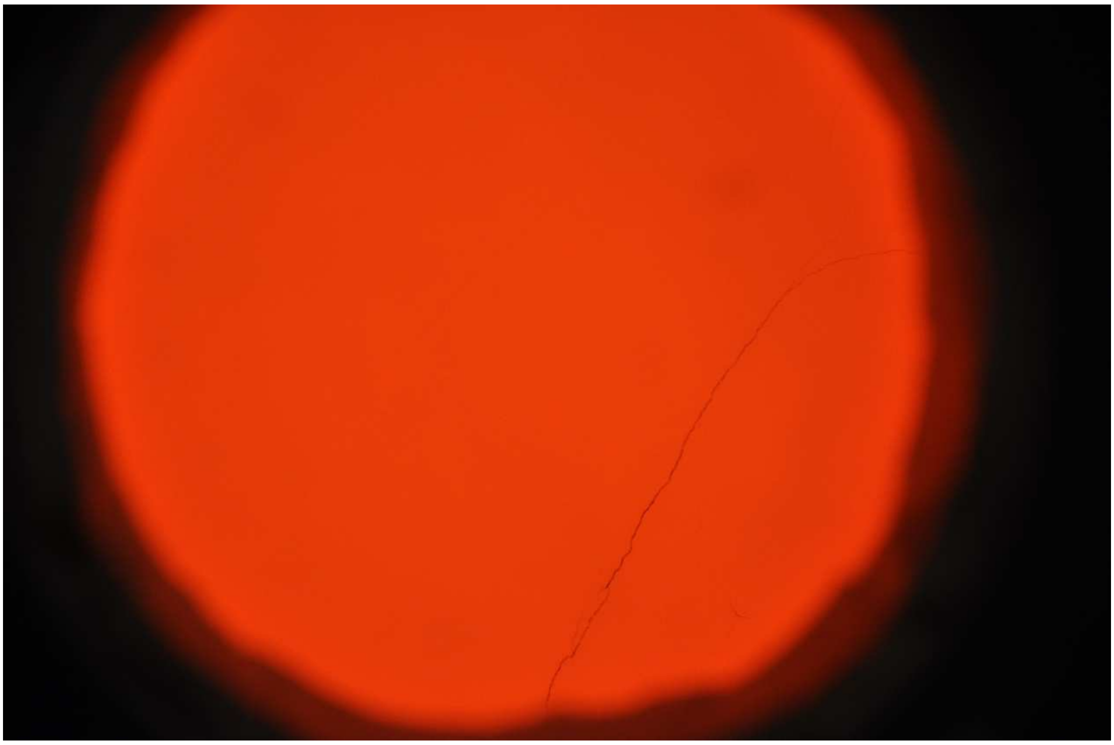


Fig. A9_14 Render crack developed on the exposed side of the wall (180 min post-test start)

References:

- EN 1363-1 Fire resistance tests. General requirements
- EN 1364-1:2015 Fire resistance tests for non-loadbearing elements. Walls

Fire resistance test report for LAVAWALL® A25
Test report

Name and address of the testing laboratory:

Fire Testing Facility of the Civil Engineering Department,
University of Patras. University of Patras, Rion Campus, Patras 26504, Greece.

Name and address of the assignor (sponsor):

"ΛΑΒΑ ΜΕΤΑΛΛΕΥΤΙΚΗ ΚΑΙ ΛΑΤΟΜΙΚΗ ΑΕ"
Δ. Σολωμού 32 , Τ.Κ. 14123, Λυκόβρυση Αττικής

Date of the test:

1 November 2019

Unique reference nomenclature of the test:

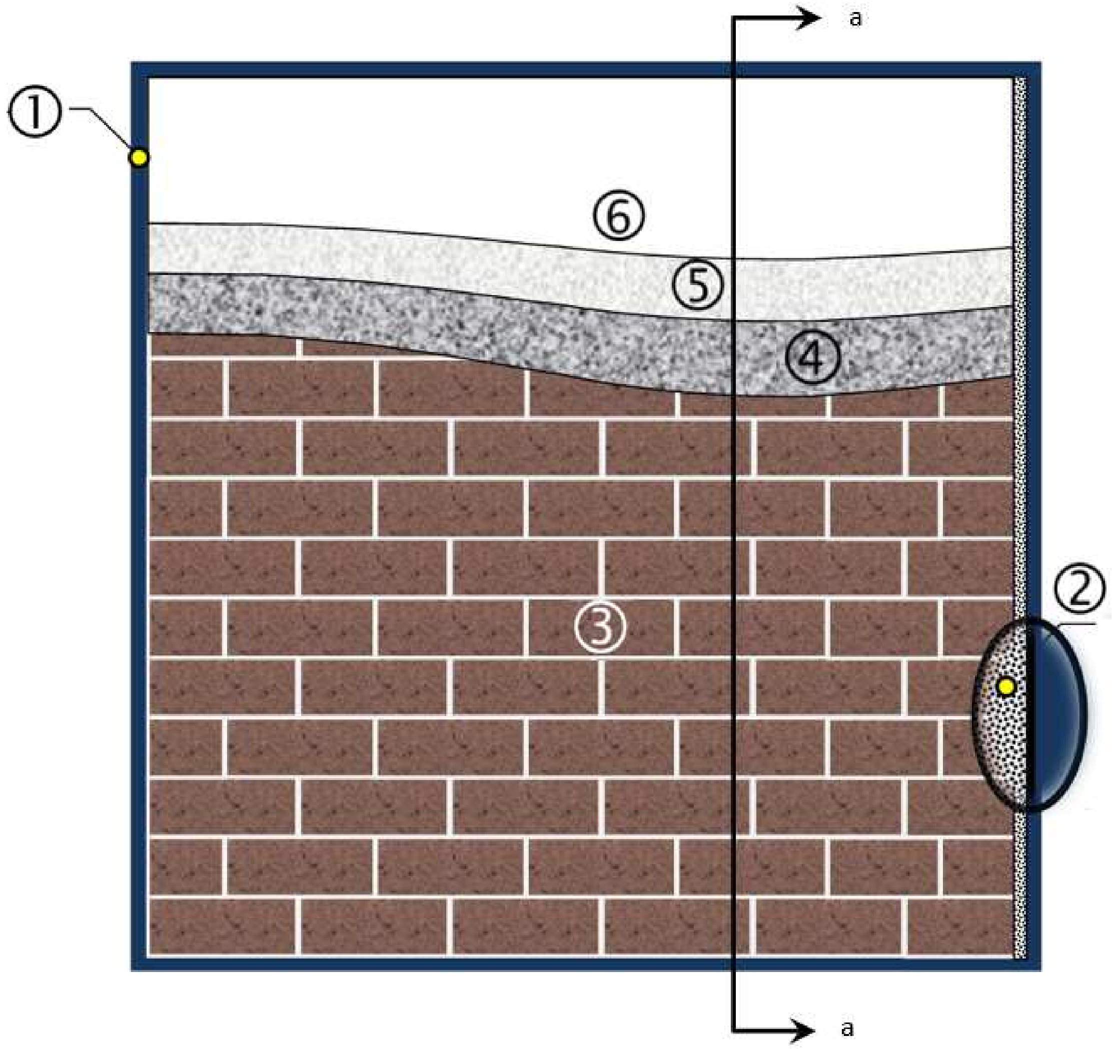
LAVAWALL_A25

Name of the manufacturer of the test specimen:

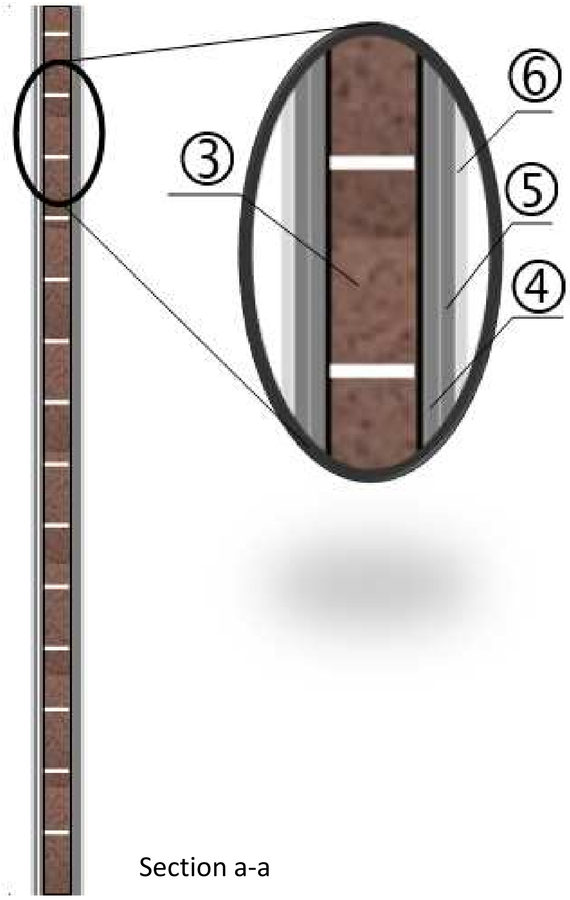
University of Patras – Structural Materials Lab staff (skilled mason)

Constructional details of the test specimen:

The test specimen comprised a single-wythe (leaf) wall installed (constructed and tested) in a rigid steel test frame, lined with refractory concrete blocks along all four sides (supporting construction, as per EN 1363-1). The wall comprised LAVAWALL® A25 building blocks (cavities left clear) in a running bond pattern bonded with a fit-for-purpose LAVAWALL adhesive and was fully representative of the construction intended for use in practice, including surface finishes. All constituent materials along with explicit instructions on handling the LAVAWALL products and constructing the wall were provided by the sponsor. The wall was rendered on both sides with the rendering layered in three sheets; from the wall surface outwards: a cement-based throw-on render, a cement-based troweled one and a fine marble mortar made from lime putty. Wall surface moistening preceded the application of the first layer of render on both sides. The total thickness of the render (on each wall face) and of the rendered wall was equal to 20 mm and 130 mm, respectively. The wall was symmetrical in respect to its mid-plane. The wall measured 3.00 m × 3.00 m (as in length × height). Since the height of the wall as constructed and used in practice is comparable to that of the test specimen the latter was restrained along its top edge (with the bottom and the vertical edge on the left – looking from the unexposed side – also restrained). The vertical edge on the right – looking from the unexposed side – was left without restraint in order to allow wall dilatation lengthwise. The gap (expansion joint) was tightly packed with a fire resistant and compressible material (mineral wool) that provided a seal without restricting freedom of wall movement. Constructional details are depicted in **Fig. A25_1**.



① Rigid steel frame (lined with refractory concrete blocks) – 3.0 m × 3.0 m (clear)
② Expansion joint tightly packed with mineral wool (50 mm – thick)
③ LAVAWALL® A25 building block
④ cement-based throw-on render layer (8 mm – thick)
⑤ cement-based troweled render layer (8 mm – thick)
⑥ fine marble mortar made from lime putty (4 mm – thick)
Unexposed side view



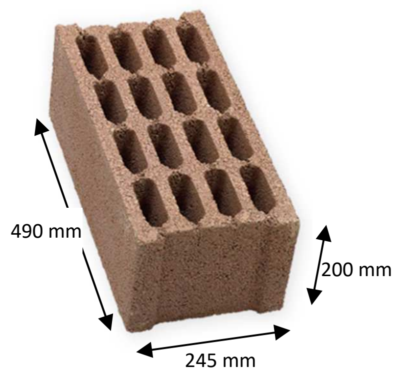


Fig. A25_1 Constructional details of the specimen

Pre-test conditioning of the test specimen:

At the time of the test the condition of the wall was similar to its strength and moisture content expected in normal service. Prior to testing the test specimen was stored for 28 days in an ambient atmosphere of 50% relative humidity at 23°C. The supporting construction born no influences on the behavior of the specimen.

Pre-test preparation:

Fig. A25_2 illustrates the layout of thermocouples on the unexposed side of the test specimen. **Table A25_1** lists the coordinates of the thermocouples' positions (bottom left corner being the origin). Thermocouples 1 to 5 were used for the determination of the average temperature of the wall's unexposed side. The rest of the thermocouples were used for the determination of the maximum temperature developed on the wall's unexposed side. Wall deflections were measured by a laser distance meter (range: 0.05 m to 100 m; measurement accuracy: 1.5 mm) placed on a fixed platform positioned 5 m away from the unexposed side of the specimen. The measurement point (laser target) is shown in **Fig. A25_2** (triangular point "W") and the general measurement principle is shown in **Fig. A25_3**.

The general layout of the specimen just prior to testing is given in **Fig. A25_4**.

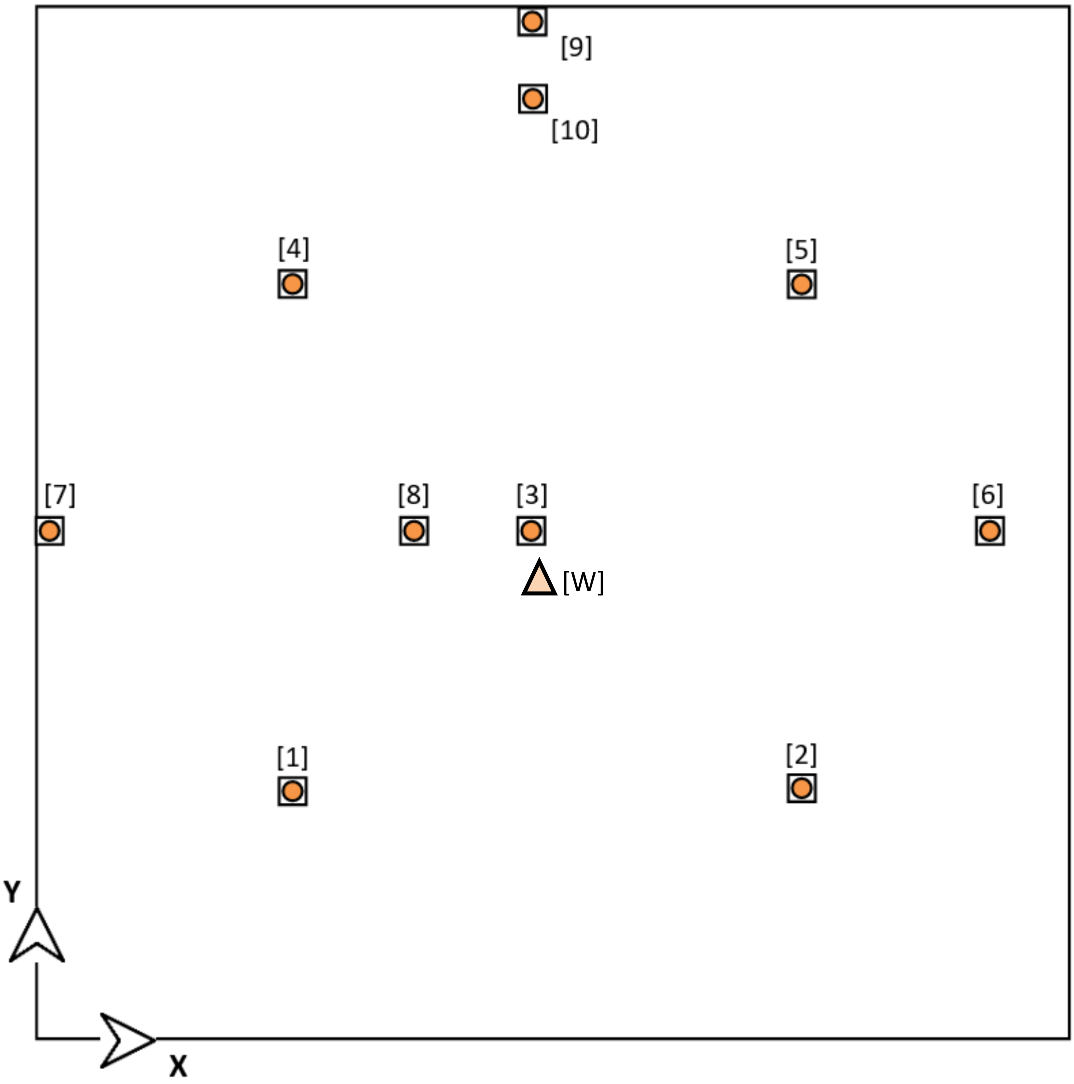


Fig. A25_2 Layout of the thermocouples' positions and deflection measurement point on the unexposed face of the test specimen.

Table A25_1 Positions of thermocouples (in mm)[4]

	Positions									
[mm]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
X	790	2455	1525	790	2455	2920	35	1160	1525	1525
Y	775	775	1490	2320	2320	1490	1490	1490	2965	2885

[4] Note (as per EN 1364-1): For uninsulated non-loadbearing walls, glazed or unglazed, the temperature of the unexposed face is not required to be measured and no thermocouples are therefore required to be attached.

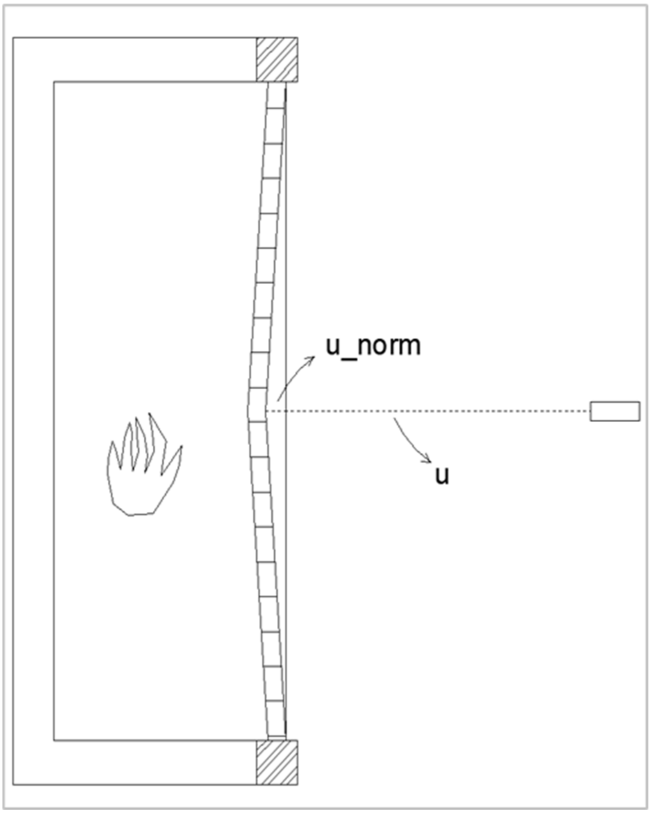


Fig. A25_3 Measuring the deflection of the wall at midpoint.

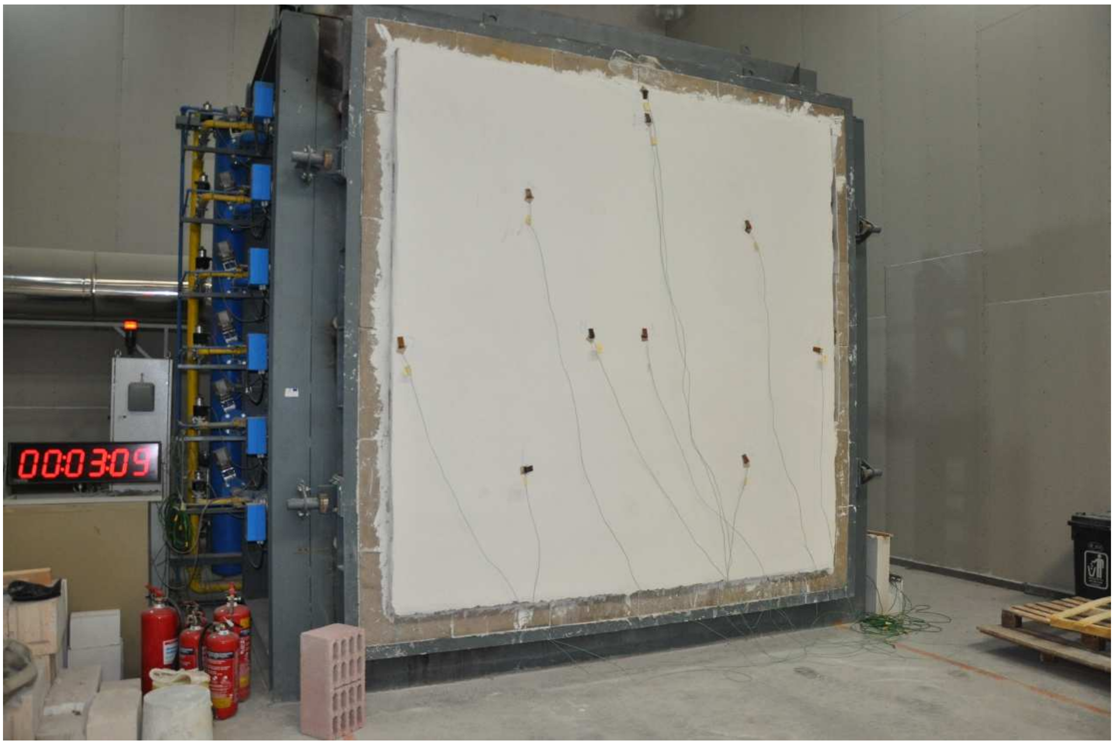


Fig. A25_4 General layout of the specimen during testing (00:03:09 post-test start).

Test procedure:

The test was carried out in accordance with EN1364-1:2015 Fire resistance tests for nonloadbearing elements Part 1: Walls.

The average temperature of the furnace was monitored and controlled such that it followed **Eq. (A25_1)**.

$T = 345 \log_{10}(8t+1)+20$ **Eq. (A25_1)**

where,

T is the average furnace temperature, in °C;
t is the time, in min.

Ambient temperature was continuously recorded during testing and ranged between 20°C and 22°C (at the commencement of the test, ambient temperature was equal to 20°C [5]).

Test results:

The time versus (actual) furnace temperature curve (in comparison to the standard – i.e. target – time versus temperature one) is given in **Fig. A25_5a**. The time versus furnace pressure is given in **Fig. A25_5b**. The pressure (relative to the surrounding laboratory) remained fairly constant (11.09 Pa = 1.13×10^{-4} at; i.e. close to zero) after an initial transient that lasted approximately 15 minutes. The percentage deviation (d_c) in the area of the time versus actual furnace temperature curve from the area of the standard time/temperature curve is shown in **Fig. A25_6**; this deviation [abs(d_c)] is compared in **Fig. A25_6** to the maximum permissible one referenced in EN 1363-1 (tolerance; red line in **Fig. A25_6**). For the total duration of the test (excluding the first 5 min, as per EN 1363-1)[6] d_c was lower than the tolerance. The rapid temperature increase in the first 5 min of the test was responsible for the exceedance of the tolerance (common to fire resistance tests – see EN 1363-1).

The temperature recorded by the furnace thermoplates (10 in number) versus time is shown in **Fig. A25_7**. At any time after the first 37 min of test, the temperature recorded by any thermoplate in the furnace did not differ from the corresponding temperature of the standard temperature/time curve by more than 100°C [7].

The deflection of the wall at midpoint (u_norm, in **Fig. A25_3**) as a function of time is given in **Fig. A25_8**.

Fire integrity assessment: Fire integrity is the ability of the wall, when exposed to fire on one side, to prevent the passage through it of flames and hot gases and to prevent the occurrence of flames on the unexposed side. The specimen continued to maintain its separating function **for more than 180 min** without either:

(a) causing the ignition of a cotton pad applied in accordance to clause 10.4.5.2 of EN 1363-1;
(b) permitting the penetration of a gap gauge as specified in clause 10.4.5.3 of EN 1363-1;
(c) resulting in sustained flaming.

[5] EN 1363-1 specifies that the ambient air temperature should be (20±10)°C at the commencement of the test.
[6] Excluding the first 7 min, in this test.
[7] Nevertheless, EN 1363-1 requires that at any time after the first 10 min of test, the temperature recorded by any thermoplate in the furnace does not differ from the corresponding temperature of the standard temperature/time curve by more than 100°C. Manual switching off of two burners at 18 min post-test start (in order to control the rapid increase of the furnace temperature) resulted in the non-compliance of two thermoplates with the aforementioned requirement up to 40 min post-test start.

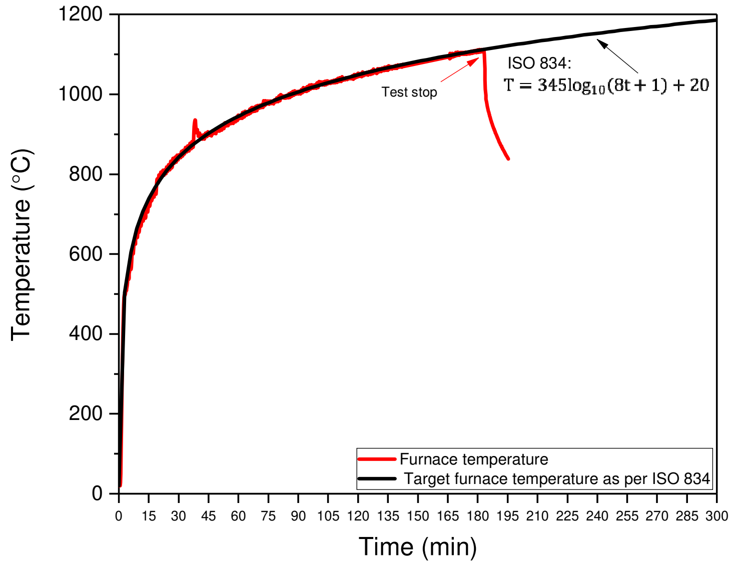
<u>Fire insulation assessment</u>: Fire insulation is the ability of the wall to withstand fire applied at only one side, without transferring the fire to the unexposed side as a result of significant heat transfer from the heated side to the unheated side. That is, fire insulation is the ability of the wall to restrict the temperature rise of the unexposed face to below specified levels. Fire insulation is the time completed in minutes for which the wall continues to maintain its separating function without developing temperatures on its unexposed surface which either:

i. increase the average temperature above the initial average temperature by more than 140°C,
ii. increase at any point of the unexposed wall surface above the initial temperature by more than 180°C.

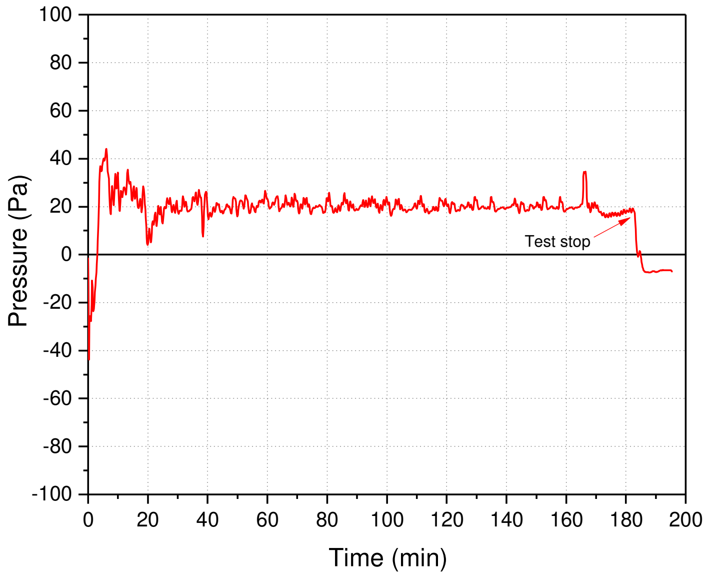
The assessment of point (i) and (ii) is shown in **Fig, A25_9** and in **Fig. A25_10**, respectively. Starting from 130 min post test start, thermocouple No 9 (TC9) exhibited a rapid temperature rise due to its proximity to the wall's extremity.

Thermal imaging was used in order to visualize the wall's temperature field on the unexposed side. Such a visualization is given in **Fig. A25_11**; the thermal image was taken 180 min post-test start. The detachment of the top edge of the wall from the supporting frame (visible in **Fig. A25_11**) was the cause for the rapid temperature rise of TC9.

The test was terminated at 3 h 05 min.



(a)



(b)

Fig. A25_5 (a) Time versus (actual) furnace temperature curve (in comparison to the standard – i.e. target – time versus temperature curve); (b) Time versus furnace pressure

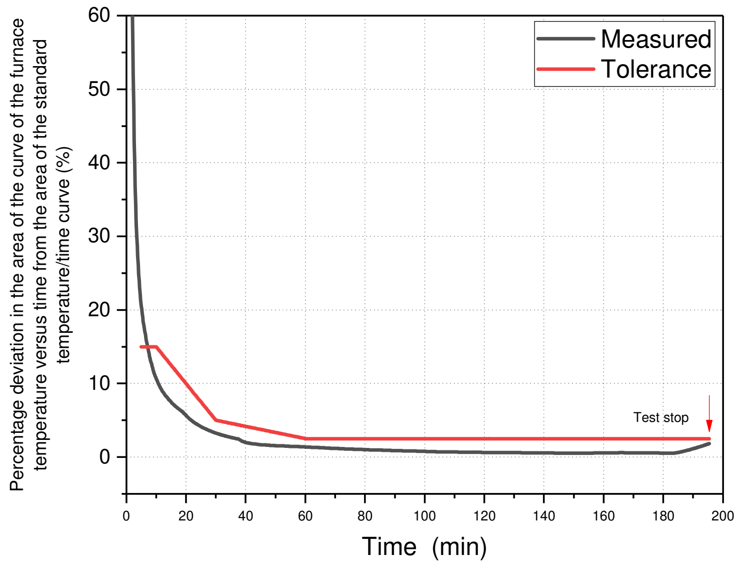


Fig. A25_6 Percentage deviation in the area of the time vs. actual furnace temperature curve from the area of the standard time/temperature curve and maximum permissible one as per EN 1363-1

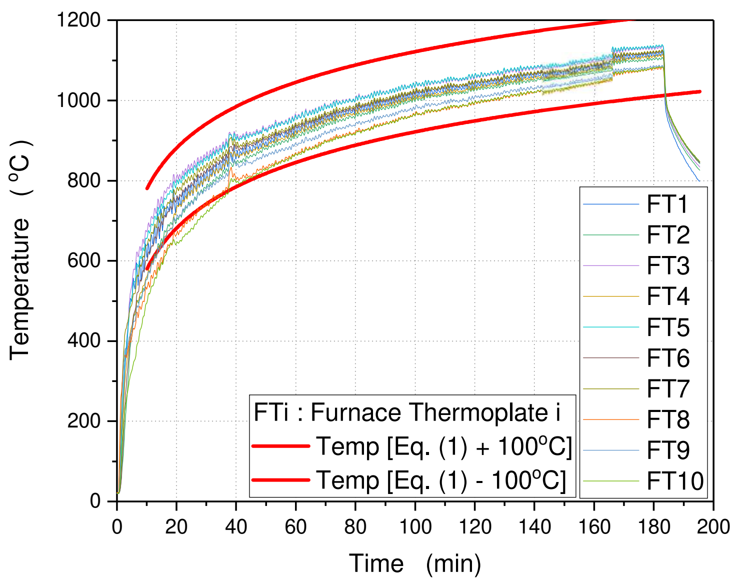


Fig. A25_7 Time records of temperature recorded by each thermoplate in the furnace in comparison to limit temperatures (standard temperature ±100°C)

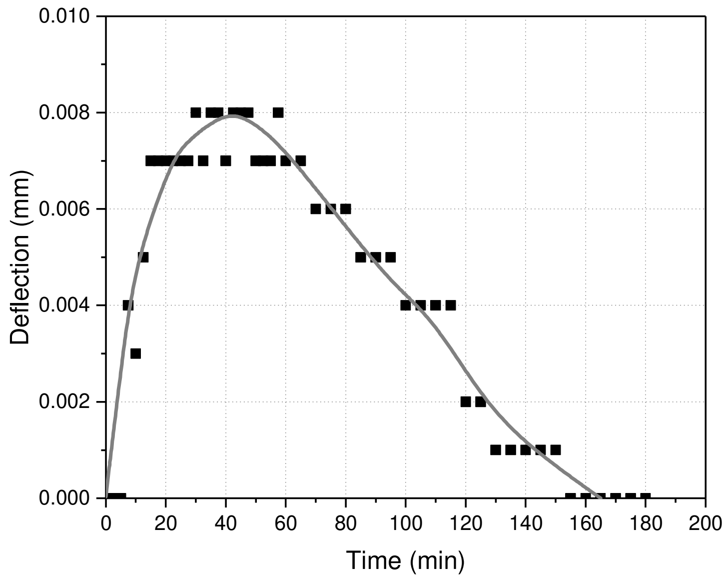


Fig. A25_8 Deflection of the wall at midpoint as a function of time

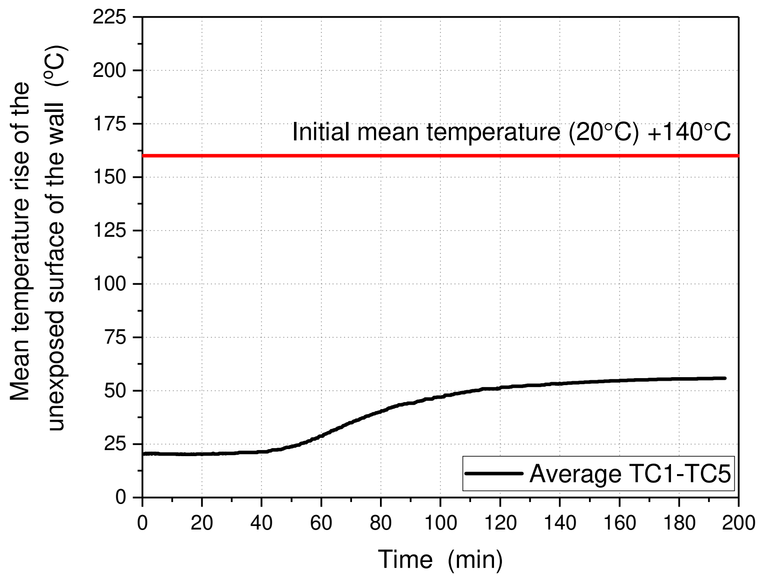


Fig. A25_9 Mean temperature rise of the unexposed surface of the wall versus time [fire insulation: assessment of point (i)]

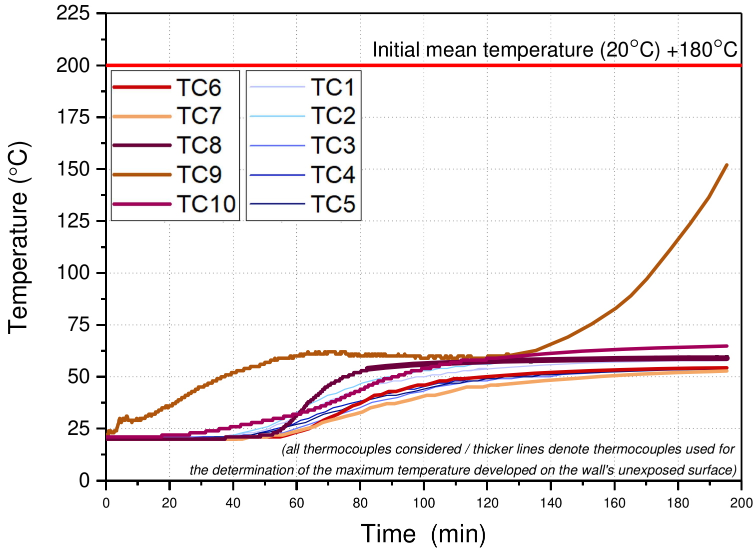


Fig. A25_10 Temperature rise at any point of the unexposed wall surface versus time [fire insulation: assessment of point (ii)]

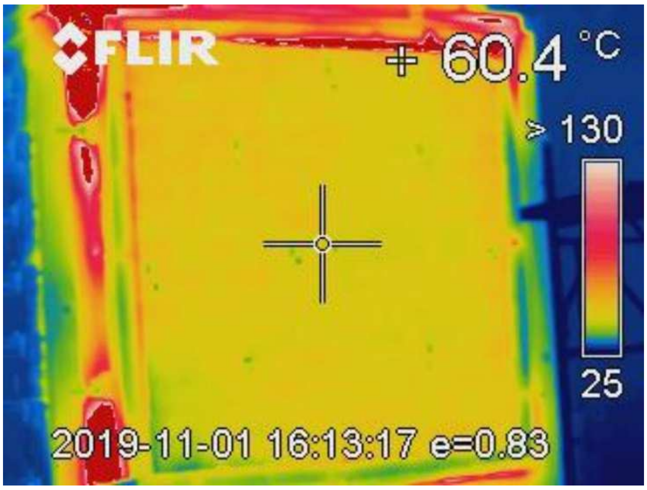


Fig. A25_11 Thermal image of the unexposed wall side at 180 min post-test start

References:

- EN 1363-1 Fire resistance tests. General requirements
- EN 1364-1:2015 Fire resistance tests for non-loadbearing elements. Walls