Research Programme of the Research Fund for Coal and Steel

FIre and Seismic performances of Hybrid fire WALLs in case of single-storey industrial and commercial steel buildings (FISHWALL)

Fire test report on steel members fire-protected by sandwich panels

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PAVUS
FIRE TESTING INSTITUTE

WP2: Fire performance of lightweight sandwich panels for partition walls and fire protection

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Contributing partners		
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A	D2.8	first version (06/06/2023)	Jiří Vaněk	All partners	Christophe RENAUD
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ABSTRACT

It is well known that the intrinsic fire resistance of single-storey unprotected steel-framed buildings is largely sufficient to guarantee the evacuation of occupants in the event of fire. In consequence, for this type of building, the main concern of national fire regulations in Europe is how to prevent the spread of fire to the whole building. To achieve this objective, two performances shall be usually satisfied, namely, the appropriateness of constructive systems to ensure that there is no progressive collapse between fire compartments, and the efficiency of fire walls to stop the fire inside the initial compartment regardless of the state of structures exposed to fire. In practice, many constructional solutions can be implemented in order to preserve the integrity of the fire walls, while accepting that the fire exposed part of the structure may collapse. One of the most common solutions is to place a non-load bearing wall between two independent steel structures and to connect it to them by means of "fusible" links. In fire situation, these fusible links have to allow the wall to be disconnected from the structure affected by fire without endangering the separating function of the wall, which shall remain fixed to the steel structure on the other side of the wall and therefore not exposed to fire. However, due to the lack of corresponding scientific evidence, questions are being very often raised about the real efficiency of such systems in fire situation, which, in certain cases, have also to provide an adequate seismic resistance, if they are used in seismic areas.

Today, concrete or masonry wall solutions are frequently used for the compartmentation of buildings, predominately for low-rise commercial and industrial steel buildings. However, as an alternative, lightweight sandwich panels (comprising two thin flat metal faces and an insulated core) could become an appropriate steel fire wall solution, offering numerous benefits in comparison to other solutions, including fire resistance, durability, flexibility, easy dismounting and fast construction times. But, there is an evident lack of technical information about the adequate fire performance of such type of wall solutions when they are implemented in single-storey buildings with unprotected steel structure, which constitutes a major obstacle for their large use.

In this context, the overall goal of the FISWHALL project is to develop a design guidance and recommendations for an innovative hybrid fire wall solution based on lightweight steel-faced sandwich panels associated with unprotected steel structure under both fire and seismic actions, but considered individually. This will be achieved through the following specific tasks: i) Establishing of a full range of experimental evidence about the fire and seismic behaviour of the investigated hybrid fire wall solution by carrying out a number of tests; ii) Investigating intensively the fire and seismic performances of the above hybrid fire wall solution in combination with unprotected single-storey steel structures through a variety of parametric numerical studies by means of validated FE numerical models; iii) Developing both cost-effective and innovative “fusible” connection systems for fire walls to be used in combination with unprotected steel structures of single-storey buildings; and iv) Developing a design guidance and practical recommendations for the studied hybrid fire wall and fusible links solutions, on the basis of above studies, from which engineers can carry out very efficient design.

The present report aims at summing up the results of fire tests carried out at the Testing Laboratory of PAVUS according to EN 13381-4 [1] on steel members fire-protected with sandwich panels. The detailed fire test report is provided in Annexe of the report.

1 INTRODUCTION

In order to prevent the spread of fire inside buildings, fire safety regulations commonly require buildings to be divided into several zones of limited size and separated by means of partition fire walls. Among the possible wall solutions, the compartmentation of single-storey steel-framed buildings can be achieved by implementing directly the wall into the building and to solidly fix it to the main steel structure, which remains continuous at the position of fire wall. In such situation, any structural member supporting the partition fire wall solidly attached to the building structure should also have the same fire resistance as that required for the wall to preserve the integrity and insulation performance of the separating element. Fire resistance is frequently achieved by applying fire protection to the structural members but common passive fire protections, such as sprayed materials or intumescent coatings. In addition to aesthetic and maintenance problems, such fire protection can add significantly to the cost of the construction, in particular for high fire resistance rating. Due to an easy and fast implementation, sandwich panels forming the partition fire wall could also be used as a low-cost encasement fire protection system (which can be prefabricated by bending the panels) for its supporting steel members, as alternative to common passive fire protections, avoiding the involvement of any other subcontractor.

In this context, a set of two standard fire tests was carried out at the Testing Laboratory of PAVUS on steel members fire-protected by an encasement system made of a single layer of sandwich panels to demonstrate that structural steel members could be adequately fire protected with such type of panels. The tests were performed according to EN 13381-4 [1].

The present report aims at summing up the results of these fire tests. The detailed fire test report is provided in Annexe. The data then gained will be use in a subsequent task dedicated to the thermal analysis of tests results for evaluating the contribution of the investigated encasement system to the fire resistance of structural members.

2 TESTS SPECIMENS AND TESTS ARRANGEMENT

Only a short description of both test specimens and test arrangements is given hereafter. More detailed information are given in Appendix A, which contains the fire test report provided by PAVUS.

During the test design, it was planned to test different panel thicknesses for the encasement system, ranging from 100 to 300mm to cover most of thicknesses of the sandwich panel ranges selected for fire tests. Eurobond Rockspan Extra, Rainspan and Firemaster Extra panels produced by Euroclad were used according to available thicknesses. In total, two pairs of loaded and unloaded I-shaped steel beams (with 3 exposed sides) as well as thirteen unloaded short I-shaped steel columns (with 4 exposed sides) with various section factors (from 51 to 220 m-1) and different protection thickness were tested (as listed in Table 1). The specimens were selected according to EN 13381-4 [1]. They were divided into two testing configurations; in the first test, the loaded beam and reference beam with maximum selected panel thickness together with 6 short columns were tested; in the second test, the loaded beam and reference beam with minimum thickness together with 7 short columns were tested. Loading was applied with jacks.

It should be noted that sandwich panels were cut to the required dimensions according to the protected steel section. They were fixed either directly to the steel profiles (to the flanges) or either using secondary supporting steel systems (mounted to the web) using stainless screws. Four screws were used per panel. The secondary supporting steel systems were made from steel U profiles and, when appropriate, with additional L-shaped profiles depending on the thickness of the panel and the size of the steel profile tested. Some glue was locally put between the panel joints and also between the sandwich panels and the steel profiles.

Fire tests were conducted according to EN 13381-4 [1], recording two sets of data during the tests: temperatures of fire and steel profiles and deflection of loaded steel beams according to the standard provisions. The overall behaviour of test specimens (steel members and protection system) was also monitored visually.

Table 1: List of test specimens

Specimen	Cross-section size	Section factor A_p/V (m^{-1})	Section Range factor k_s	Range of k_s	Panel thickness d_p (mm)	Thickness range factor K_d	Range of k_d
LBmin	IPE 400	121.0	0.414	0.2 to 0.8	100.0	-	-
RBmin	IPE 400	121.0	0.414	0.2 to 0.8	100.0	-	-
LBmax	IPE 400	121.0	0.414	0.2 to 1.0	300.0	-	-
RBmax	IPE 400	121.0	0.414	0.2 to 1.0	300.0	-	-
SIC1	HEM 280	51.0	0.000	0.0	100.0	0	0
SIC2	HEM 280	51.0	0.000	0.0	175.0	0.375	0.2 to 0.5
SIC3	HEM 280	51.0	0.000	0.0	240.0	0.700	0.5 to 0.8
SIC4	HEA 300	110.0	0.349	0.2 to 0.5	100.0	0.000	0.0
SIC5	HEA 300	110.0	0.349	0.2 to 0.5	240.0	0.700	0.5 to 0.8
SIC6	HEA 300	110.0	0.349	0.2 to 0.5	300.0	1.000	1.0
SIC7	HEA 220	140.0	0.527	0.5 to 0.8	100.0	0.000	0.0
SIC8	HEA 220	140.0	0.527	0.5 to 0.8	175.0	0.375	0.2 to 0.5
SIC9	HEA 220	140.0	0.527	0.5 to 0.8	240.0	0.700	0.5 to 0.8
SIC10	HEA 220	140.0	0.527	0.5 to 0.8	300.0	1.000	1.0
SIC11	IPE 200	220.0	1.000	1.0	175(100*)	0.375	0.2 to 0.5
SIC12	IPE 200	220.0	1.000	1.0	240.0	0.700	0.5 to 0.8
SIC13	IPE 200	220.0	1.000	1.0	300.0	1.000	1.0
LB : loaded beam – RB : Reference unloaded beam – SIC : Short I column *) Thickness change agreed by partners							

Some photos of the test specimen's assembly are shown in Figure 1. Some photos of the test specimens before both tests are given in **Erreur ! Source du renvoi introuvable.** Figure 3.

Figure 1: Views of the test specimen’s assembly

	
a) View from furnace outside	b) View from furnace inside

Figure 2: Views of the testing setup and test specimens for the test n°1

	
a) View from furnace outside	b) View from furnace inside

Figure 3: Views of the testing setup and test specimens for the test n°2

3 TEST RESULTS AND MAIN OBSERVATIONS

Only brief results and observations are given here. Detailed test results are reported in Appendix A.

During the test, it should be noted that no significant damage of the tested encasement system were noted on short specimens, only disbonding of the fire-exposed steel sheets from insulated of the sandwich panels during both tests (see Figure 6a). In addition, a detachment of mineral from the bottom flange of the loaded beam protected with the minimum panel thickness beam (LBmin specimen) was observed due to the large beam deflection occurring during the test (see Figure 6b).

An example of temperature rises recorded during the test is given in Figure 4. All measured values were recorded in Excel sheets to provide the data to be used or the thermal analyse (task 2.4).

Based on results of the first fire test discussed during the meeting held at Trento in February 2023, it should be noted that partners indicated that unanticipated or unforeseen shadow effects have probably affected advantageously the heating of steel profiles, by limiting it, because of the small space separating the steel specimens protected with the highest panel thicknesses (see Figure 2). Thus, partners expressed doubts about the accuracy of temperatures recorded for the specimens protected with 300mm thick panels. Consequently, some results of the first test having been judged inoperable, partners agreed that some changes were needed for the second test in order to be able to conduct a thermal analysis of test results according to the standard EN 13381-4, as planned in the subsequent task 3.5.

The specimens have already been mounted and taking into account that a complete modification of the setup was impossible, it was decided to only change the panel thickness applied around the specimen SIC11, changing from 175 mm to 100 mm (see Table 1), ensuring also sufficient spacing between specimens. In addition, some addition plate-thermometers were installed between test specimen to measure hot gas temperatures and to ensure that test specimens were surrounded by fire conditions in accordance with the standard fire curve, as expected.

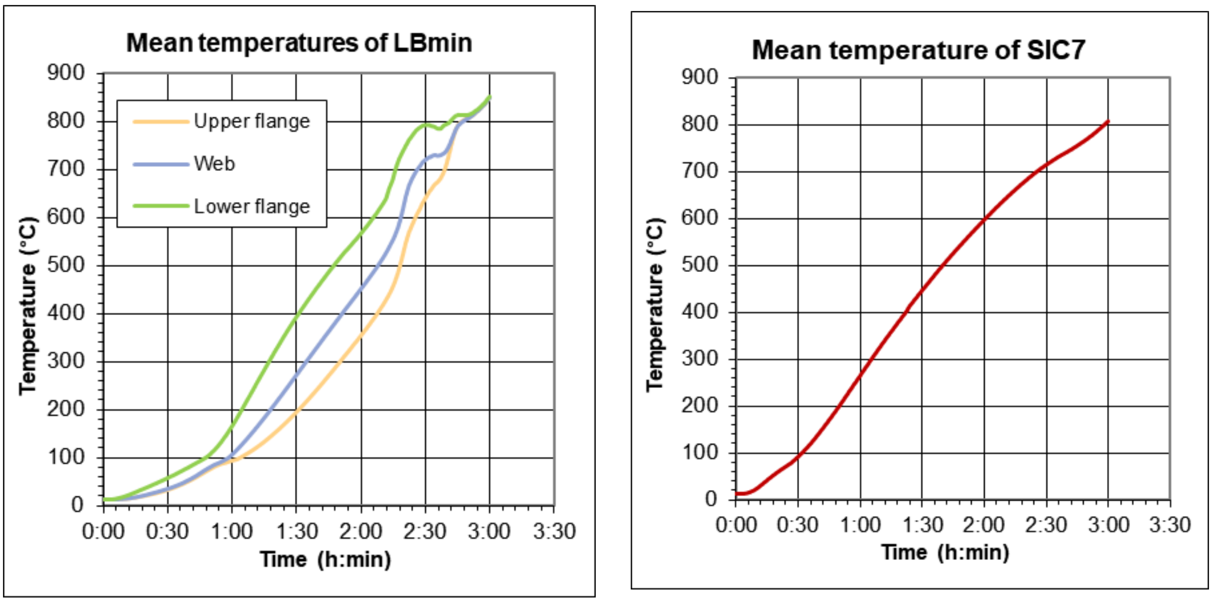

Figure 4: Example of temperature-time curves recorded during the tests

a) Fire test n°1 b) Fire test n°2

Figure 5: View of the test specimens during the tests

a) Disbonding of the fire-exposed steel sheets of sandwich panels

b) Falling down of protection from the bottom flange of the loaded beam

Figure 6: Views of test specimens after the tests

4 CONCLUSIONS

This report aimed at summing up results of two fire tests carried out at the Testing Laboratory of PAVUS on steel members fire-protected by an encasement system made of a single layer of sandwich panels with different thicknesses. For testing, Eurobond Rockspan Extra, Rainspan and Firemaster Extra panels produced by Euroclad were used. Two sets of data were recorded during tests according to the standard EN 13381-4: the temperatures of both fire and steel profiles and the deflection of loaded steel beams. All measured values were recorded in Excel sheets to provide data easily to use. The overall behaviour of steel members as well as the protection system was also monitored visually.

It should be noted that the fire resistance tests showed that the tested encasement solution based on sandwich panels provided an efficient fire protection of steel members, as expected. However, having suspicions that unforeseen shadow effects may have happened during the first fire test, during experiment, some specimens of the second test had to be changed comparing to original plan. Because it was economically impossible to perform any additional fire test, partners decided to simply change the thickness of panels applied around some specimens (by adopting the minimum selected value). The modification will allow conducting a thermal analysis of test results for evaluating the contribution of the investigated encasement system to the fire resistance of structural members, as planned in the subsequent Task 3.5. However, the analysis will have a range of application a bit shorter than initially planned and limited to protection system with 100mm thick panels only.

A detailed analysis and discussion of experimental data will be provided in deliverable related to the thermal analysis of tests results.

5 REFERENCES

[1] EN 13381-4 Test methods for determining the contribution to the fire resistance of structural members — Part 4: Applied passive protection to steel members, Brussels, Belgium, CEN, 2013.

[2] EN 1363-1: Fire resistance tests - Part 1: General requirement, 2021.

[3] Deliverable D1.4: Design of tests, RFSC project FISHWALL, 2020.

[4] Fire resistance test report n° Pr-23-2.025-En for determining the contribution to the fire resistance of steel members by applied passive protection - single-layer fire protection system made of sandwich panels Eurobond Rockspan Extra, Rainspan and Firemaster Extra, 27-02-2023, PAVUS.

APPPENDIX A. FIRE TEST REPORT N°PR-23-2.025-EN

PAVUS
FIRE TESTING INSTITUTE

Order No.: Z210220039

PAVUS, a.s.
AUTHORIZED BODY 216
NOTIFIED BODY 1391
ACCREDITED TESTING LABORATORY
EGOLF MEMBER

ilac-MRA
L 1026

FIRE TESTING LABORATORY VESELÍ NAD LUŽNICÍ
Testing Laboratory No. 1026 accredited by ČIA
Notified Testing Laboratory
workplace Veselí nad Lužnicí

FIRE RESISTANCE TEST REPORT

No. Pr-23-2.025-En

issued on 2023-02-27

For product

determining the contribution to the fire resistance of steel members by applied passive protection

single-layer fire protection system made of sandwich panels Eurobond Rockspan Extra, Rainspan and Firemaster Extra

Sponsor: **Consortium of the RFCS project FISHWALL**

cticm, UNIVERSITÀ DI TRENTO, CTU, JORISIDE, BRIAND, PAVUS, L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT, Efectis, euroclad group

Test method:

ČSN EN 13381-4:2018

Test method for determining the contribution to the fire resistance of structural members – Part 4: Applied passive protection to steel members

Test Report includes 66 pages (5 pages of text + 7 Annexes)

Number of copies: 2
Copy number: 1

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1 INTRODUCTION

The fire resistance tests were performed based on the order of Consortium of the RFCS project FISHWALL in Fire testing laboratory of PAVUS, a.s. in Veselí nad Lužnicí.

The assessment was made on the basis of the following documents:

[1] ČSN EN 1363-1:2021 Fire resistance tests - Part 1: General requirements

[2] ČSN EN 13381-4:2018 Test method for determining the contribution to the fire resistance of structural members - Part 4: Applied passive protection to steel members

[3] ILAC-G17:01/2021 Guidelines for Measurement Uncertainty in Testing

[4] JCGM 100:2008 GUM 1995 with minor corrections, Evaluation of measurement data - Guide to the expression of uncertainty in measurement (Available from www.BIPM.org)

[5] Specimen-related technical documentation delivered by the test sponsor

For the purposes of this report terms, definitions, and symbols stated in ČSN [2], together with the following abbreviations, apply:

I	means both I and H shapes
LB	Loaded beam
RB	Reference beam
SIC	Short I-section columns
ES	fire exposed side of the specimen
mean	mean steel temperature, see [2]: 3.1.12
ATL	Accredited Testing Laboratory
CAI	Czech Accreditation Institute
US	unexposed side of the specimen

2 TEST SPECIMENS

2.1 Fire protection system

2.1.1 Fire protection material

Sandwich panels Eurobond Rockspan Extra, Rainspan and Firemaster Extra were used as a fire protection material. Panels are manufactured by Euroclad Group Ltd.

Technical parameters (nominal values):

- reaction to fire classification — A2-s1, d0 (according to EN 13501-1);
- thickness of panels — (100, *125*, *150*, 175, *200*, 240, 300) mm; *(thicknesses in italics were not tested)*
- density — 120 kg/m^3 (stone wool core, nominal value);
- thermal conductivity — 0.045 W/mK (stone wool core);
- metal sheets — th. 0.5 mm (interior and exterior side), galvanized and coated.

The fire protection material was applied as the single-layer system; the panels of thicknesses 100, 175, 240 and 300 mm were used. One panel has width of 1200 mm, cut according to dimensions of steel section.

In the mid-span of LBmin there were mounted vertical joints in the fire protection.

2.1.2 Supporting system

Sandwich panels were cut to the required dimensions according to the protected steel section. They were fixed either directly to the steel profiles (to the flanges) or either using secondary supporting steel systems (to the web), with stainless screws DrillFast DF12-SSA4-HT-6.3 (producer Fixfast Ltd) with variable length according to the thickness of the tested panel. Four screws were used per panel. The secondary supporting steel systems were mounted between the flanges of tested steel profiles. They were made from steel U profiles 100x60x2mm and, when appropriate with additional L-shaped profiles depending on the thickness of the panel and the size of the steel profile tested (see Annex G). Sandwich panels were locally glued with adhesive FIREPRO Glue (manufacturer ROCKWOOL Limited) inside the joints between sandwich panels themselves and also between the sandwich panels and the steel profiles.

2.1.3 Sampling, application of protection material

The testing laboratory was not involved in sampling. Details of delivered components of the fire protection system are given in the next table.

Table 1 – Sandwich panels

Material	Thickness	Batch No	Production date
Firemaster Extra	100 mm	7726	2022-05-26
Rockspan Extra	175 mm	6125	2022-05-18
Rainspan	240 mm	9425	2022-05-17
Rockspan Extra	300 mm	7211	2022-07-29

The fire protection system was applied by the sponsor from 26th to 28th September 2022 for the first testing configuration (partly also for the second testing configuration) and from 24th to 26th January 2023 for the second testing configuration.

Samples of the fire protection material according to [2]: Annex B were taken during the assembly and stored in the laboratory.

The test specimens were taken in accordance with the documentation of the sponsor given in Annex F. Until the performance of the tests the test specimens and specimens for measuring of properties of fire protection material were placed in the testing hall at the ambient temperature of (21 to 25) °C, and the relative humidity of (51 to 55) %.

2.2 Description of test specimens

2.2.1 General

The sponsor selected Test Package 3 according to [2]: Table 1. Summary of specimens is given in Annex B. After the first test, thickness of the fire protection applied to specimen SIC11 was changed from 175 mm to 100 mm by the sponsor, which means requirements of [2]: Table 5 were not met in this case.

2.2.2 Steel sections

Steel test specimens were constructed according to [2]: 6.3 with sizes according to [2]: 6.2.

Details of steel section (cross-section dimensions of each test specimen and relevant section factors) are summarized in Annex B of this report.

2.2.3 Properties of fire protection material

Measurement of properties of fire protection materials was performed according to [2]: Annex B.

The measurement results of properties of the fire protection material are reported in Annex B.

3 INSTALLATION OF TEST SPECIMENS, RESTRAINT APPLICATION

3.1 General

The tests were carried out on a horizontal test furnace with the following internal dimensions: 3 000 mm (width) x 8 500 mm (length) x 2 980 mm (height); in the longitudinal direction the furnace was adjusted to 4 500 mm. The furnace was covered by slabs designed to fulfil all requirement of [2]: 7 for installation of the loaded beam between the slabs and fixing of unloaded sections to the soffit of the slabs.

3.2 Loaded beam (LB)

The loaded beam was installed according to [2]: 7.1 at next parameters:

- the length of the specimen was L_{spoc} = 4 700 mm;
- the span between the supports was L_{sup} = 4 500 mm;
- the length exposed to heating was L_{exp} = 4 200 mm.

3.3 Reference (unloaded) beam (RB)

The reference (unloaded) beam was installed according to [2]: 7.2.

3.4 Short I-section columns (SIC)

The unloaded short columns were installed according to [2]: 7.4, fixed to the soffit of the furnace cover.

4 APPLICATION OF INSTRUMENTATION

4.1 General

The instrumentation for measurement of the ambient temperature, the furnace temperature, the steel temperature, the furnace pressure, the load, and the deformation complied with the requirements of [2]: 9 and [1]: 9.

The test equipment and measurement equipment used for the test are stated in Annex A.

4.2 Instrumentation for measurement and control of furnace temperature

The furnace temperature was controlled and measured using the plate thermometers placed according to [2]: 9.2.2 in the region of the loaded beam specimen; these plate thermometers covered also requirements of [2]: 9.2.4 for short sections fixed to furnace roof tested together with the loaded beam. In the test performed on 13th February 2023, there were added 5 next plate thermometers between short sections according to request of the sponsor.

Results of temperature measurements of installed plate thermometers is shown in Annex D.

4.3 Instrumentation for measurement of steel temperatures

K-type thermocouples, the diameter of each wire of 0.5 mm, were used for a measurement of the steel temperature following the consultation between the laboratory and the test sponsor regarding their suitability, see [2]: C.2. Hot junctions of the thermocouples were located according to [2]: 9.3, the thermocouples were fixed and routed according to [2]: Annex C.

Identification of installed thermocouples is shown in Annex D, together with the results of temperature measurements.

5 TEST PROCEDURE AND TEST RESULTS

5.1 General

The test procedure met the requirements of [2]: 10 and [1]: 10. The tests were performed on 5th October 2022 and on 13th February 2023 in the presence of representative of the sponsor.

5.2 Commencement of the test

Not more than 5 minutes before the commencement of the tests the initial values of all measured quantities were recorded, checked for measurement consistency, and the datum values shall be established. At the commencement of the test the requirements of [1]: 10.3 were fulfilled.

5.3 Control of the furnace

The furnace was heated by oil burner system.

The furnace temperature was measured using the plate thermometers mentioned in part 5 of this report to control the furnace according to criteria of [1]: 5.1.

The furnace pressure was controlled by a speed of the exhaust fan to meet criteria [1]: 5.2 (the overpressure of 20 Pa established 100 mm bellow the underside of the cover slabs).

5.4 Loading

The loaded beams were subjected to the load calculated according to [2]: 5.3; see Annex C.

The load was applied and controlled according to [2]: 10.3.

5.5 Data recording

During the tests all the measured quantities were continuously monitored and recorded at 10-seconds intervals.

5.6 Observation

The general behaviour of the test specimens through the tests was monitored and recorded according to [2]: 10.6.

5.7 Termination of test

The tests were stopped after 180 minutes according to request of the sponsor.

6 TEST RESULTS AND FIELD OF DIRECT APPLICATION OF RESULTS

Acceptability of the test results was judged by rules given in [2]: 11.1. Data recorded during the tests are presented in Annex D and summarised as given in [2]: 11.2. The furnace temperatures and the furnace pressure met the requirements of [1]: 5.

The general behaviour of the specimens is reported in Annex E of this test report. Photos are given in Annex G.

The field of direct application of the results for the specimens according to [1]: 12.1 v) cannot be given in this test report. Limits of the applicability of the results of the assessment according to [2]: 15 were taken into account and will be given in the report of the assessment, see [2]: 14, and in the classification report according to EN 13501-2.

The test results refer only to the tested specimens including the way of its mounting into the construction (see Part 2 of this Report).

This report provides the constructional details, the test conditions, the results obtained and the interpolated data obtained when the specified fire protection system described herein was tested following the procedures of [2] and [1]. Any deviation with respect to thickness and density of fire protection material and constructional details, loads, stresses, edge or end conditions other than those allowed under the field of application could invalidate the test result.

Report sheets and Annexes are valid only if stamped with an embossed stamp.

Worked out by: .... Jiří VANĚK, Technical Officer

Approved by: .... Jiří KÁPL, ATL Manager

ANNEX A: TESTING AND GAUGING DEVICES, MEASUREMENT UNCERTAINTY

Test equipment:	Registration No.:
Horizontal furnace (+ equipment pressure and temperature control inside the furnace)	0007
Hydraulic unit	0009
Pressure probe in the furnace	0011

Measurement equipment:	Measured quantity	Metrological registration No.:
Differential pressure transducer	Pressure (voltage)	3 09 29
Dataloggers	Temperature	3 10 66, 85
Plate thermometers (STC type K ∅ 2 mm)	Temperature (emf)	3 10 11
Device for measuring ambient temperature (STC type K ∅ 3 mm)	Temperature (emf)	3 10 09
TC type K 2 x ∅ 0.5 mm (steel temperature)	Temperature (emf)	3 10 14, 15
Hydraulic jack	Loading force	3 07 58, 59
Pressure gauge	Hydraulic pressure	3 09 30
Deflection gauge	Axial deformation	3 01 39
Stopwatch	Time	3 05 12
Caliper	Dimension	3 01 50
Measuring tape	Dimension	3 01 29

Measurement traceability of all measurement equipment is reported in the metrological registration card of the equipment; identified by the same metrological registration number as the equipment.

Quantity		**Expanded uncertainties**
Time from commencement of test		< 0,03 min
Temperature (type K thermocouple, compensating cables, datalogger)	• furnace (TC Class 1)	< 3.1 °C
	• ambient (TC Class 1)	< 1.1 °C
	• steel (TC Class 2)	< 3.9 °C
Hydraulic pressure		< 0.06 MPa
Load		< 1.2 kN
Deformation		< 1.5 mm
Thickness of fire protection material		< 3.5 %
Overpressure in the furnace		< 3.4 Pa

The reported expanded measurement uncertainty is stated as the combined standard measurement uncertainty multiplied by the coverage factor $k = 2$ such that the coverage probability corresponds to approximately 95 %.", see [3] and [4].

The measurement uncertainty arising from sampling is not included in the expanded measurement uncertainty. "Because of the nature of fire resistance testing and the consequent difficulty in quantifying the uncertainty of measurement of fire resistance, it is not possible stated a degree of accuracy of the result", see EN 1363-1: 12.1 w).

ANNEX B: TEST SPECIMENS, MEASUREMENT

B.1 Selection of test specimens

Summary of LB (loaded beam), RB (reference, unloaded beam)

Specimen	Section	s_p (m^{-1})	K_s (-)	Range of K_s	d_p (mm)
LBmin	IPE 400	121.0	0.414	0.2 to 0.8	100.0
RBmin	IPE 400	121.0	0.414	0.2 to 0.8	100.0
LBmax	IPE 400	121.0	0.414	0.2 to 1.0	300.0
RBmax	IPE 400	121.0	0.414	0.2 to 1.0	300.0

Summary of SIC (Short I-section column)

Specimen	Section	s_p (m^{-1})	K_s (-)	Range of K_s	d_p (mm)	K_d (-)	Range of K_d
SIC1	HEM 280	51.0	0.000	0.0	100.0	0.000	0.0
SIC2	HEM 280	51.0	0.000	0.0	175.0	0.375	0.2 to 0.5
SIC3	HEM 280	51.0	0.000	0.0	240.0	0.700	0.5 to 0.8
SIC4	HEA 300	110.0	0.349	0.2 to 0.5	100.0	0.000	0.0
SIC5	HEA 300	110.0	0.349	0.2 to 0.5	240.0	0.700	0.5 to 0.8
SIC6	HEA 300	110.0	0.349	0.2 to 0.5	300.0	1.000	1.0
SIC7	HEA 220	140.0	0.527	0.5 to 0.8	100.0	0.000	0.0
SIC8	HEA 220	140.0	0.527	0.5 to 0.8	175.0	0.375	0.2 to 0.5
SIC9	HEA 220	140.0	0.527	0.5 to 0.8	240.0	0.700	0.5 to 0.8
SIC10	HEA 220	140.0	0.527	0.5 to 0.8	300.0	1.000	1.0
SIC11	IPE 200	220.0	1.000	1.0	100.0	0.000	0.2 to 0.5
SIC12	IPE 200	220.0	1.000	1.0	240.0	0.700	0.5 to 0.8
SIC13	IPE 200	220.0	1.000	1.0	300.0	1.000	1.0
	min	51.0			100.0		
	max	220.0			300.0		

Table 5 of EN 13381-4

Section Range Factor K_s	Thickness Range Factor K_d 0.0	0.2 to 0.5	0.5 to 0.8	1.0
0.0	SIC1	SIC2	SIC3	
0.2 to 0.5	SIC4		SIC5	SIC6
0.5 to 0.8	SIC7	SIC8	SIC9	SIC10
1.0	SIC11		SIC12	SIC13

Key

s_p	Nominal Boxed Section Factor: see EN 13381-4: Tables F.2, F.4
K_s	Section Range Factor: see EN 13381-4: 6.6.3.1 and Table 5
d_p	Nominal Protection Thickness
K_d	Thickness Range Factor, see EN 13381-4: 6.6.3.2

Note: Thickness of the fire protection material applied on SIC11 was changed from 175 mm to 100 mm by the sponsor, which means requirements of [2]: Table 5 were not met in this case.

B.2 Specimens list, cross-sections of the specimens

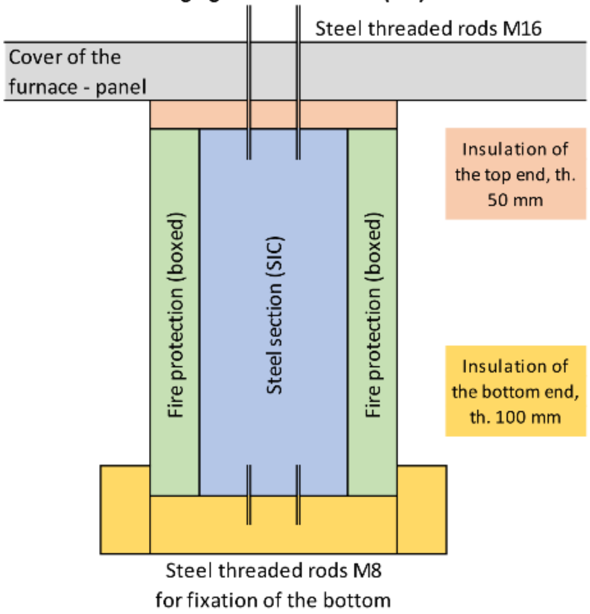
Summary of LB (loaded beam), RB (reference, unloaded beam)

Specimen	Section	Length (mm)	Width (mm)	Height (mm)	Panel th. (mm)
LBmin	IPE 400	4700	180	400	100
RBmin	IPE 400	950	180	400	100
LBmax	IPE 400	4700	180	400	300
RBmax	IPE 400	950	180	400	300

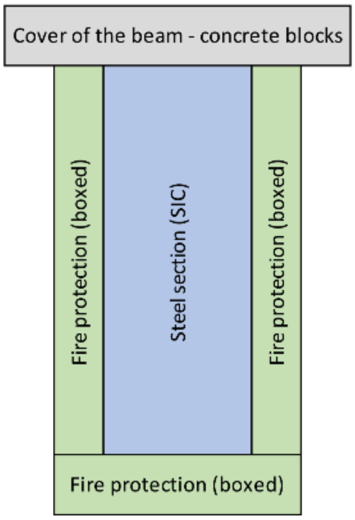
Summary of SIC (Short I-section column)

Specimen	Section	Length (mm)	Width (mm)	Height (mm)	Panel th. (mm)
SIC1	HEM 280	950	288	310	100
SIC2	HEM 280	950	288	310	175
SIC3	HEM 280	950	288	310	240
SIC4	HEA 300	950	300	290	100
SIC5	HEA 300	950	300	290	240
SIC6	HEA 300	950	300	290	300
SIC7	HEA 220	950	220	210	100
SIC8	HEA 220	950	220	210	175
SIC9	HEA 220	950	220	210	240
SIC10	HEA 220	950	220	210	300
SIC11	IPE 200	950	100	200	100
SIC12	IPE 200	950	100	200	240
SIC13	IPE 200	950	100	200	300

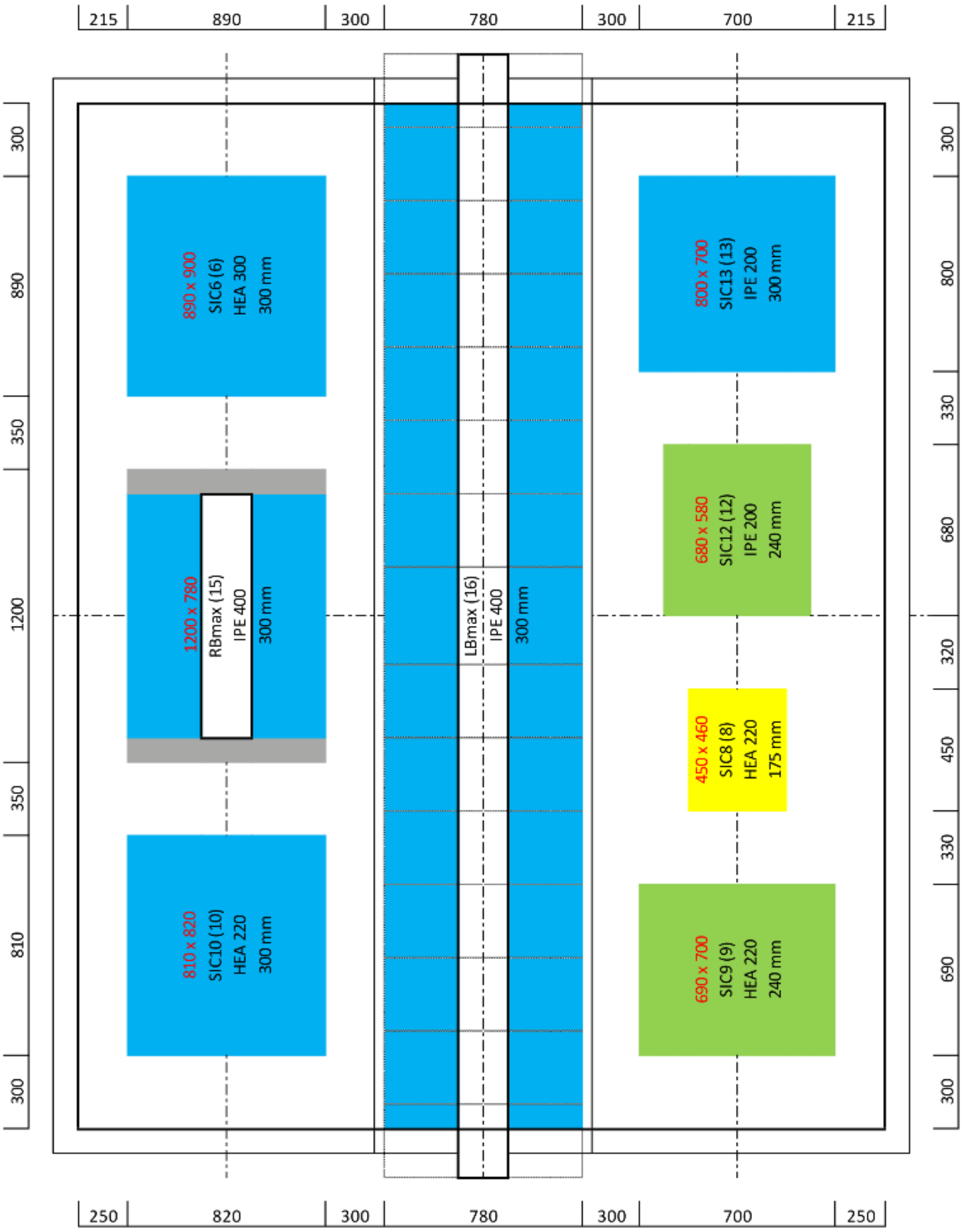
Scheme of the hanging of short columns (SIC) in the furnace



Scheme of LB, RB

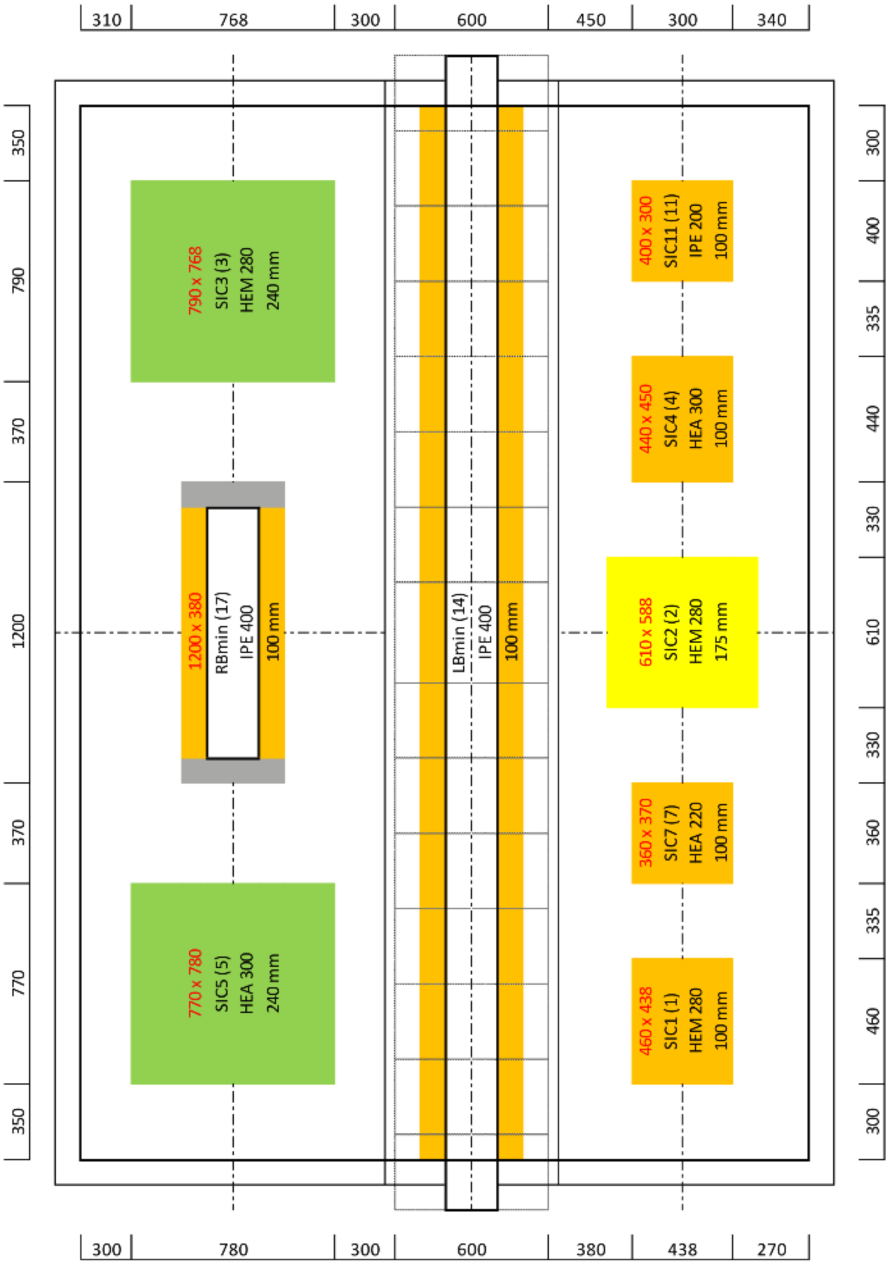


B.3 Test setup - test of 2022-10-05



Distance between specimens in mid-height of SICs > 300 mm, distance from the furnace wall > 200 mm.

B.4 Test setup - test of 2023-02-13



Distance between specimens in mid-height of SICs > 300 mm, distance from the furnace wall > 200 mm.

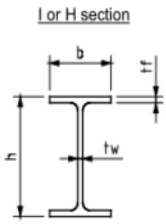
B.5 Dimensions of sections

Mean actual dimensions of the section, section factor

Specimen Reference	No	Section (mm)	Depth h (mm)	Breadth b (mm)	Web thickness t_w (mm)	Flange thickness t_f (mm)	Protection type	Protection sides	Section factor A_p/V (m^{-1})
LBmin	14	IPE 400	401.2	181.3	8.4	12.7	boxed	3	126.9
RBmax	15	IPE 400	401.3	179.8	9.0	12.4	boxed	3	125.0
LBmax	16	IPE 400	401.3	181.0	8.4	12.6	boxed	3	127.7
RBmin	17	IPE 400	401.2	181.4	8.4	12.6	boxed	3	127.3
SIC1	1	HEM 280	313.0	286.5	18.2	32.2	boxed	4	52.2
SIC2	2	HEM 280	313.0	286.5	18.2	32.2	boxed	4	52.2
SIC3	3	HEM 280	312.9	286.5	18.2	32.1	boxed	4	52.3
SIC4	4	HEA 300	293.0	298.3	8.5	13.4	boxed	4	115.1
SIC5	5	HEA 300	289.8	299.1	8.6	13.2	boxed	4	116.1
SIC6	6	HEA 300	289.7	299.0	8.6	13.3	boxed	4	115.2
SIC7	7	HEA 220	211.0	219.1	7.3	10.5	boxed	4	143.3
SIC8	8	HEA 220	211.2	218.7	7.4	10.8	boxed	4	140.7
SIC9	9	HEA 220	212.8	220.8	7.2	10.7	boxed	4	142.0
SIC10	10	HEA 220	212.7	220.8	7.0	10.8	boxed	4	142.4
SIC11	11	IPE 200	200.9	101.4	5.8	8.0	boxed	4	224.7
SIC12	12	IPE 200	200.6	101.4	5.8	8.0	boxed	4	224.9
SIC13	13	IPE 200	200.5	101.6	5.6	7.9	boxed	4	228.6

Key

Depth of the I section, in mm — h
Breadth of the I section, in mm — b
Thickness of the web of the I section, in mm — t_w
Thickness of the flange of the I section, in mm — t_f
Section factor of the protected steel section calculated according to EN 13381-4: Figure 1, in m^{-1} — A_p/V



B.6 Properties of fire protection material

Item: **Firemaster Extra 100 mm** **specimen A**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	998.00
b	296.00
thickness	**100.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	5551.2	**187.9**	18.792		
2022-10-04	5512.2			0.708	0.708
2022-10-05	5510.7			0.027	**0.735**

Item: **Firemaster Extra 100 mm** **specimen B**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	1000.00
b	296.00
thickness	**100.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	5453.7	**184.2**	18.425		
2022-10-04	5410.2			0.804	0.804
2022-10-05	5406.7			0.065	**0.869**

The material was dried in an oven operating at a temperature of (105 ± 5) °C according to [1]: F.3.2.

Item: **Rockspan Extra 175 mm** **specimen A**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	1010.00
b	286.00
thickness	**176.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	8499.7	**167.2**	29.425		
2022-10-04	8476			0.280	0.280
2022-10-05	8472.8			0.038	**0.317**

Item: **Rockspan Extra 175 mm** **specimen B**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	997.00
b	286.00
thickness	**176.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	8352.3	**166.4**	29.292		
2022-10-04	8321.2			0.374	0.374
2022-10-05	8318			0.038	**0.412**

The material was dried in an oven operating at a temperature of (105 ± 5) °C according to [1]: F.3.2.

Item: **Rainspan 240 mm** **specimen A**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	999.00
b	285.00
thickness	**241.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	11348.9	**165.4**	39.861		
2022-10-04	11297.2			0.458	0.458
2022-10-05	11287.8			0.083	**0.541**

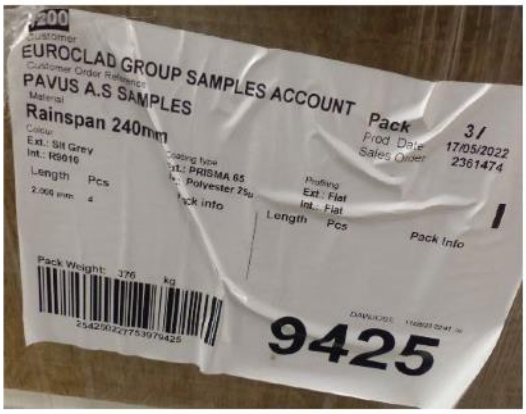
Item: **Rainspan 240 mm** **specimen B**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	997.00
b	285.00
thickness	**240.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	11151.2	**163.5**	39.245		
2022-10-04	11097.2			0.487	0.487
2022-10-05	11090.8			0.058	**0.545**

The material was dried in an oven operating at a temperature of (105 ± 5) °C according to [1]: F.3.2.



Item: **Rockspan Extra 300 mm** **specimen A**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	997.00
b	285.00
thickness	**299.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	13149.7	**154.8**	46.278		
2022-10-04	13114.3			0.270	0.270
2022-10-05	13109.4			0.037	**0.307**

Item: **Rockspan Extra 300 mm** **specimen B**
Description: Mineral wool sandwich panel

Measured dimension of the specimen just prior to the time of test (mm):

	mean
a	998.00
b	285.00
thickness	**299.00**

Date	Weight	Cubic density	Surface density	Moisture difference	Moisture total
	[g]	[kg.m^{-3}]	[kg.m^{-2}]	[%]	[%]
2022-10-03	13051.2	**153.5**	45.885		
2022-10-04	13004.5			0.359	0.359
2022-10-05	12998.2			0.048	**0.408**

The material was dried in an oven operating at a temperature of (105 ± 5) °C according to [1]: F.3.2.

ANNEX C: LOAD

C.1 Calculation of load applied to LBmax - test of 2022-10-05

Calculation of applied moment and jack loads was performed according to [2]: 5.3 and EN 1993-1-1: 6.2.5.

Acceleration of gravity $g = 9.807 \cdot m \cdot s^{-2}$

The beam is supported over 4.5m span. Loading is to be via 2 jacks at 1600 mm from suports

over the span of $L_{sup} := 4500mm$

and loaded via 2 jacks at the distance from suports of $s := 40\% \cdot L_{sup} = 1800 \cdot mm$

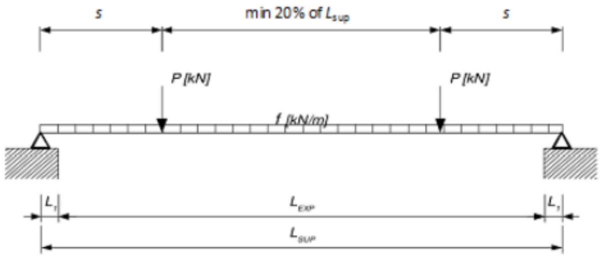


Figure 1: Static scheme of beam specimen

Steel Section: IPE 400, grade S275

Yield strenght(CELSA Certificate No.202040444) $R_{ch} := 314MPa$

Plastic section modulus $W_{pl} := 1307 \cdot 10^3 mm^3$

Partial safety factor for the material property $\gamma_{M1} := 1$

Mass per metre $m_a := 66.3kg \cdot m^{-1}$

Load spacers

Mass per load point $m_s := 30kg$

Aerated concrete topping

Length, width, thickness of blocks $l := 250mm$ $w := 600mm$ $t := 200mm$

Density of blocks $\rho_t := 650kg \cdot m^{-3}$

Mass per metre $m_t := \rho_t \cdot \frac{w \cdot t \cdot l}{l + 3cm} = 70 \cdot kg \cdot m^{-1}$

Fire protection

Thickness $d_p := 300mm$

Density $\rho_p := 150kg \cdot m^{-3}$

Mass per metre $m_p := \rho_p \cdot d_p (2 \cdot h + b + 2 \cdot d_p) = 71.262 \cdot kg \cdot m^{-1}$

Moment due to dead weight $M_c := \frac{1}{8} \cdot (m_a + m_t + m_p) \cdot g L_{sup}^2 + m_s \cdot g \cdot s$

$M_c = 5.67 \cdot kN \cdot m$

Load

Central bending moment acc. to EN 1993-1-1: 6.2.5 $M_b := \frac{0.6 \cdot W_{pl} \cdot R_{eh}}{\gamma_{M1}} = 246.24 \cdot kN \cdot m$

The moment required to be generated by the 2 jacks $M_j := M_b - M_c = 240.57 \cdot kN \cdot m$

Load of each jack (3 07 58, 59) $P := \frac{M_j}{s} = 133.648 \cdot kN$

$SLOPE := 9.4180 \frac{kN}{MPa}$ $INTERCEPT := 0.2028kN$ $p_{hydraulic} := \frac{P - INTERCEPT}{SLOPE} = 14.169 \cdot MPa$

Uniform load (dead weight of section, cover slabs and protection) $q := (m_a + m_t + m_p) \cdot g = 2.032 \cdot kN \cdot m^{-1}$

Maximum deflection before the test $\nu_0 := \frac{(P + m_s \cdot g) \cdot s}{24 \cdot E \cdot I} \cdot \left(3 \cdot L_{sup}^2 - 4s^2\right) + \frac{5}{384 \cdot E \cdot I} \cdot q \cdot L_{sup}^4$

$\nu_0 = 10.1 \cdot mm$

Deflection at which the load shall be removed $D_{max} := \frac{L_{sup}}{30} = 150 \cdot mm$

Limiting rate of deflection (EN 1363-1:11.1a) $\frac{L_{sup}^2}{9000 \cdot h \cdot min} = 5.6 \cdot mm \cdot min^{-1}$

C.2 Calculation of load applied to LBmin - test of 2023-02-13

Calculation of applied moment and jack loads was performed according to [2]: 5.3 and EN 1993-1-1: 6.2.5.

Calculation of jack load

Acceleration of gravity $g = 9.807 \cdot m \cdot s^{-2}$

The beam is supported over 4.5m span. Loading is to be via 2 jacks at 1600 mm from suports

over the span of $L_{sup} := 4500mm$

and loaded via 2 jacks at the distance from suports of $s := 40\% \cdot L_{sup} = 1800 \cdot mm$

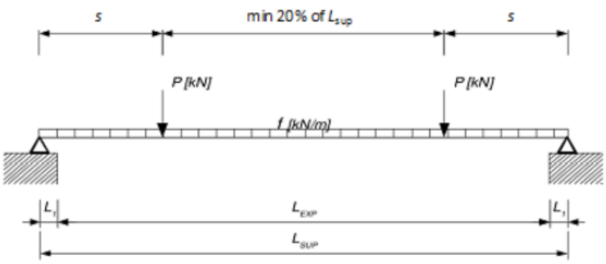


Figure 1: Static scheme of beam specimen

Steel Section: IPE 400, grade S275

Yield strenght(CELSA Certificate No.202040444) $R_{eh} := 314MPa$

Plastic section modulus $W_{pl} := 1307 \cdot 10^3 mm^3$

Partial safety factor for the material property $\gamma_{M1} := 1$

Mass per metre $m_a := 66.3kg \cdot m^{-1}$

Load spacers

Mass per load point $m_s := 30kg$

Aerated concrete topping

Length, width, thickness of blocks $l := 250mm$ $w := 600mm$ $t := 200mm$

Density of blocks $\rho_t := 650kg \cdot m^{-3}$

Mass per metre $m_t := \rho_t \cdot \frac{w \cdot t \cdot l}{l + 3cm} = 70 \cdot kg \cdot m^{-1}$

Fire protection

Thickness $d_p := 100mm$

Density $\rho_p := 120kg \cdot m^{-3}$

Mass per metre $m_p := \rho_p \cdot d_p (2 \cdot h + b + 2 \cdot d_p) = 14.204 \cdot kg \cdot m^{-1}$

Moment due to dead weight $M_c := \frac{1}{8} \cdot (m_a + m_t + m_p) \cdot g L_{sup}^2 + m_s \cdot g \cdot s$

$M_c = 4.26 \cdot kN \cdot m$

Load

Central bending moment acc. to EN 1993-1-1: 6.2.5 $M_b := \frac{0.6 \cdot W_{pl} \cdot R_{eh}}{\gamma_{M1}} = 246.24 \cdot kN \cdot m$

The moment required to be generated by the 2 jacks $M_j := M_b - M_c = 241.98 \cdot kN \cdot m$

Load of each jack (3 07 58, 59) $P := \frac{M_j}{s} = 134.435 \cdot kN$

$SLOPE := 9.4020 \frac{kN}{MPa}$ $INTERCEPT := -0.676kN$ $p_{hydraulic} := \frac{P - INTERCEPT}{SLOPE} = 14.37 \cdot MPa$

Uniform load (dead weight of section, cover slabs and protection) $q := (m_a + m_t + m_p) \cdot g = 1.472 \cdot kN \cdot m^{-1}$

Maximum deflection before the test $\nu_0 := \frac{(P + m_s \cdot g) \cdot s}{24 \cdot E \cdot I} \cdot \left(3 \cdot L_{sup}^2 - 4s^2\right) + \frac{5}{384 \cdot E \cdot I} \cdot q \cdot L_{sup}^4$

$\nu_0 = 10.1 \cdot mm$

Deflection at which the load shall be removed $D_{max} := \frac{L_{sup}}{30} = 150 \cdot mm$

Limiting rate of deflection (EN 1363-1:11.1a) $\frac{L_{sup}^2}{9000 \cdot h \cdot min} = 5.6 \cdot mm \cdot min^{-1}$

ANNEX D: TEST MEASUREMENT

D.1 Furnace control, ambient temperature - test of 2022-10-05

Test conditions according to EN 1363-1: 5

Time	Furnace temperatures										Deviation d_e			Deviation from T		Probe pressure			Ambient
	T	90	91	92	93	94	95	96	97	avg	shall be within		actual	min	max	shall be within		actual	temperature
(h:min:s)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(%)	(%)	(%)	(°C)	(°C)	(Pa)	(Pa)	(Pa)	(°C)
0:00:00	20	16	16	16	16	15	16	16	16	16								13.4	17
0:05:00	576	675	650	583	583	655	601	607	617	621			6.7					10.0	17
0:10:00	678	731	668	659	716	693	659	663	682	684	-15	15	4.4	-20	53	8.2	18.2	14.1	17
0:15:00	739	792	741	730	778	750	733	725	752	750	-12.5	12.5	2.9	-14	53	10.2	16.2	14.0	18
0:30:00	842	861	832	829	856	840	827	816	839	838	-5.0	5.0	1.7	-25	19	10.2	16.2	13.6	19
0:45:00	902	939	910	902	906	914	910	885	909	910	-3.8	3.8	1.1	-17	37	10.2	16.2	13.8	19
1:00:00	945	980	953	946	949	954	952	934	951	952	-2.5	2.5	1.0	-11	34	10.2	16.2	12.8	18
1:15:00	979	1010	985	978	980	986	985	969	983	984	-2.5	2.5	1.0	-10	31	10.2	16.2	14.2	19
1:30:00	1006	1035	1011	1006	1008	1013	1014	999	1011	1012	-2.5	2.5	0.9	-7	29	10.2	16.2	14.2	19
1:45:00	1029	1050	1034	1029	1026	1027	1035	1025	1032	1032	-2.5	2.5	0.8	-4	21	10.2	16.2	13.6	19
2:00:00	1049	1053	1045	1052	1053	1039	1047	1057	1048	1049	-2.5	2.5	0.8	-10	8	10.2	16.2	15.5	20
2:15:00	1067	1079	1074	1069	1071	1076	1074	1075	1073	1074	-2.5	2.5	0.7	2	13	10.2	16.2	12.4	20
2:30:00	1082	1097	1090	1082	1085	1098	1090	1088	1088	1090	-2.5	2.5	0.7	0	15	10.2	16.2	13.5	20
2:45:00	1097	1124	1112	1094	1104	1118	1109	1099	1108	1109	-2.5	2.5	0.7	-3	27	10.2	16.2	13.2	21
3:00:00	1110	1127	1115	1105	1125	1121	1114	1114	1118	1117	-2.5	2.5	0.7	-5	17	10.2	16.2	13.3	21

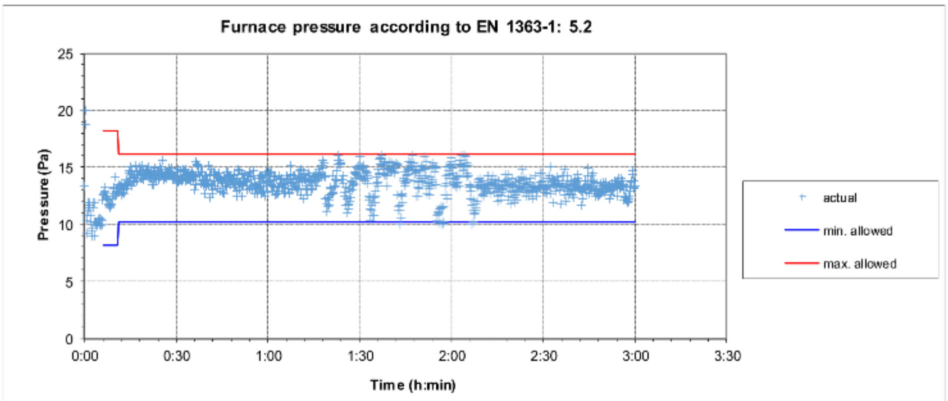
Key

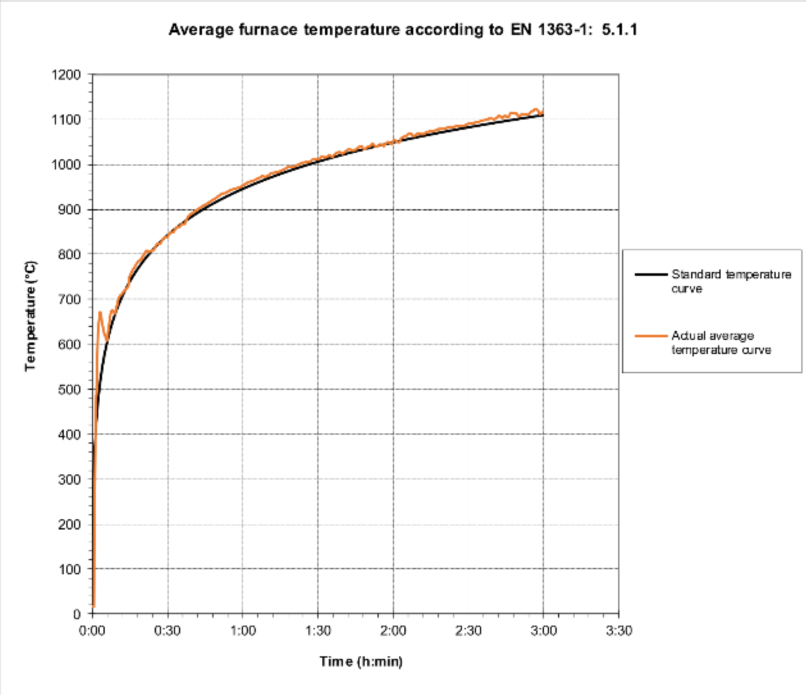
- t is the time, in min;
- T is the standard average furnace temperature, in °C, $\{T\} = 345.\log_{10}(8\{t\}+1) + 20$;
- avg is the actual average furnace temperature, in °C;
- d_e is the percentage deviation in the area of he actual average temperature/time curve from the area of the standard temperature/time curve;

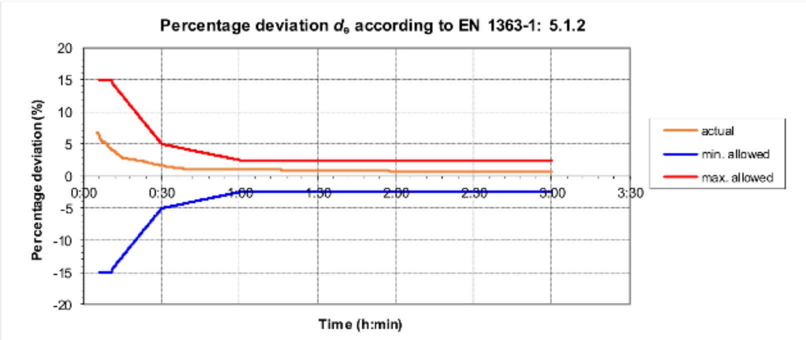
"Pressure" is the difference of the pressure in the furnace and the ambient pressure at the same hight level:

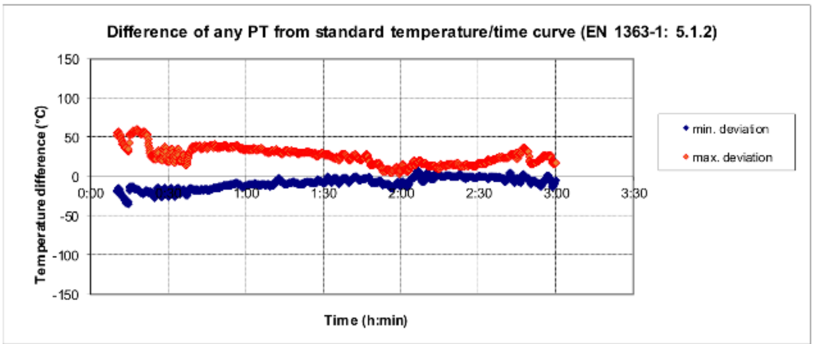
The pressure of 20 Pa is required 100 mm below the underside of the separating element, at the height of 3 m

The pressure of 13 Pa is expected in pressure sensor 2.2 m




Average furnace temperature according to EN 1363-1: 5.1.1
Temperature (°C)
Time (h:min)
Standard temperature curve
Actual average temperature curve


Percentage deviation d_e according to EN 1363-1: 5.1.2
Percentage deviation (%)
Time (h:min)
actual
min. allowed
max. allowed


Difference of any PT from standard temperature/time curve (EN 1363-1: 5.1.2)
Temperature difference (°C)
Time (h:min)
min. deviation
max. deviation

D.2 Furnace control, ambient temperature - test of 2023-02-13

Test conditions according to EN 1363-1: 5

Time	Furnace temperatures															Deviation d_e			Deviation from T		Probe pressure			Ambient
	T	70	71	72	73	74	75	76	77	80	81	82	83	84	avg	shall be within		actual	min	max	shall be within		actual	temperature
(h:min:s)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(%)	(%)	(%)	(°C)	(°C)	(Pa)	(Pa)	(Pa)	(°C)
0:00:00	20	12	13	13	13	13	12	13	14	12	13	13	13	13	13								24.0	13
0:05:00	576	624	594	569	581	565	557	544	562	609	582	587	579	589	580			-3.1					15.6	14
0:10:00	678	713	687	675	688	676	656	630	650	675	687	697	712	673	678	-15	15	-0.1	-49	34	8.2	18.2	10.7	14
0:15:00	739	794	765	751	738	757	719	708	718	746	767	760	770	744	749	-12.5	12.5	0.1	-31	56	10.2	16.2	12.7	13
0:30:00	842	876	848	852	850	845	836	828	836	834	859	857	865	841	848	-5.0	5.0	0.6	-14	35	10.2	16.2	11.6	14
0:45:00	902	934	910	921	925	910	907	901	910	900	922	929	942	909	917	-3.8	3.8	0.8	-2	40	10.2	16.2	12.5	14
1:00:00	945	980	956	956	950	950	942	948	941	951	959	958	965	948	954	-2.5	2.5	1.0	-4	34	10.2	16.2	11.9	14
1:15:00	979	1007	992	992	987	989	976	989	979	988	994	997	1008	986	991	-2.5	2.5	1.0	-3	29	10.2	16.2	11.6	15
1:30:00	1006	1034	1022	1020	1014	1021	1006	1020	1005	1022	1021	1022	1028	1014	1019	-2.5	2.5	1.1	-1	28	10.2	16.2	13.6	15
1:45:00	1029	1057	1046	1043	1038	1044	1030	1044	1032	1050	1045	1044	1049	1039	1043	-2.5	2.5	1.1	1	28	10.2	16.2	15.6	15
2:00:00	1049	1073	1064	1060	1058	1064	1051	1065	1052	1066	1061	1061	1067	1056	1061	-2.5	2.5	1.1	2	24	10.2	16.2	11.7	15
2:15:00	1067	1090	1075	1065	1076	1073	1076	1076	1070	1084	1070	1063	1070	1061	1073	-2.5	2.5	1.1	-6	23	10.2	16.2	14.3	16
2:30:00	1082	1112	1093	1084	1093	1090	1092	1094	1090	1105	1090	1082	1090	1077	1092	-2.5	2.5	1.1	-5	30	10.2	16.2	14.7	16
2:45:00	1097	1124	1105	1102	1114	1103	1108	1106	1104	1113	1104	1100	1111	1092	1107	-2.5	2.5	1.1	-5	27	10.2	16.2	13.1	17
3:00:00	1110	1145	1126	1119	1122	1119	1120	1126	1123	1138	1127	1113	1120	1114	1124	-2.5	2.5	1.1	3	35	10.2	16.2	12.9	17

Note: *Themometers 80-84 were placed additionally between short sections SIC beyond the requirement of EN 13381-4.*

Key

t is the time, in min;

T is the standard average furnace temperature, in °C, $\{T\} = 345.\log_{10}(8\{t\}+1) + 20$;

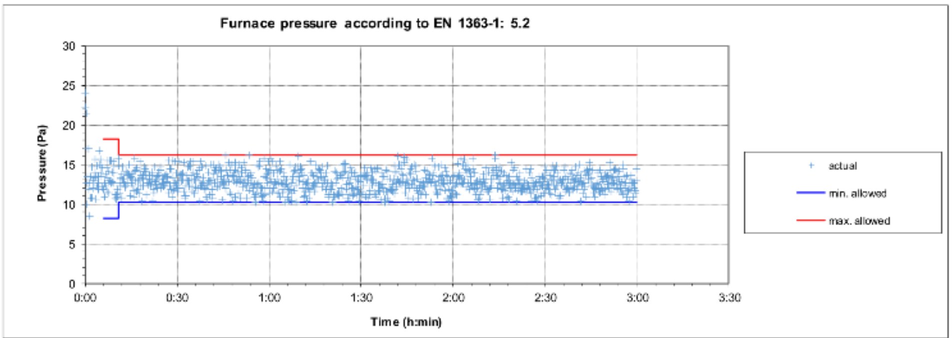
avg is the actual average furnace temperature, in °C;

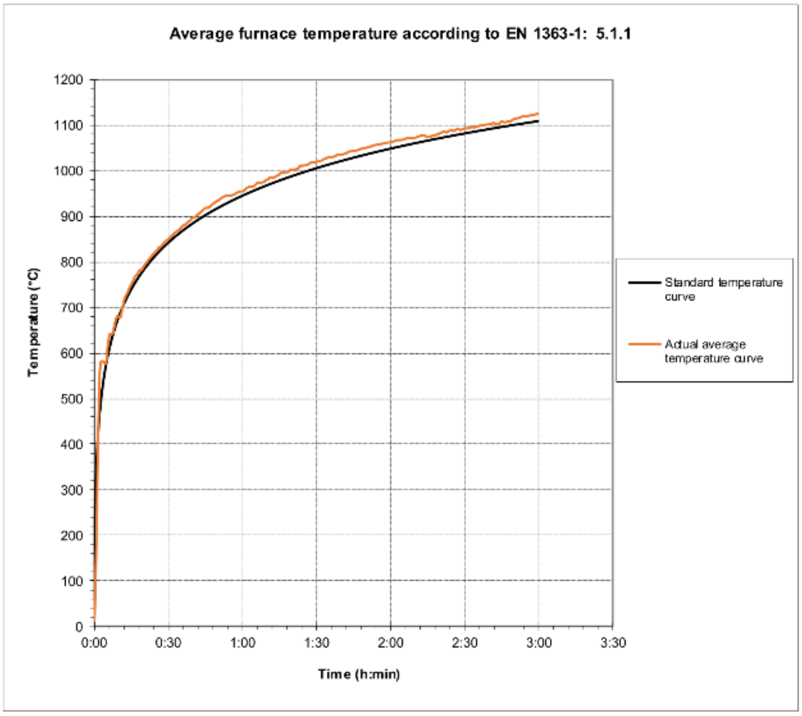
d_e is the percentage deviation in the area of he actual average temperature/time curve from the area of the standard temperature/time curve;

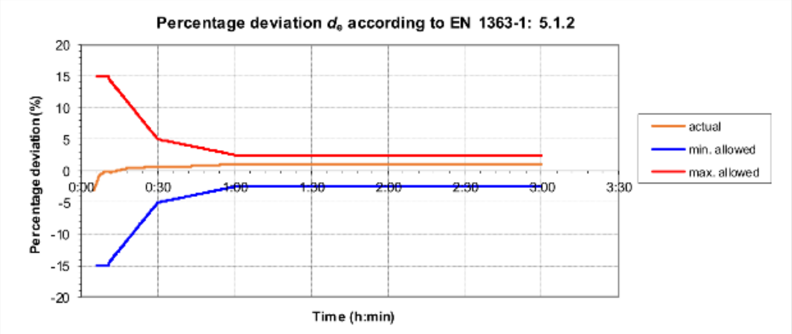
"Pressure" is the difference of the pressure in the furnace and the ambient pressure at the same hight level:

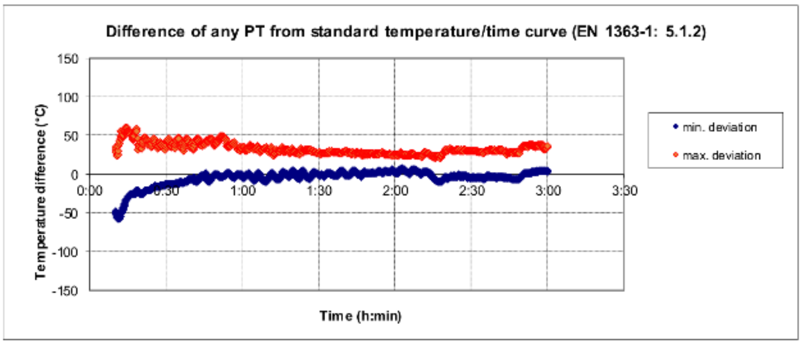
The pressure of 20 Pa is required 100 mm below the underside of the separating element, at the height of 3 m

The pressure of 13 Pa is expected in pressure sensor 2.2 m




Average furnace temperature according to EN 1363-1: 5.1.1
Temperature (°C)
Time (h:min)
Standard temperature curve
Actual average temperature curve

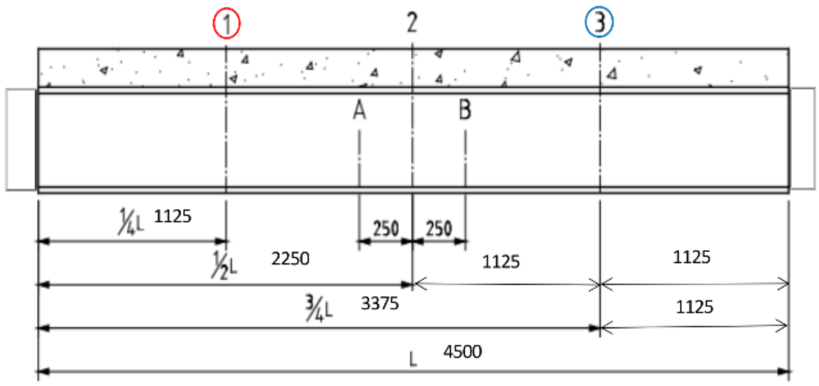

Percentage deviation d_e according to EN 1363-1: 5.1.2
Percentage deviation (%)
Time (h:min)
actual
min. allowed
max. allowed


Difference of any PT from standard temperature/time curve (EN 1363-1: 5.1.2)
Temperature difference (°C)
Time (h:min)
min. deviation
max. deviation

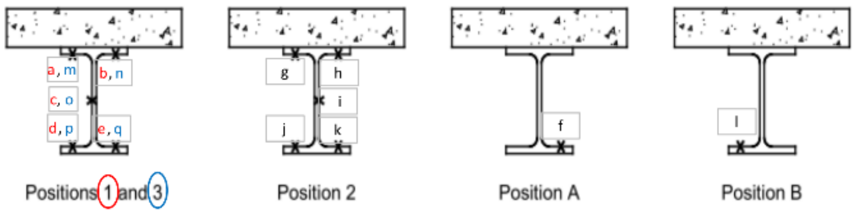
D.3 Steel temperatures

Thermocouple locations/orientation for loaded beams

All dimensions are in mm



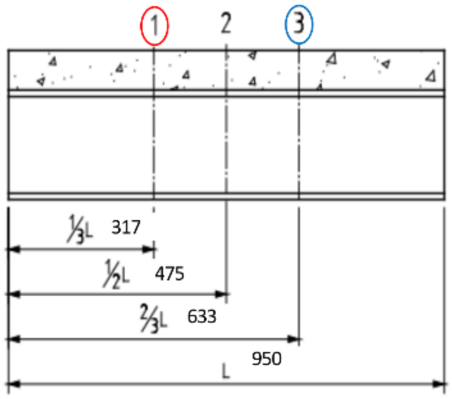
Loaded beam side elevation



Key Position of TC (a to q) / Label of logger input (integers)

Specimen		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
LBmax	**16**	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
LBmin	**14**	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

Thermocouple locations / orientation for short beams



Short beam side elevation

Positions 1 and 3 **Position 2**

Key Position of TC (a to i) / Label of logger input (integers)

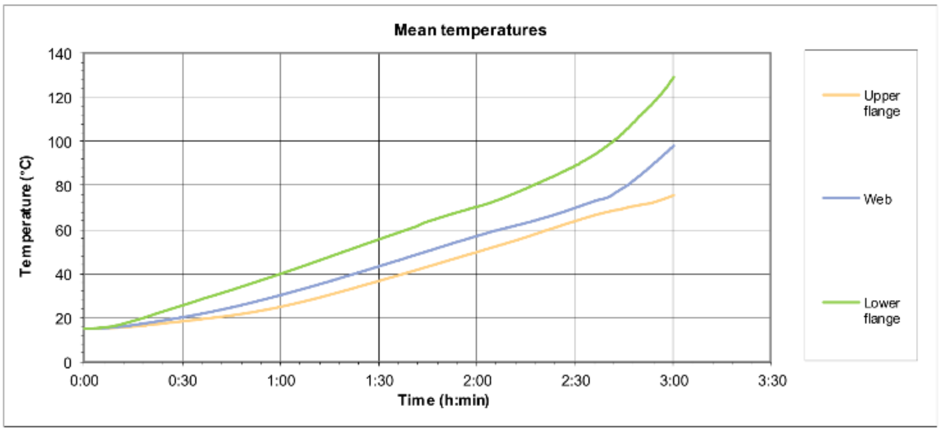
Specimen		a	b	c	d	e	f	g	h	i
RBmax	**15**	70	71	72	73	74	75	76	77	78
RBmin	**17**	40	41	42	43	44	45	46	47	48

Steel temperatures of LBmax

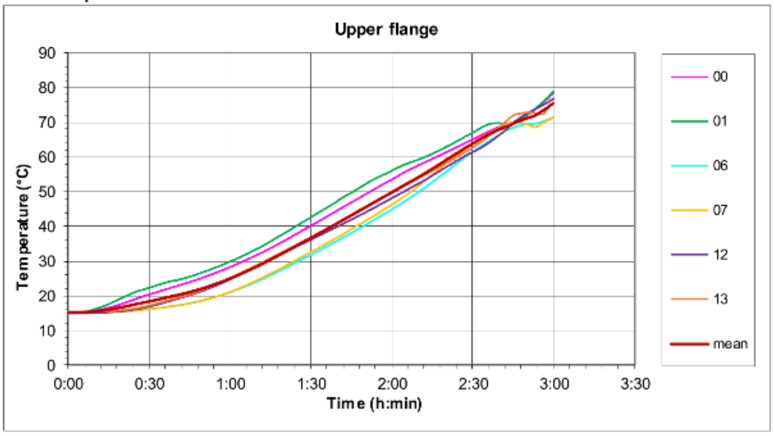
Time	Steel temperature (°C)																			
	Upper flange							Web				Lower flange								
(h:min:s)	00	01	06	07	12	13	mean	02	08	14	mean	03	04	05	09	10	11	15	16	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
0:05:00	15	15	15	15	15	15	15	15	15	15	15	15	17	15	15	15	15	16	15	15
0:10:00	16	16	15	15	15	15	15	16	16	15	16	16	21	16	15	15	15	18	16	17
0:15:00	16	18	15	15	15	15	16	18	17	16	17	22	25	17	16	16	17	20	17	19
0:30:00	20	22	16	16	17	17	18	23	21	17	20	32	34	21	21	20	23	32	23	26
0:45:00	24	26	18	18	20	20	21	27	25	22	25	37	39	28	28	26	32	40	33	33
1:00:00	28	30	21	21	25	25	25	32	31	28	30	44	44	35	36	33	41	47	41	40
1:15:00	34	36	26	26	30	31	30	38	37	35	37	51	51	42	44	42	48	55	50	48
1:30:00	40	43	32	33	36	37	37	45	44	42	43	59	57	49	52	50	55	64	60	56
1:45:00	47	50	38	39	42	43	43	52	51	48	50	66	64	56	59	57	65	73	70	64
2:00:00	54	56	45	46	48	50	50	59	57	55	57	71	72	62	67	64	70	80	78	70
2:15:00	60	61	53	55	55	56	57	64	63	62	63	79	79	68	76	71	77	91	89	79
2:30:00	65	67	62	64	61	63	64	71	70	69	70	90	93	75	84	78	83	107	104	89
2:45:00	70	70	69	70	70	72	70	79	79	79	79	111	119	85	94	90	92	124	122	105
3:00:00	79	79	72	72	77	76	76	99	98	97	98	139	150	110	115	116	115	145	145	129

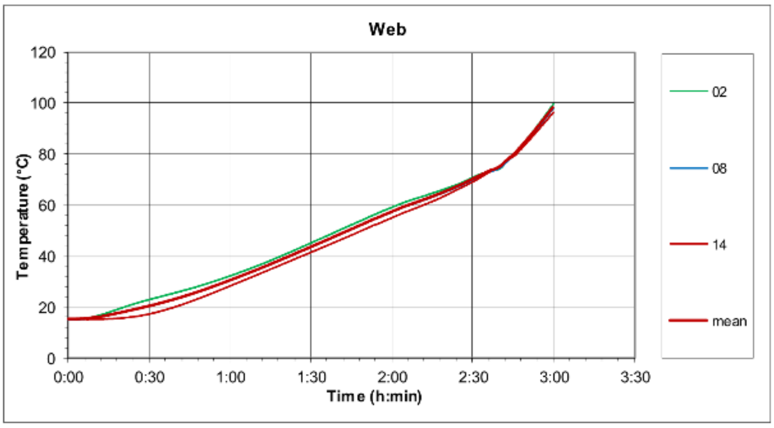
Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

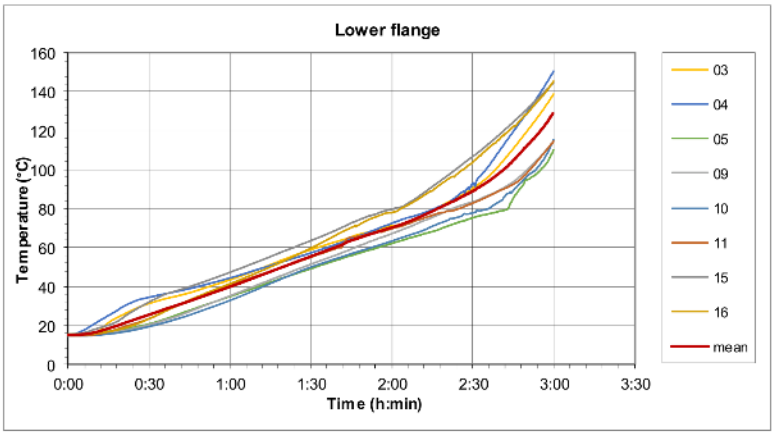
XX Designation of measuring joint of TC as figured in Annex B



Steel temperatures of LBmax





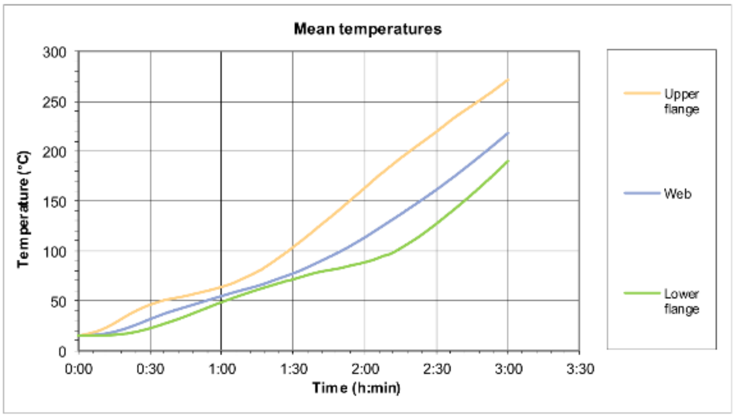


Steel temperatures of RBmax

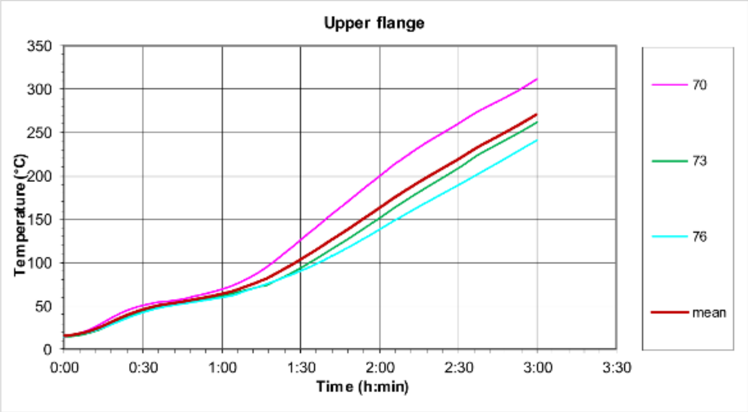
Time	Steel temperature (°C)											
	Upper flange				Web				Lower flange			
(h:min:s)	70	73	76	mean	71	74	77	mean	72	75	78	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15	15
0:05:00	18	16	18	17	15	16	16	15	15	15	15	15
0:10:00	23	20	20	21	16	17	17	17	15	16	15	15
0:15:00	31	25	25	27	19	19	19	19	16	16	16	16
0:30:00	51	44	43	46	32	31	32	32	21	25	22	22
0:45:00	58	54	53	55	44	44	44	44	33	37	33	34
1:00:00	70	62	60	64	55	55	55	55	48	52	47	49
1:15:00	91	73	74	79	65	64	65	65	60	63	60	61
1:30:00	126	94	91	104	80	77	76	77	71	73	71	72
1:45:00	163	122	113	133	100	92	89	94	81	82	80	81
2:00:00	200	151	138	163	122	111	107	113	90	89	87	89
2:15:00	233	181	165	193	147	134	129	137	106	102	101	103
2:30:00	260	209	189	219	173	158	154	161	131	127	124	127
2:45:00	286	236	215	246	201	185	181	189	161	157	153	157
3:00:00	311	262	241	271	231	214	210	218	195	190	186	190

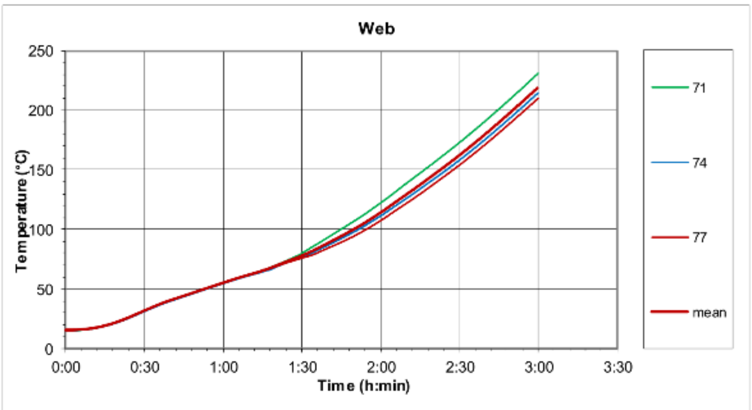
Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

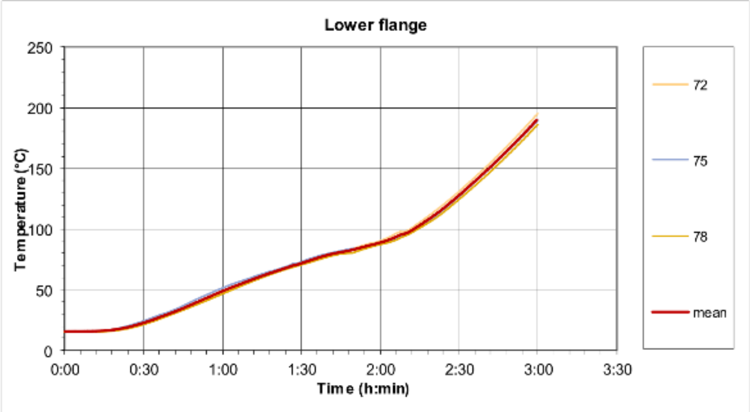
XX Designation of measuring joint of TC as figured in Annex B



Steel temperatures of RBmax





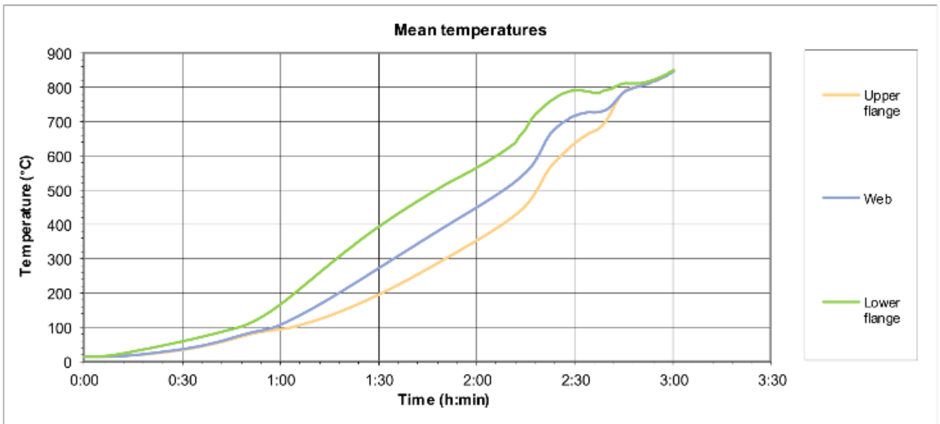


Steel temperatures of LBmin

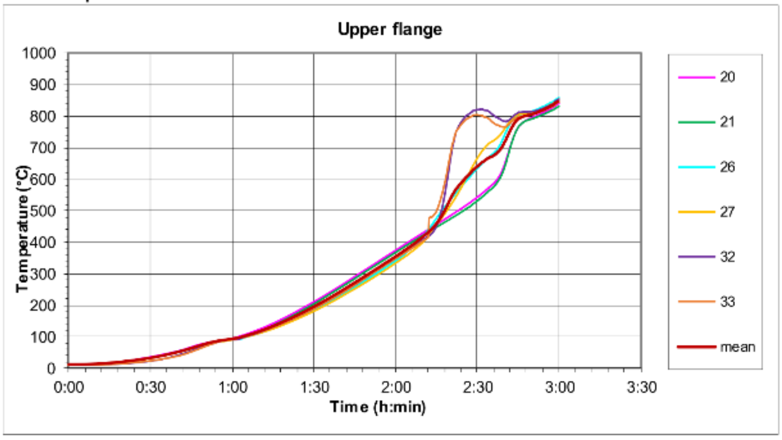
Time	Steel temperature (°C)																		
	Upper flange							Web				Lower flange								
(h:min:s)	20	21	26	27	32	33	mean	22	28	34	mean	23	24	25	29	30	31	35	36	mean
0:00:00	11	12	12	12	12	12	12	12	12	11	12	12	12	12	12	11	12	11	12	12
0:05:00	12	12	12	13	12	12	12	12	13	12	12	13	13	12	13	12	12	12	15	13
0:10:00	14	13	14	14	12	12	13	14	15	12	14	23	23	16	17	16	17	16	21	19
0:15:00	17	16	17	17	14	14	16	19	18	14	17	36	37	23	24	22	24	22	30	27
0:30:00	37	34	34	33	24	25	32	41	35	28	35	71	71	50	52	49	51	52	61	57
0:45:00	68	64	66	63	56	53	63	71	68	62	67	97	101	83	85	83	84	96	110	92
1:00:00	96	92	93	92	93	93	93	114	103	102	107	210	177	154	142	145	143	169	192	166
1:15:00	143	137	127	126	131	131	133	196	172	180	183	342	291	278	242	246	244	299	322	283
1:30:00	211	205	185	182	190	190	195	291	257	268	272	456	407	380	347	352	349	415	440	393
1:45:00	291	286	258	253	266	265	271	383	347	358	363	541	501	471	448	452	450	499	532	487
2:00:00	375	369	341	334	350	349	354	467	443	443	451	607	578	557	549	555	551	552	586	567
2:15:00	457	449	475	453	452	498	457	543	591	527	554	666	645	639	738	744	737	630	660	682
2:30:00	543	533	633	666	822	806	640	616	721	819	719	733	715	713	859	853	812	833	819	792
2:45:00	764	766	802	805	813	800	790	768	789	809	788	823	820	799	811	815	820	814	800	813
3:00:00	841	833	858	854	856	847	848	834	849	860	848	847	854	837	847	842	877	859	850	852

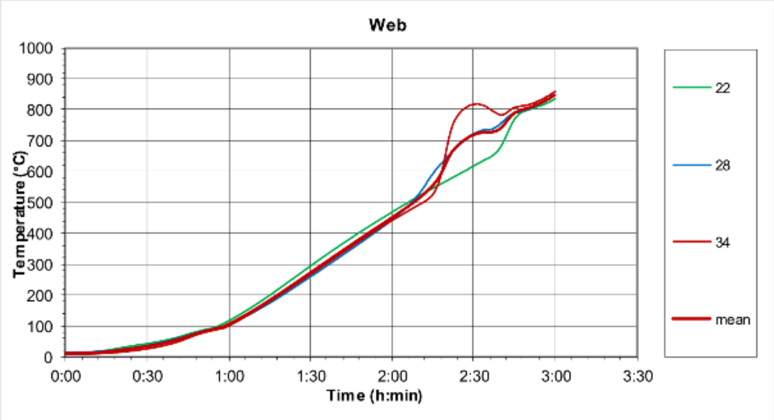
Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

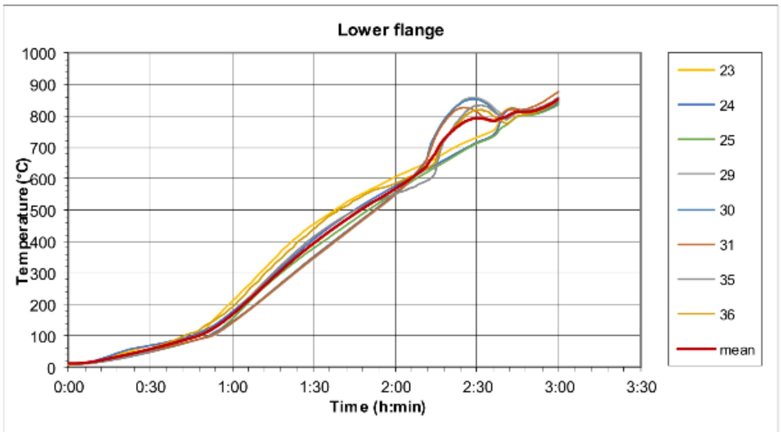
XX Designation of measuring joint of TC as figured in Annex B



Steel temperatures of LBmin





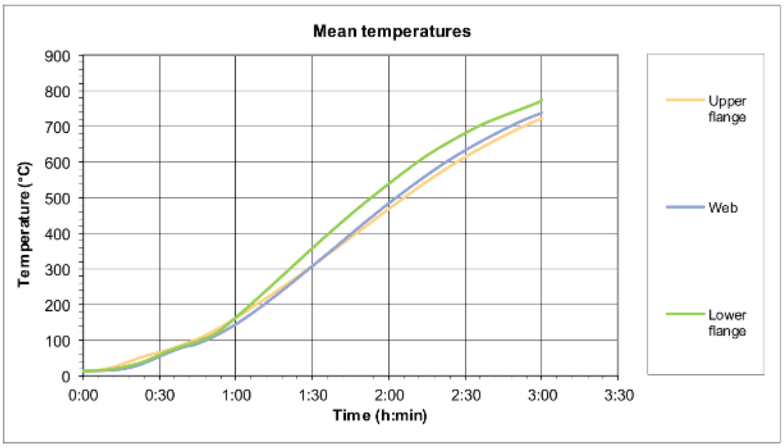


Steel temperatures of RBmin

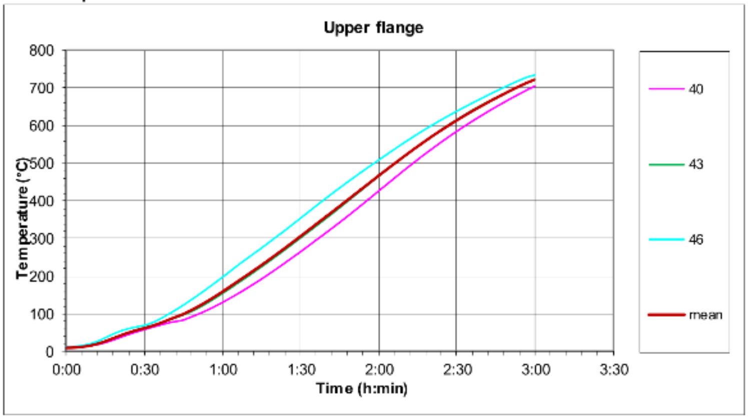
Time	Steel temperature (°C)											
	Upper flange				Web				Lower flange			
(h:min:s)	*40*	*43*	*46*	mean	*41*	*44*	*47*	mean	*42*	*45*	*48*	mean
0:00:00	11	12	12	11	11	11	12	12	12	11	12	12
0:05:00	12	13	14	13	12	11	12	12	12	12	13	12
0:10:00	15	18	22	18	12	12	13	13	15	14	16	15
0:15:00	23	28	36	29	16	16	17	16	20	20	22	21
0:30:00	57	63	69	63	50	51	53	51	53	55	59	56
0:45:00	83	97	123	101	85	88	91	88	89	99	92	93
1:00:00	130	154	197	160	132	145	151	143	155	166	164	161
1:15:00	192	224	274	230	202	223	232	219	244	268	260	257
1:30:00	264	301	354	306	285	311	322	306	336	373	360	356
1:45:00	343	381	434	386	372	402	413	396	426	471	456	451
2:00:00	427	464	509	466	461	489	500	483	513	557	545	538
2:15:00	510	543	578	544	542	568	579	563	595	633	625	618
2:30:00	585	614	638	613	615	637	646	633	665	685	692	681
2:45:00	650	673	691	671	677	695	701	691	718	735	735	730
3:00:00	706	722	735	721	729	741	744	738	760	794	768	774

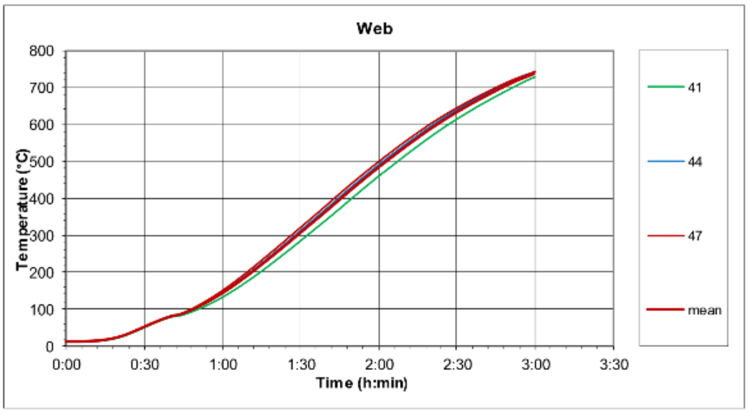
Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

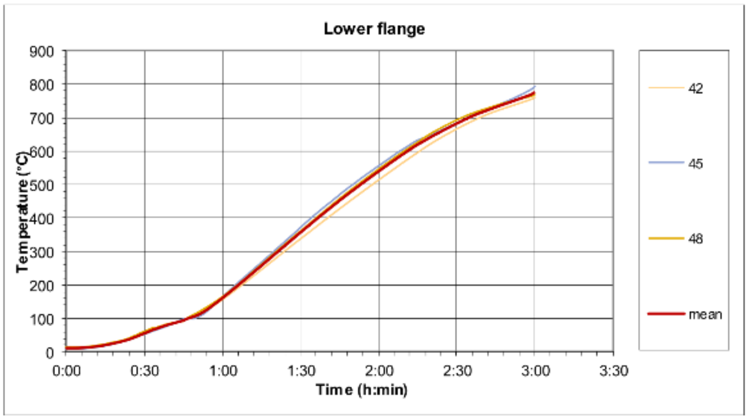
XX Designation of measuring joint of TC as figured in Annex B



Steel temperatures of RBmin

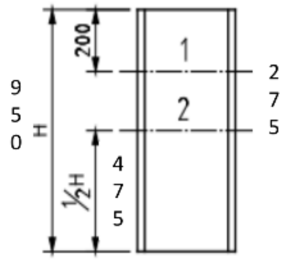




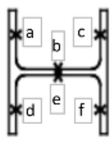


SIC1 - SIC13

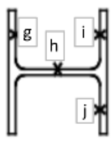
Thermocouple locations / orientation for 'I' or 'H' short columns



Short column elevation



Position 1



Position 2

Key Position of TC (a to i) / Label of logger input (interegs)

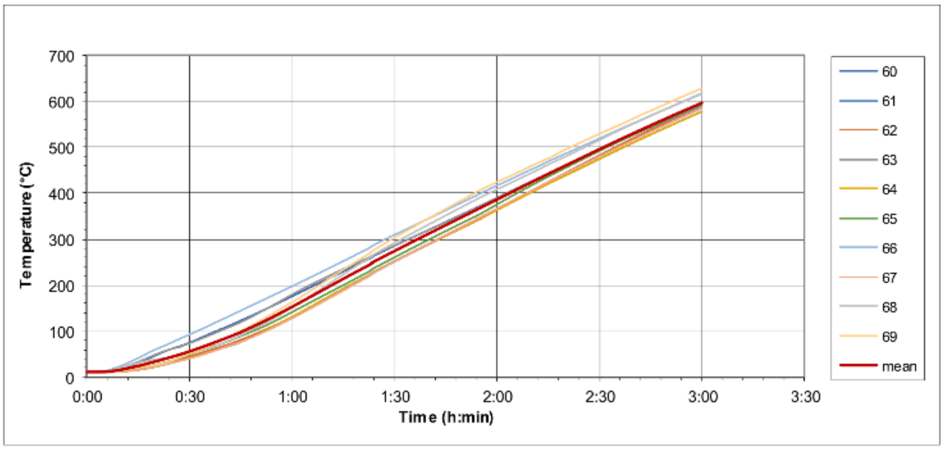
Specimen		a	b	c	d	e	f	g	h	i	j
SIC1	**1**	60	61	62	63	64	65	66	67	68	69
SIC2	**2**	40	41	42	43	44	45	46	47	48	49
SIC3	**3**	60	61	62	63	64	65	66	67	68	69
SIC4	**4**	30	31	32	33	34	35	36	37	38	39
SIC5	**5**	50	51	52	53	54	55	56	57	58	59
SIC6	**6**	60	61	62	63	64	65	66	67	68	69
SIC7	**7**	50	51	52	53	54	55	56	57	58	59
SIC8	**8**	40	41	42	43	44	45	46	47	48	49
SIC9	**9**	50	51	52	53	54	55	56	57	58	59
SIC10	**10**	80	81	82	83	84	85	86	87	88	89
SIC11	**11**	20	21	22	23	24	25	26	27	28	29
SIC12	**12**	30	31	32	33	34	35	36	37	38	39
SIC13	**13**	20	21	22	23	24	25	26	27	28	29

Steel temperatures of SIC1

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	60	61	62	63	64	65	66	67	68	69	mean
0:00:00	11	11	11	11	11	11	11	12	12	12	11
0:05:00	11	11	11	11	11	11	12	12	12	12	12
0:10:00	19	12	14	20	12	14	25	13	21	14	16
0:15:00	31	16	18	33	16	20	42	17	31	21	24
0:30:00	75	42	44	74	42	49	93	41	51	50	56
0:45:00	123	76	81	120	77	90	145	77	91	100	98
1:00:00	176	131	131	179	131	141	197	128	151	163	153
1:15:00	230	192	190	235	192	200	252	189	224	234	214
1:30:00	286	253	251	286	251	260	309	251	292	303	274
1:45:00	338	309	307	337	308	318	363	309	352	366	331
2:00:00	390	364	364	390	364	376	417	367	409	425	387
2:15:00	443	421	425	443	420	436	469	424	462	476	442
2:30:00	495	475	483	494	475	492	519	480	516	530	496
2:45:00	545	527	538	543	527	545	569	533	568	579	547
3:00:00	591	578	589	589	578	594	618	585	616	628	597

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

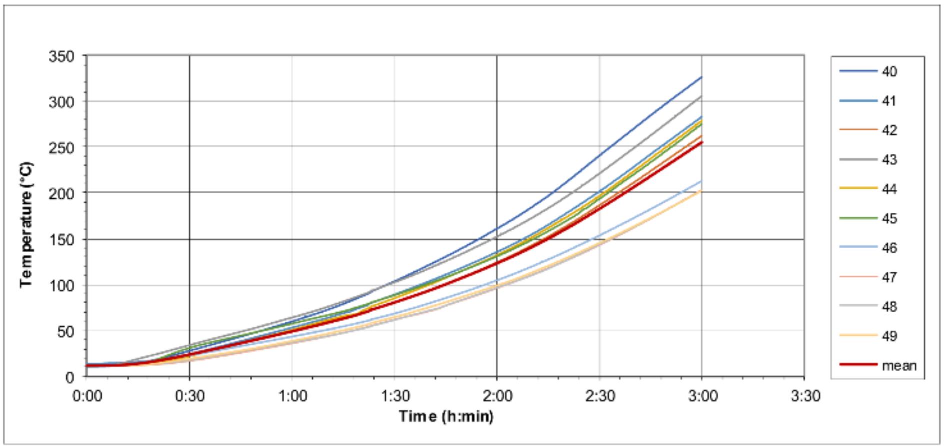


Steel temperatures of SIC2

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	40	41	42	43	44	45	46	47	48	49	mean
0:00:00	11	14	11	11	11	11	11	12	12	12	11
0:05:00	11	14	11	11	11	11	11	12	12	12	12
0:10:00	12	15	12	14	12	12	12	12	12	12	12
0:15:00	14	16	13	19	13	13	14	12	13	12	14
0:30:00	28	24	22	34	22	31	23	17	18	19	24
0:45:00	43	38	37	49	36	44	33	26	27	28	36
1:00:00	60	53	50	64	51	57	43	36	37	39	49
1:15:00	79	69	64	82	66	71	54	47	47	50	63
1:30:00	104	89	80	103	85	88	68	62	62	65	81
1:45:00	130	111	101	126	107	108	85	77	77	81	100
2:00:00	161	136	124	152	132	131	105	96	97	99	123
2:15:00	197	165	152	183	162	158	128	118	117	120	150
2:30:00	241	201	186	221	197	194	154	143	144	145	182
2:45:00	285	242	224	263	237	233	182	172	172	173	218
3:00:00	326	283	262	305	278	275	213	203	203	202	255

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

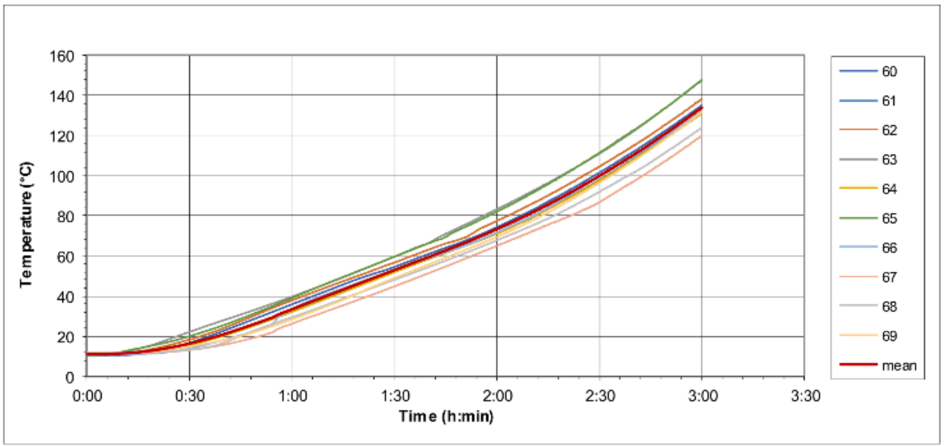


Steel temperatures of SIC3

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	60	61	62	63	64	65	66	67	68	69	mean
0:00:00	10	11	11	11	11	11	11	12	12	12	11
0:05:00	11	11	11	11	11	11	11	12	12	12	11
0:10:00	11	11	11	12	11	12	11	12	12	12	11
0:15:00	11	12	12	14	11	14	11	12	12	12	12
0:30:00	17	16	18	22	16	20	14	13	13	15	16
0:45:00	26	23	28	31	23	29	21	18	20	20	24
1:00:00	36	33	38	40	32	39	33	26	30	28	33
1:15:00	46	42	47	49	42	50	44	35	39	38	43
1:30:00	55	52	57	60	52	60	53	45	48	49	53
1:45:00	64	62	66	71	62	69	62	55	58	59	63
2:00:00	74	72	78	83	71	82	72	65	68	69	73
2:15:00	87	84	90	96	83	96	84	75	79	82	86
2:30:00	102	98	105	111	97	111	100	87	92	96	100
2:45:00	118	114	120	128	114	128	115	103	107	113	116
3:00:00	135	132	138	148	131	148	132	120	124	132	134

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

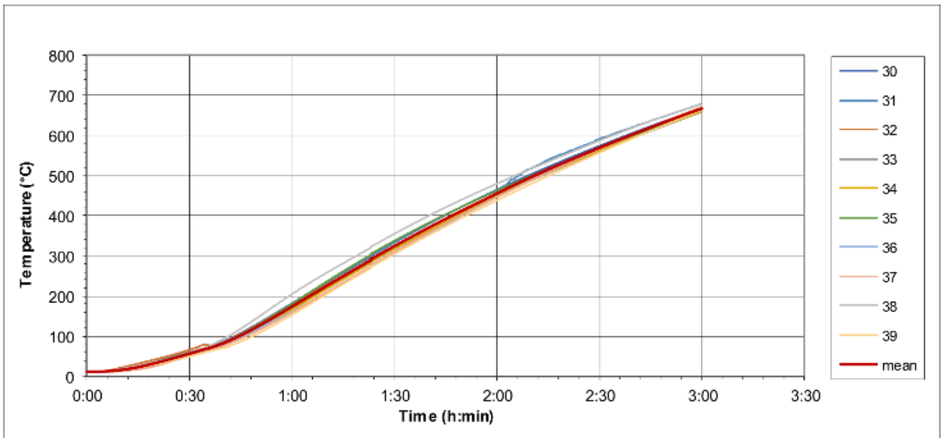


Steel temperatures of SIC4

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	30	31	32	33	34	35	36	37	38	39	mean
0:00:00	11	11	12	12	12	12	12	12	12	12	12
0:05:00	12	12	13	12	12	12	12	13	13	13	12
0:10:00	15	15	22	16	13	14	15	14	18	15	16
0:15:00	24	23	32	24	18	22	22	17	27	22	23
0:30:00	58	58	66	60	54	58	50	52	57	49	56
0:45:00	108	107	106	103	96	104	98	94	119	87	102
1:00:00	182	182	179	170	166	181	162	160	205	154	174
1:15:00	258	259	252	242	242	262	232	234	281	230	249
1:30:00	333	334	326	317	318	338	307	311	355	306	324
1:45:00	402	402	391	384	385	403	378	381	421	374	392
2:00:00	465	464	454	448	449	462	446	447	480	439	455
2:15:00	522	539	511	507	508	517	509	508	535	500	516
2:30:00	574	593	564	560	561	568	565	566	587	557	570
2:45:00	623	636	615	611	612	616	620	621	636	612	620
3:00:00	669	679	661	659	660	662	670	671	678	663	667

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

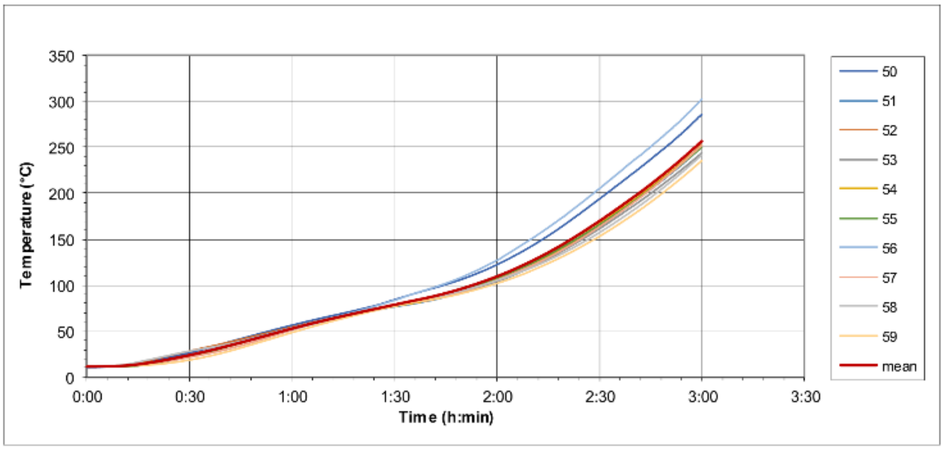


Steel temperatures of SIC5

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	50	51	52	53	54	55	56	57	58	59	mean
0:00:00	11	11	11	11	11	11	11	12	12	12	11
0:05:00	11	11	12	11	11	11	12	12	12	12	12
0:10:00	13	12	12	12	12	11	12	13	13	12	12
0:15:00	15	14	15	13	14	12	14	14	16	13	14
0:30:00	27	23	28	24	23	22	24	22	28	19	24
0:45:00	42	37	41	38	37	38	39	34	39	32	38
1:00:00	57	53	55	52	53	53	54	51	52	49	53
1:15:00	70	66	67	66	66	66	68	66	66	64	66
1:30:00	84	77	78	77	77	78	84	78	78	77	79
1:45:00	101	87	92	88	88	90	102	88	90	87	91
2:00:00	122	106	108	104	107	108	127	106	105	102	110
2:15:00	154	131	132	129	132	133	163	130	127	124	135
2:30:00	194	166	165	161	166	166	205	164	157	153	170
2:45:00	237	204	205	200	206	205	251	204	195	190	210
3:00:00	286	251	253	244	252	250	302	252	242	235	257

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

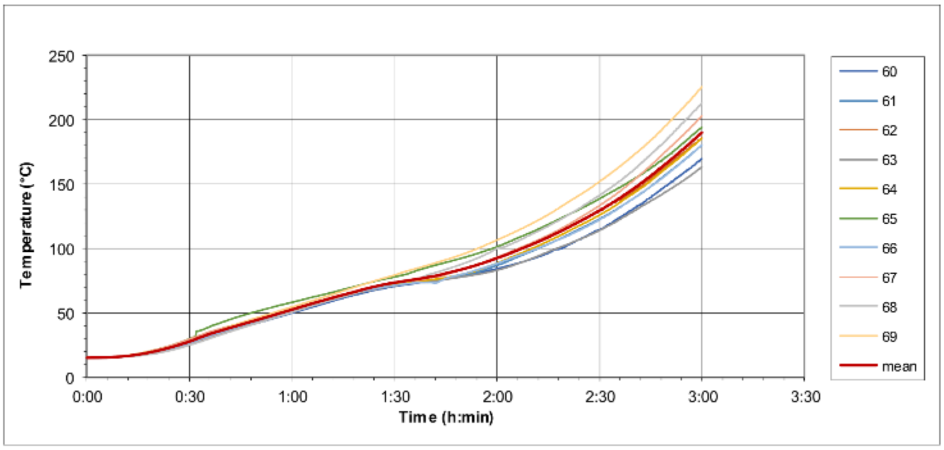


Steel temperatures of SIC6

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	60	61	62	63	64	65	66	67	68	69	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15
0:05:00	15	15	15	15	15	15	16	15	15	15	15
0:10:00	16	16	16	16	16	16	16	16	16	16	16
0:15:00	18	18	18	17	18	18	17	18	17	18	18
0:30:00	29	28	27	26	29	30	27	30	25	28	28
0:45:00	39	41	38	39	42	48	40	42	38	42	41
1:00:00	50	52	51	52	53	58	52	53	50	55	53
1:15:00	61	63	63	63	64	68	64	64	62	67	64
1:30:00	71	72	73	71	72	78	71	73	74	79	73
1:45:00	77	76	80	76	77	89	77	80	84	91	81
2:00:00	84	87	93	83	89	101	88	93	100	107	92
2:15:00	96	103	108	97	106	119	104	110	117	126	109
2:30:00	115	123	130	114	126	139	122	133	141	152	129
2:45:00	139	148	154	137	152	162	148	164	173	184	156
3:00:00	170	180	186	163	186	194	180	203	213	226	190

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

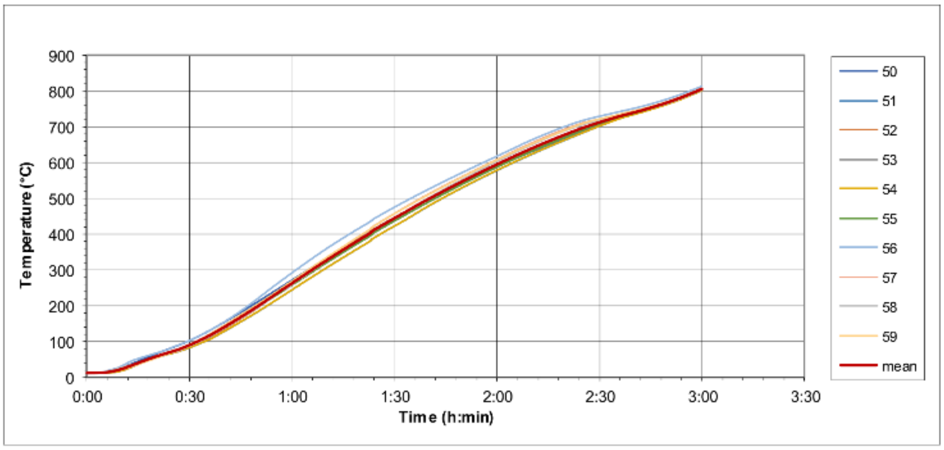


Steel temperatures of SIC7

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	50	51	52	53	54	55	56	57	58	59	mean
0:00:00	11	11	12	12	11	11	12	12	12	12	12
0:05:00	12	12	12	12	12	12	15	13	14	13	13
0:10:00	25	18	22	19	18	23	31	21	27	22	22
0:15:00	45	35	39	37	36	41	52	37	40	36	40
0:30:00	102	82	86	89	83	90	103	88	87	90	90
0:45:00	181	155	163	169	155	168	185	168	165	174	168
1:00:00	271	244	264	258	244	257	291	266	258	268	262
1:15:00	361	335	360	349	335	349	389	364	355	365	356
1:30:00	446	423	446	438	423	437	476	458	445	457	445
1:45:00	521	505	522	516	506	515	550	537	528	536	524
2:00:00	589	578	593	587	579	588	618	609	604	608	595
2:15:00	649	643	654	651	644	651	683	675	670	672	659
2:30:00	705	702	709	709	703	709	730	721	718	722	713
2:45:00	750	751	755	753	748	752	764	757	752	757	754
3:00:00	804	807	808	803	802	803	814	808	804	807	806

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

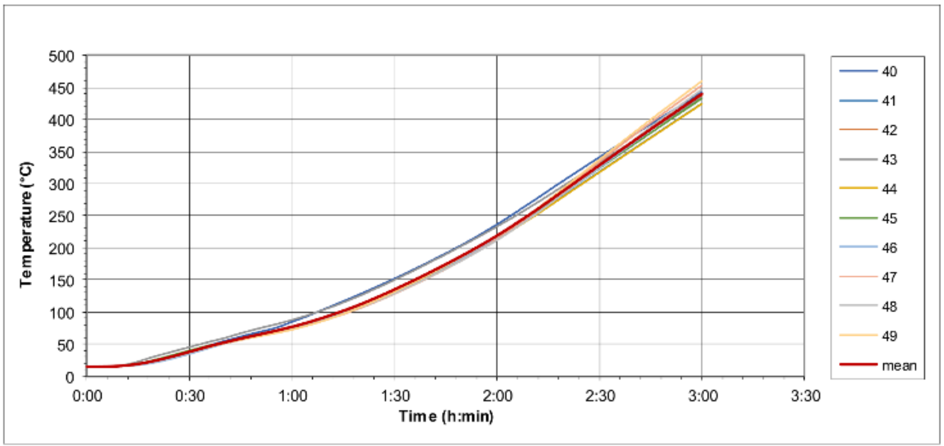


Steel temperatures of SIC8

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	40	41	42	43	44	45	46	47	48	49	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15
0:05:00	15	15	15	15	15	15	15	15	15	15	15
0:10:00	17	16	16	17	16	17	16	16	16	16	16
0:15:00	19	19	19	23	19	20	18	18	19	20	19
0:30:00	39	37	37	46	38	40	35	37	37	38	38
0:45:00	62	57	58	67	57	58	58	57	57	57	59
1:00:00	85	76	74	88	76	76	77	73	75	73	77
1:15:00	117	100	98	115	100	99	100	97	98	97	102
1:30:00	152	132	131	150	132	133	133	128	129	132	135
1:45:00	192	170	172	190	170	173	171	167	167	173	174
2:00:00	237	213	218	233	213	218	215	214	212	218	219
2:15:00	289	265	272	281	264	269	267	272	267	274	272
2:30:00	341	318	329	333	318	324	325	334	327	337	329
2:45:00	392	372	384	384	371	379	383	395	388	400	385
3:00:00	443	425	437	435	424	433	441	453	447	460	440

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

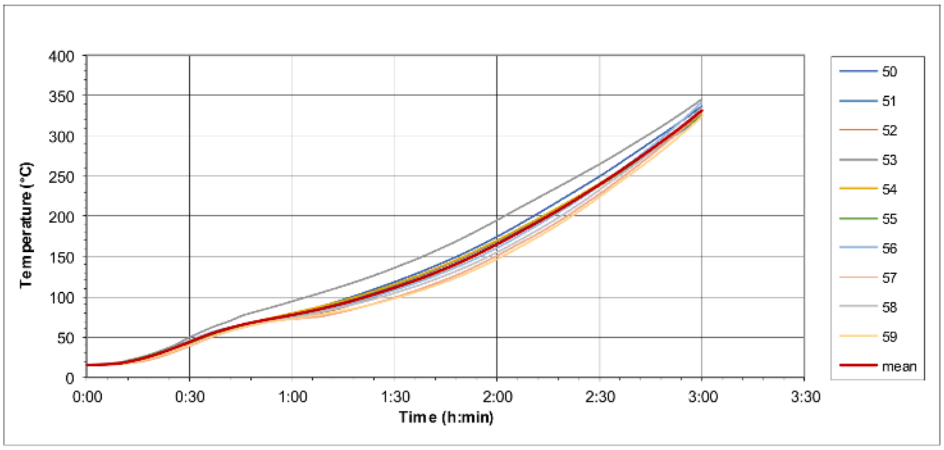


Steel temperatures of SIC9

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	50	51	52	53	54	55	56	57	58	59	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15
0:05:00	16	16	16	15	16	15	16	16	16	15	16
0:10:00	18	17	19	18	17	18	17	16	17	16	17
0:15:00	22	22	23	24	23	23	22	19	22	20	22
0:30:00	45	44	45	50	45	42	45	39	45	40	44
0:45:00	65	64	63	76	65	63	65	61	64	61	65
1:00:00	79	78	74	94	80	75	75	72	74	72	77
1:15:00	96	94	87	113	95	91	89	81	87	83	92
1:30:00	118	115	109	136	116	110	108	99	105	98	111
1:45:00	144	139	134	163	140	135	131	122	127	119	135
2:00:00	175	169	165	195	170	166	161	151	155	147	165
2:15:00	211	203	200	230	204	200	197	186	191	182	200
2:30:00	249	239	238	265	241	238	238	228	233	224	239
2:45:00	292	280	280	303	281	280	286	276	279	271	283
3:00:00	337	324	325	345	326	325	342	330	335	324	331

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

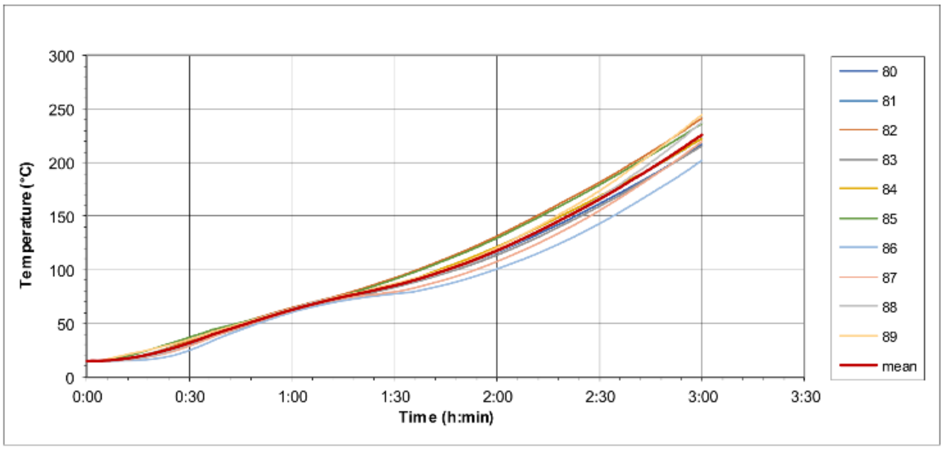


Steel temperatures of SIC10

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15
0:05:00	15	15	15	15	16	16	15	15	15	16	15
0:10:00	16	17	17	16	17	18	15	16	16	20	17
0:15:00	18	19	19	20	19	22	16	17	18	23	19
0:30:00	31	33	35	32	33	37	25	29	31	35	32
0:45:00	48	48	51	46	48	51	44	47	50	50	48
1:00:00	63	63	65	61	63	63	60	62	64	63	63
1:15:00	74	76	78	73	76	76	71	73	76	76	75
1:30:00	85	86	93	84	86	91	78	80	85	87	85
1:45:00	99	102	110	97	103	109	86	91	99	101	100
2:00:00	116	121	131	114	122	130	101	108	117	121	118
2:15:00	138	144	156	135	144	154	120	129	140	146	141
2:30:00	162	168	182	159	168	179	143	155	167	174	166
2:45:00	188	194	210	187	194	207	171	186	200	207	194
3:00:00	217	223	241	216	222	236	202	220	238	245	226

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

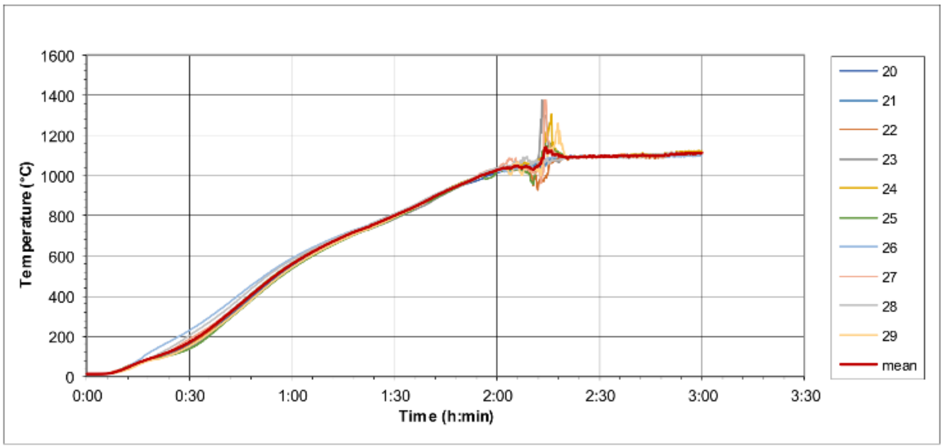


Steel temperatures of SIC11

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	mean
0:00:00	11	12	12	12	12	12	12	12	12	12	12
0:05:00	13	12	12	12	12	12	12	13	12	12	12
0:10:00	36	29	35	30	28	36	35	34	24	24	31
0:15:00	70	68	70	64	69	69	80	67	68	57	68
0:30:00	159	169	153	145	168	136	229	185	203	150	170
0:45:00	349	367	357	340	366	333	412	365	391	336	362
1:00:00	554	565	560	540	564	536	589	564	581	543	560
1:15:00	697	703	700	680	701	679	708	698	704	682	695
1:30:00	803	809	804	784	808	788	807	803	810	792	801
1:45:00	923	930	924	912	929	914	923	924	930	921	923
2:00:00	1014	1028	1028	1030	1031	1022	1025	1037	1038	1027	1028
2:15:00	1084	1074	1013	1155	1206	1146	1088	1176	1076	1115	1113
2:30:00	1099	1096	1092	1097	1095	1093	1099	1091	1095	1098	1096
2:45:00	1104	1106	1089	1094	1105	1096	1096	1093	1104	1093	1098
3:00:00	1122	1114	1107	1124	1124	1111	1101	1114	1114	1114	1114

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

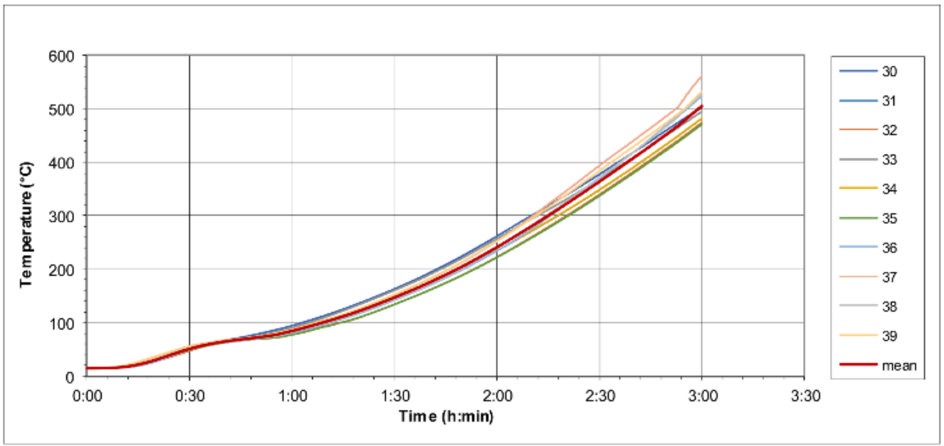


Steel temperatures of SIC12

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	30	31	32	33	34	35	36	37	38	39	mean
0:00:00	15	15	15	15	15	15	15	15	15	15	15
0:05:00	15	15	15	15	15	15	15	15	15	16	15
0:10:00	16	16	17	16	17	17	16	18	17	19	17
0:15:00	20	21	21	20	21	23	20	26	22	27	22
0:30:00	51	50	48	50	50	49	50	57	53	56	51
0:45:00	73	68	67	69	68	67	67	71	69	71	69
1:00:00	95	84	78	91	84	78	81	88	83	87	85
1:15:00	126	111	101	123	111	102	108	115	110	116	112
1:30:00	164	144	135	161	145	134	143	153	145	153	147
1:45:00	209	185	175	205	186	174	184	197	187	198	190
2:00:00	262	235	223	257	235	222	235	253	240	253	241
2:15:00	319	289	279	311	290	277	297	321	303	315	300
2:30:00	377	348	340	368	349	337	369	394	371	384	364
2:45:00	440	413	405	430	413	402	445	464	444	452	431
3:00:00	502	482	474	495	482	471	524	561	529	533	505

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B

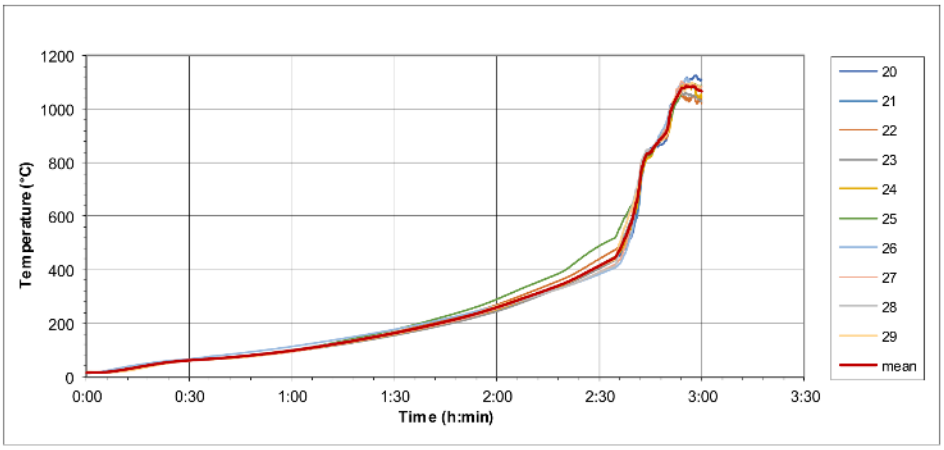


Steel temperatures of SIC13

Time	Steel temperature (°C)										
	Position 1						Position 2				
(h:min:s)	20	21	22	23	24	25	26	27	28	29	mean
0:00:00	15	15	20	15	15	15	15	15	15	15	16
0:05:00	18	18	19	17	18	18	22	16	18	16	18
0:10:00	27	25	25	24	26	26	34	20	25	20	25
0:15:00	38	37	39	35	37	39	46	31	36	30	37
0:30:00	63	62	61	62	62	63	67	61	62	61	62
0:45:00	78	74	75	76	74	77	89	72	79	73	77
1:00:00	97	95	97	95	95	99	114	94	102	96	98
1:15:00	124	124	128	122	124	135	144	124	131	127	128
1:30:00	157	159	168	155	159	177	177	160	166	163	164
1:45:00	197	201	214	195	201	227	218	201	206	205	206
2:00:00	247	253	270	245	252	290	266	254	257	265	260
2:15:00	318	321	343	315	321	370	318	316	316	326	326
2:30:00	409	415	440	405	414	489	383	391	389	412	415
2:45:00	854	842	839	835	827	835	846	840	850	842	841
3:00:00	1111	1085	1022	1032	1043	1087	1070	1084	1069	1068	1067

Temperature recorded at 10 s intervals. In the table, they figure in 5 minute intervals

XX Designation of measuring joint of TC as figured in Annex B



D.4 Load, deformation

Load and deflection of LBmax

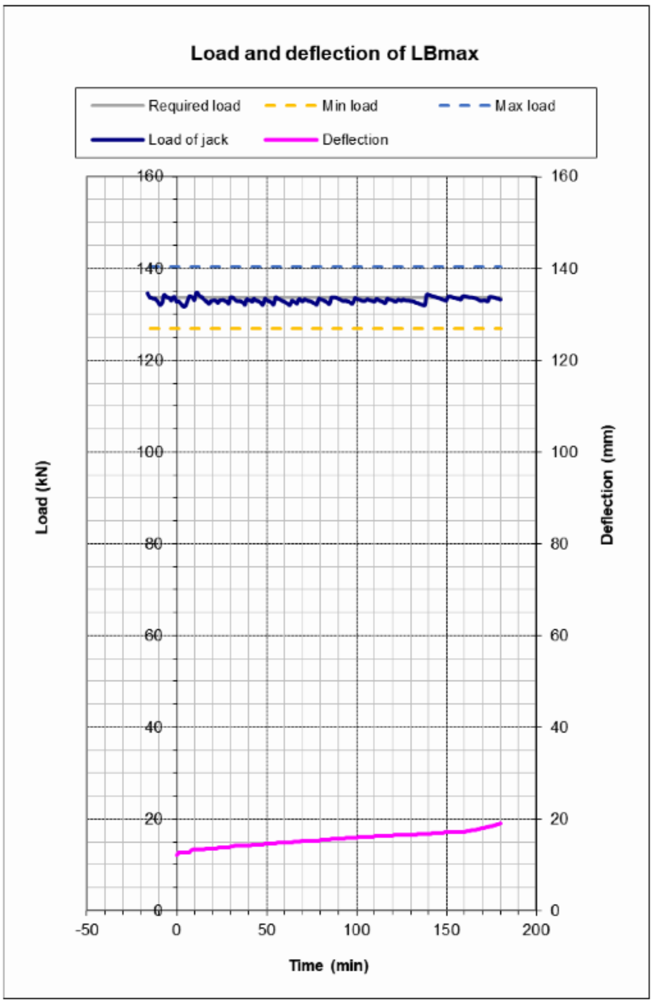
Time t (min)	Load of jack P (kN)	Moment M_b (kN.m)	Mean bottom flange temp. (°C)	Deflection D (mm)	Rate of deflection dD/dt CDF (mm/min)	BDF (mm/min)
-23				0.0		
-16	134.5	247.8		12.1		
-15	133.7	246.3		12.1		
-1	133.7	246.3		12.1		
0	132.7	244.6	15.2	12.1		
1	132.8	244.7	15.2	12.7	0.3	0.6
10	133.1	245.3	16.5	13.4	0.0	0.1
20	133.0	245.0	20.9	13.6	0.0	0.0
30	133.6	246.2	25.7	13.9	0.1	0.1
40	133.1	245.3	30.4	14.3	0.1	0.1
50	133.2	245.4	35.1	14.6	0.0	0.0
60	132.7	244.5	40.0	14.9	0.0	0.0
70	132.8	244.7	45.1	15.2	0.0	0.0
80	133.2	245.4	50.4	15.4	0.0	0.1
90	133.4	245.7	55.6	15.7	0.0	0.0
100	133.4	245.7	60.8	15.9	0.1	0.1
110	132.8	244.7	66.1	16.3	0.1	0.1
120	133.1	245.2	70.4	16.4	0.1	0.0
130	132.9	244.9	75.6	16.6	0.0	0.0
140	134.2	247.3	82.1	16.8	0.1	0.1
150	133.0	245.1	89.1	17.1	0.0	0.0
160	134.0	246.8	98.4	17.2	0.1	0.0
170	133.0	245.1	112.0	18.0	0.1	0.1
180	133.2	245.4	129.2	19.0		0.1

P_{mean} = 133.1 kN

-23 min datum point, relative to the supports, before application of the test load, see EN 13381-4: 10.5
-1 min zero point, after application of the test load and before the test commencement, see EN 13381-4: 10.5
CDF Centered Differencing Formula
BDF Backward Differencing Formula

The clear span is L_{sup} = 4500 mm
The limiting deflection according to EN 13381-4: 10.3.1 $L_{sup}/30$ = 150.0 mm
The limiting deflection according to EN 1363-1:11.1 a) $L_{sup}^2/(400h)$ = 126.6 mm
The limiting rate of deflection according to EN 1363-1: 11.1 a) $L_{sup}^2/(9000h)$ = 5.63 mm/min

where h is the distance from the extreme fibre of the cold design compression zone to the extreme fibre of the cold design tension zone h = 400 mm


Load and deflection of LBmax
Required load
Min load
Max load
Load of jack
Deflection
Load (kN)
Deflection (mm)
Time (min)
160
140
120
100
80
60
40
20
0
-50
0
50
100
150
200

Load and deflection of LBmin

Time t (min)	Load of jack P (kN)	Moment M_b (kN.m)	Mean bottom flange temp. (°C)	Deflection D (mm)	Rate of deflection dD/dt CDF (mm/min)	BDF (mm/min)
-22				0.0		
-16	133.9	246.7		12.5		
-15	134.3	247.4		12.5		
-1	134.1	247.0		12.5		
0	133.8	246.5	11.6	12.5		
1	133.4	245.7	11.6	12.6	0.0	0.1
10	133.2	245.5	18.6	12.7	0.1	0.0
20	133.5	246.0	36.8	13.6	0.1	0.1
30	132.6	244.3	57.0	14.4	0.1	0.0
40	133.4	245.8	79.9	15.0	0.0	0.0
50	133.6	246.2	107.8	15.7	0.1	0.1
60	133.9	246.8	166.3	19.5	0.7	0.7
70	134.2	247.3	243.8	25.5	0.5	0.4
80	134.9	248.6	321.9	31.0	0.5	0.5
90	134.4	247.6	393.2	35.5	0.4	0.2
100	133.6	246.2	456.7	40.2	0.8	0.9
110	133.9	246.7	514.4	57.8	3.1	2.8
115	133.2	245.5	540.3	78.1	5.7	5.6
116	133.0	245.1	545.8	83.9	6.8	5.8
120	133.6	246.2	566.8	128.2	15.1	15.9
121	133.7	246.3	572.1	142.4	14.1	14.2
122	133.5	245.9	577.7	156.4		14.0
123			583.7			
130			627.2			
140			742.0			
150			792.2			
160			794.4			
170			813.5			
180			851.6			

P_{mean} = 133.8 kN

-22 min datum point, relative to the supports, before application of the test load, see EN 13381-4: 10.5

-1 min zero point, after application of the test load and before the test commencement, see EN 13381-4: 10.5

CDF Centered Differencing Formula

BDF Backward Differencing Formula

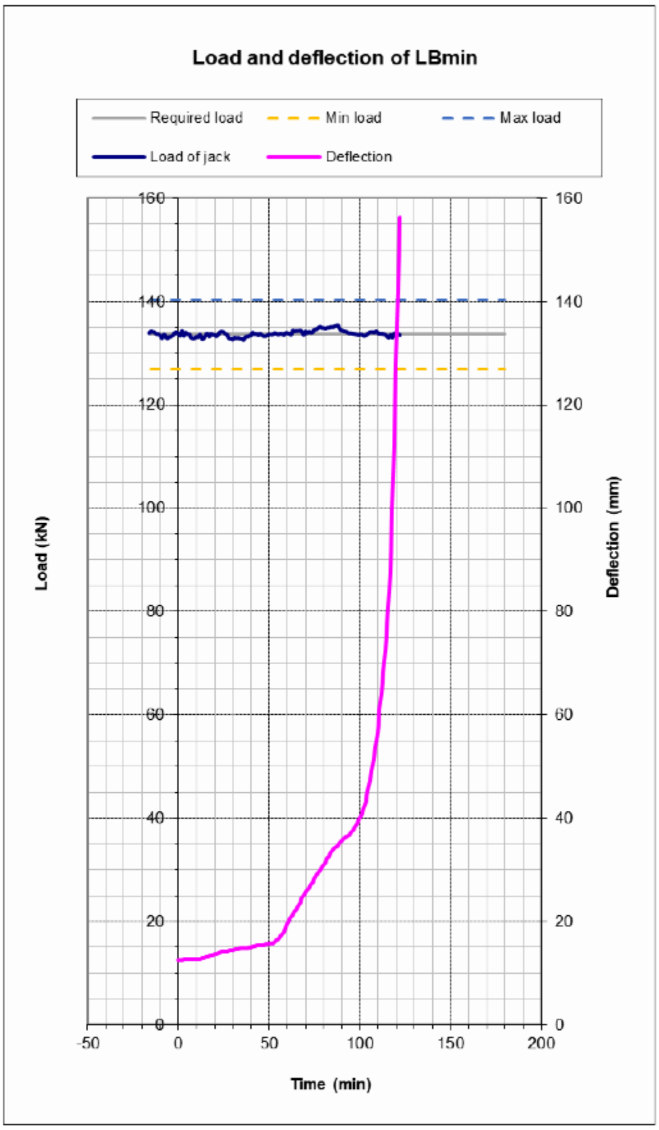
The clear span is L_{sup} = 4500 mm

The limiting deflection according to EN 13381-4: 10.3.1 $L_{sup}/30$ = 150.0 mm

The limiting deflection according to EN 1363-1:11.1 a) $L_{sup}^2/(400h)$ = 126.6 mm

The limiting rate of deflection according to EN 1363-1: 11.1 a) $L_{sup}^2/(9000h)$ = 5.63 mm/min

where h is the distance from the extreme fibre of the cold design compression zone to the extreme fibre of the cold design tension zone h = 400 mm


Load and deflection of LBmin
Required load
Min load
Max load
Load of jack
Deflection
Load (kN)
Deflection (mm)
Time (min)
160
140
120
100
80
60
40
20
0
-50
0
50
100
150
200

ANNEX E: OBSERVATION

Behaviour of the test specimens - test 2022-10-05

Time	Observation
5 min	Bending of the steel sheets of the sandwich panels, more on LB
30 min	Bottom ends by some SICs are slightly opening
90 min	Continuous bending of steel sheet, especially on LB
up to 180 min	Without substantive changes
181^{st} min	Termination of the test, at the request of the sponsor

Behaviour of the test specimens - test 2023-02-13

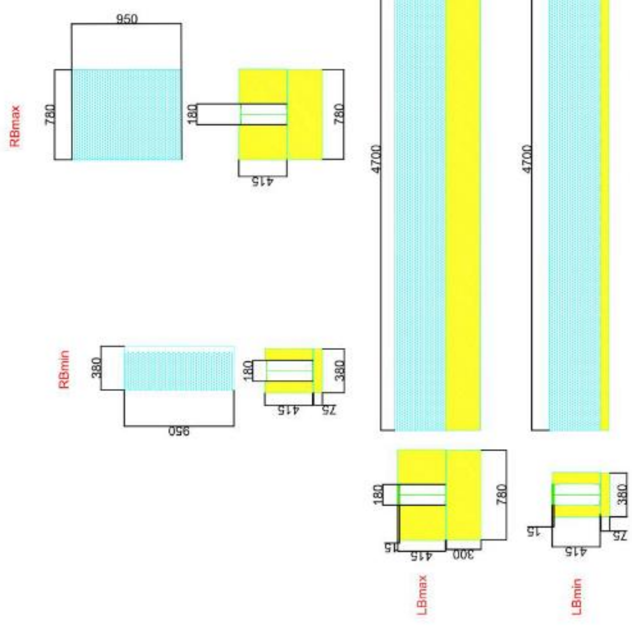
Time	Observation
5 min	Bending of the steel sheets of the sandwich panels, more on LB
30 min	Continuous bending of steel sheet, on LB from all sides
120 min	Higher deflection of the fire protection on LB
122 min	***Load removed when the deflection exceeded limiting value according to clause 10.3.1 of [2]***
140 min	Mineral wool from sandwich panel on LB fell down from the bottom flange
up to 180 min	Without substantive changes
181^{st} min	Termination of the test, at the request of the sponsor

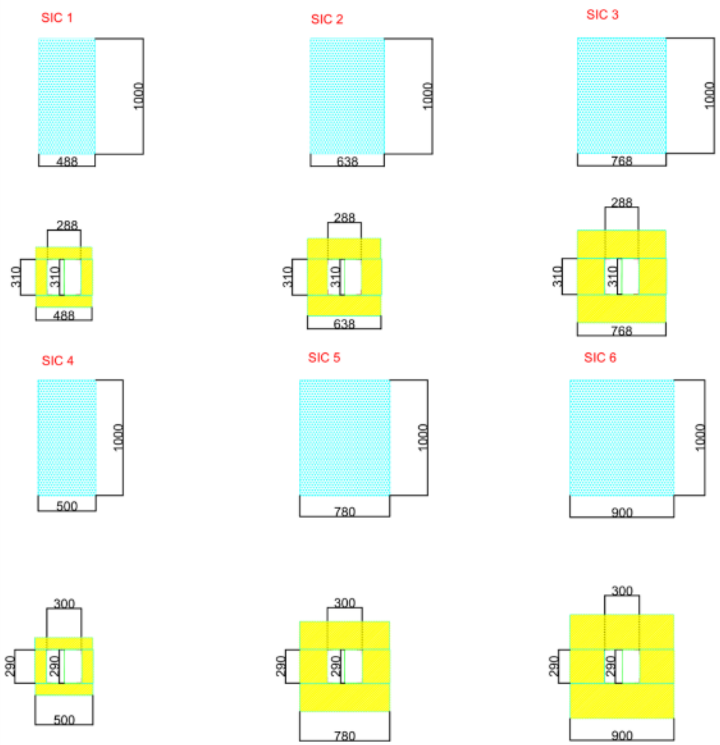
ANNEX F: DOCUMENTATION

The documentation used in this Annex was provided by the sponsor.

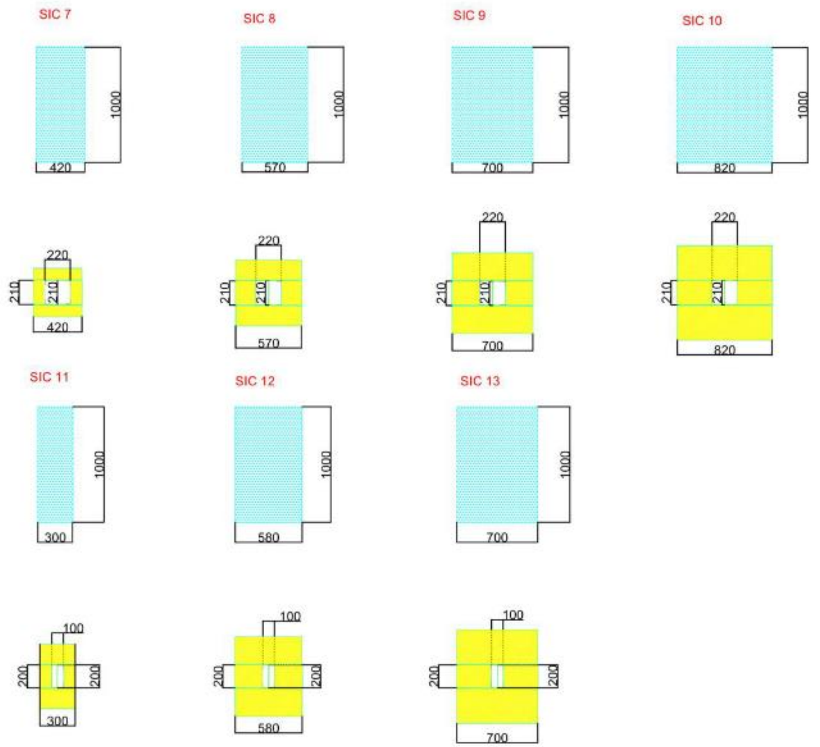
List of materials (LB | RB)

case	panel tickness [mm]	Length [mm]	Width [mm]	number
LBmin	100	4700	415	2
	100	4700	380	1
LBmax	300	4700	415	2
	300	4700	780	1
RBmin	100	950	415	2
	100	950	380	1
RBmax	300	950	415	2
	300	950	780	1





List of materials (SIC)				
case	panel tickness [mm]	Length [mm]	Width [mm]	number
SIC 1	100	1000	310	2
	100	1000	488	2
SIC 2	175	1000	310	2
	175	1000	638	2
SIC 3	240	1000	310	2
	240	1000	768	2
SIC 4	100	1000	290	2
	100	1000	500	2
SIC 5	240	1000	290	2
	240	1000	780	2
SIC 6	300	1000	290	2
	300	1000	900	2



List of materials (SIC)				
case	panel tickness [mm]	Length [mm]	Width [mm]	number
SIC 7	100	1000	210	2
	100	1000	420	2
SIC 8	175	1000	210	2
	175	1000	570	2
SIC 9	240	1000	210	2
	240	1000	700	2
SIC 10	300	1000	210	2
	300	1000	820	2
SIC 11	100	1000	200	2
	100	1000	300	2
SIC 12	240	1000	200	2
	240	1000	580	2
SIC 13	300	1000	200	2
	300	1000	700	2

ANNEX G: PHOTOS

Test of 2022-10-05

Assembly of specimens

US before the test

ES before the test

ES after 60 min

ES after 180 min

Specimens after the test in the furnace

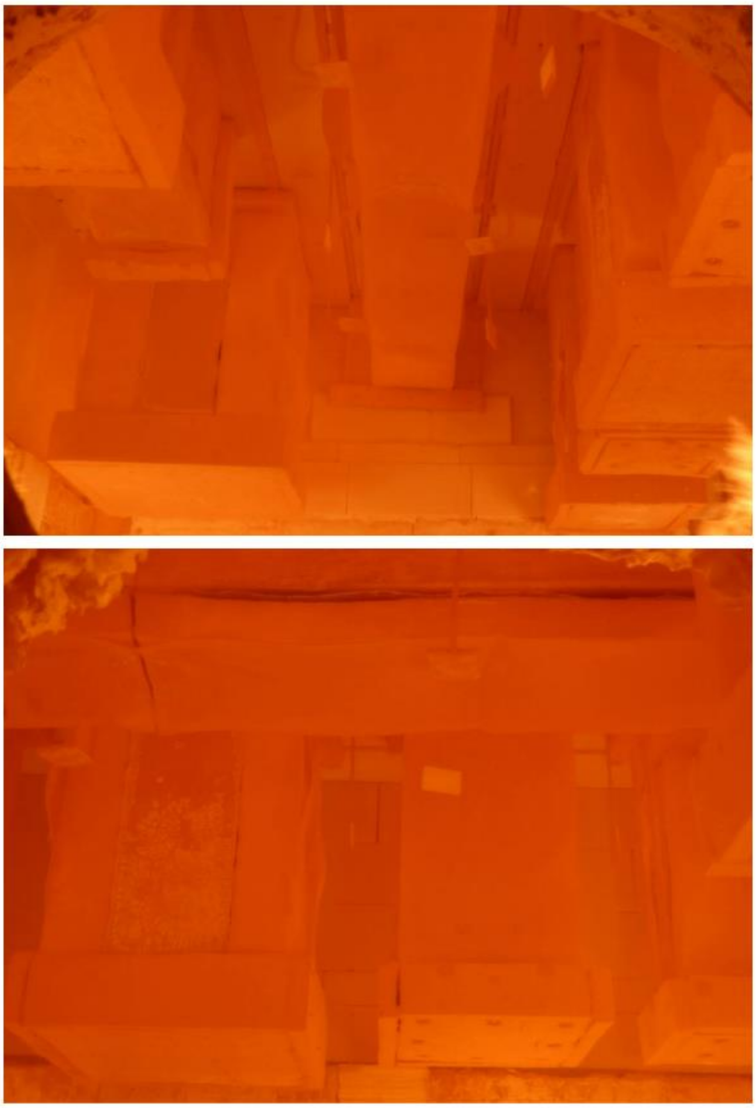
Test of 2023-02-13

Assembly of specimens

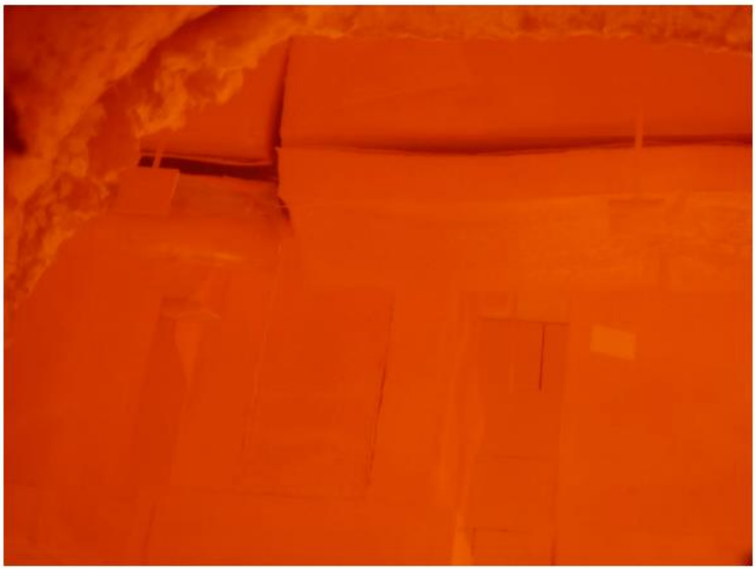
LBmin on the furnace

US before the test

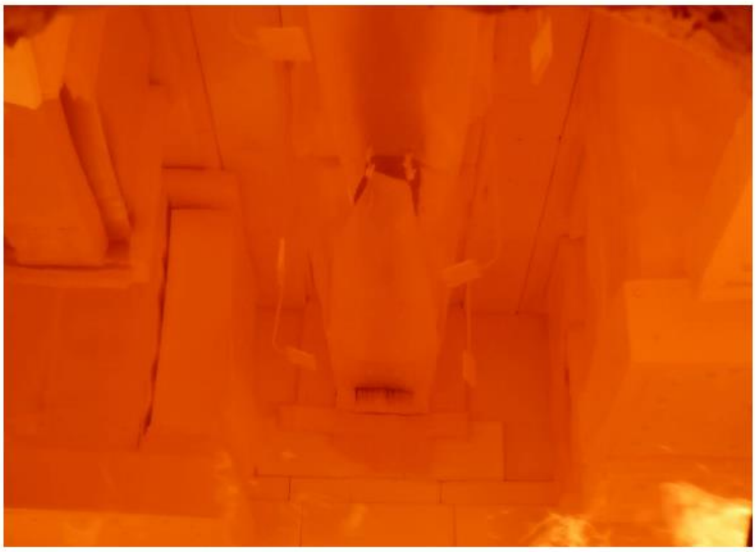
ES before the test



ES after 90 min



ES after 140 min



ES after 180 min

Specimens after the test in the furnace

Specimens after the test in the furnace