FIRE RESEARCH
SAFETY

Collection of Façade Fire Tests Including Timber Structures

Daniel Brandon

RISE Rapport 2020:50

Collection of Façade Fire Tests Including Timber Structures

Daniel Brandon

Abstract

Collection of Façade Fire Tests Including Timber Structures

This report describes three case studies that each involved an analysis of a fire test of an external wall that included a timber structure or part of a timber structure. These external walls all had wooden façade panels, were ventilated behind the façade panels and had glass wool or stone wool insulation. The three case studies aim to assess the contribution of structural timber to the fire development and the fire spread. In addition, the potential of façade systems with combustible materials to limit the fire spread through and along the external wall was assessed. The fire tests were performed for commercial purposes and their results were made available for this study. Not all details of the façade systems details are included in this report.

The analysis discussed in this report indicates that the timber structures did not contribute to the fire development and the fire spread in two of the three tests. The structural members in the external wall remained unaffected during the test. Visual inspection of the third test showed locally some superficial coloring and charring. However, the temperature measurements of the remaining test did not indicate any contribution of the structural timber to the fire development and fire spread. The energy contribution corresponding to the local and superficial coloring and charring is considered negligible.

Two of the three tests analyzed in this study were performed in accordance with the Swedish façade fire testing standard SP Fire 105. Both tests were assessed by the accredited testing institute to meet the requirements set by the Swedish Building regulations that: (1) the fire spread inside the external wall shall be limited; (2) the risk for fire spread along the façade surface shall be limited and; (3) the risk for injuries as a consequence of falling parts from the external wall shall be limited.

Key words: Façade fires, Façade fire tests, External wall, Timber structure

RISE Research Institutes of Sweden AB

RISE Rapport 2020:50
ISBN: 978-91-89167-33-9
Lund 2020

Content

Abstract **2**
Innehåll **3**
Foreword **4**
1 Introduction **5**
2 Scope **5**
3 Background **5**
4 Test 1: SP Fire 105 façade test of an external wall with CLT **6**
4.1 Setup of Test 1 7
4.2 Results of Test 1 10
5 Test 2: SP Fire 105 façade test of an external wall with backing particle board **15**
5.1 Setup of Test 2 15
5.2 Results of Test 2 18
6 Test 3: Fire resistance test of an external wall exposed on the external side **21**
6.1 Setup of Test 3 21
6.2 Results of Test 3 23
7 Discussion **25**
8 Conclusion **25**
References **26**

Foreword

This report is written to provide some scientific background for the UK government consultation to “in-effect ban the use of combustible materials in and on the external walls of certain buildings” in 2020.

This report summarizes and discusses fire tests of external walls with a timber structure or a part of a timber structure.

The work was commissioned by Henkel and the data used in this report was provided by Isover Saint-Gobain, Moelven and Knauf. Whereby Isover and Moelven provided data of Test 1 and 2 of this report and Knauf of Test 3 of this report

1 Introduction

This report summarizes the outcome of three façade fire tests, in which the setup included a timber structure or part of a timber structure. Two of the tests were performed in accordance with the Swedish standard façade fire test method SP Fire 105. The other test was a fire resistance test of a load bearing external wall including façade, exposed on the external size, according to EN 1363-1:2012.

With permission of the owners of the test reports, a summary of confidential reports is made, with solely a focus on the fire damage of the structural timber and contribution of the structural timber members of external walls to a façade fire. The tests are partly anonymized, and product or brand names are left out of this report. The tested external walls are being used in practice.

The final sections of this report comprise of a discussion and conclusions that can be drawn from these fire tests.

2 Scope

This report only considers data and photographic evidence that can be used to assess:

- the contribution of the timber structure as a fuel to an external fire (as a result of exposure of a façade fire).

- the damage of the timber structure caused by the fire exposure induced on the façade.

- the potential for façade systems with combustible materials to limit fire spread through the external wall and along the façade.

- the potential for façade systems with glass and stone wool insulation to limit fire spread through the external wall and along the façade. A discussion to interpret the data of this report is included.

3 Background

Combustible materials can contribute to the combustion energy of a fire. However, sufficient insulation and/or protection can prevent these materials to contribute to the fire development and fire spread completely.

Thermogravimetric Analysis (TGA) can be used to indicate contribution of a combustible material to fires. Figure 1 shows the relationship between mass and temperature of wood from a TGA test. The mass loss that occurs by heating wood to temperatures over 100˚C is caused by the vaporization of moisture that is embedded in the timber. If wood is heated further, it will start to lose mass (and therefore emit gasses) at temperatures higher than 200˚C. At temperatures under 200˚C there is no release of any combustible gasses, meaning that the wood cannot contribute any combustion energy to the fire. At temperatures between 200 and 280˚C slow pyrolysis occurs and at temperatures exceeding 280˚C degrees, rapid pyrolysis occurs (Browne, 1958). Wood temperatures

ranging between 200 and 280 therefore indicate a less significant contribution to fire load in comparison with higher wood temperatures.

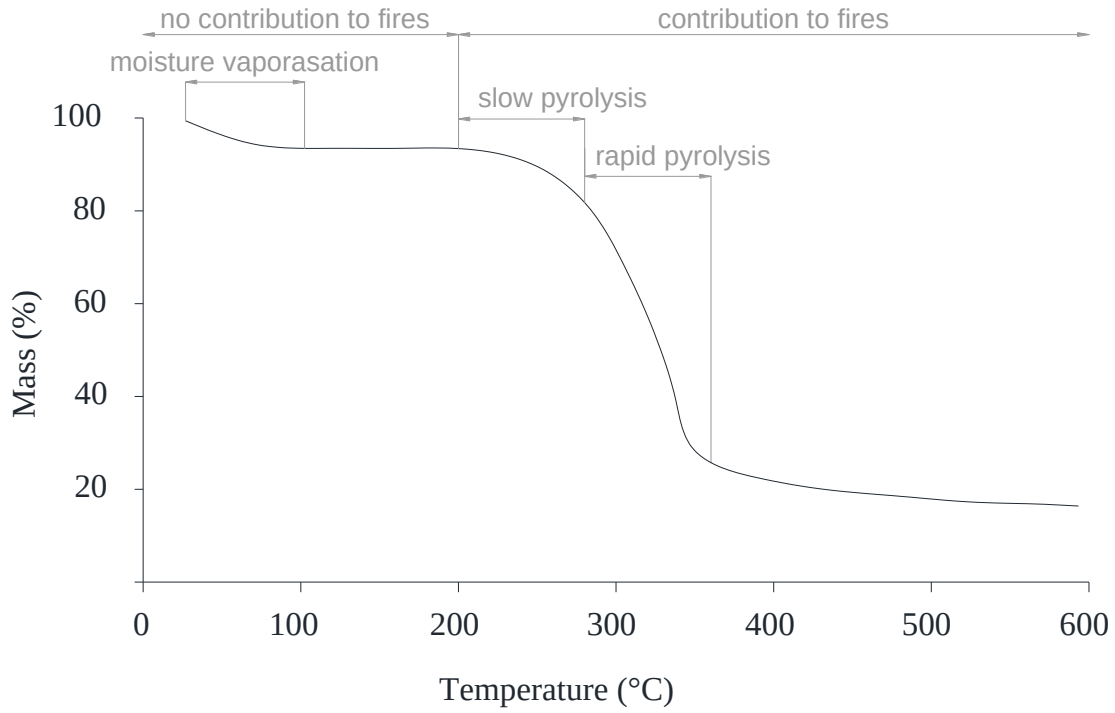

Figure 1: Typical results of thermogravimetric analysis (TGA) of wood.

In addition to the temperature of the wood, visual observations of charring indicate a contribution of the wood to the fire development. Hereby, the depth of the char layer of the timber members gives an indication of the quantity of the contribution.

4 Test 1: SP Fire 105 façade test of an external wall with CLT

This chapter summarizes test results of a façade fire test according to SP Fire 105. The fire test was performed to assess compliance with three requirements by the Swedish Building Regulations (BFS 2011:6) for external walls of buildings of building class BR1[1]. These three requirements (translated from Swedish) are:

- The fire spread inside the external wall shall be limited
- The risk for fire spread along the façade surface shall be limited
- The risk for injuries as a consequence of falling parts from the external wall shall be limited.

[1] Building class BR1 is for buildings with a high demand of fire protection (BFS 2011:6). In practice, most buildings in Sweden with 3 to 16 stories are classified as BR1 buildings.

According to the assessment reports by RISE (RISE report 8P09453-01-1rev2 and 8P09453-01-2rev2), the external wall of Test 1 meets these requirements.

The information given in this section is obtained from the test report (RISE report 8P09453-1rev1) and from raw data, with permission of, ISOVER Saint Gobain and Moelven, the owners of this report. Limited information of the façade system is given as details are confidential.

4.1 Setup of Test 1

The setup is in accordance with SP Fire 105, Issue No: 5 (1994). The SP Fire 105 method evaluates a large-scale façade fire with a test object of 4 x 6 m (width x height). The test resembles the real façade system as much as possible and includes two fictitious window openings to assess the performance of details and fire stops around the window. The fire source is positioned in a fire room underneath the façade (Figure 2) and consists of 60 liters of heptane in trays with attached flame suppressors.

The test specimen discussed in this section was a complete external wall comprising of a 120 mm thick Cross Laminated Timber (CLT) slab and a façade system. The façade system comprised of waterproof fire-impregnated heat treated wooden façade panels of fire class B-s2,d0 according to EN 13501-1 and a 100mm glass wool insulation layer of fire class A1 according to EN 13501-1, among other things not detailed in this report because of confidentiality. The façade system was ventilated between the façade and insulation material. There was no fire insulation or fire protection between the CLT member and the layer of glass wool insulation. Figure 2 shows the setup of this test. The test included the required measurements of temperatures under the eave (Thermocouples C1 and C2 in Figure 2), the required heat flux measurement at the center of the lower fictitious window and extra temperature measurements. All extra temperature measurements taken on the CLT surface (thermocouples C11 to C16) have been included this report, to allow assessment of the involvement of the CLT panel in the fire. The locations of the thermocouples on the CLT surface (C11-16), the thermocouples under the eave (C1 and C2) and the heat flux meter are shown in Figure 2. Figure 3 and Figure 4 show photos taken before and during the test, respectively.

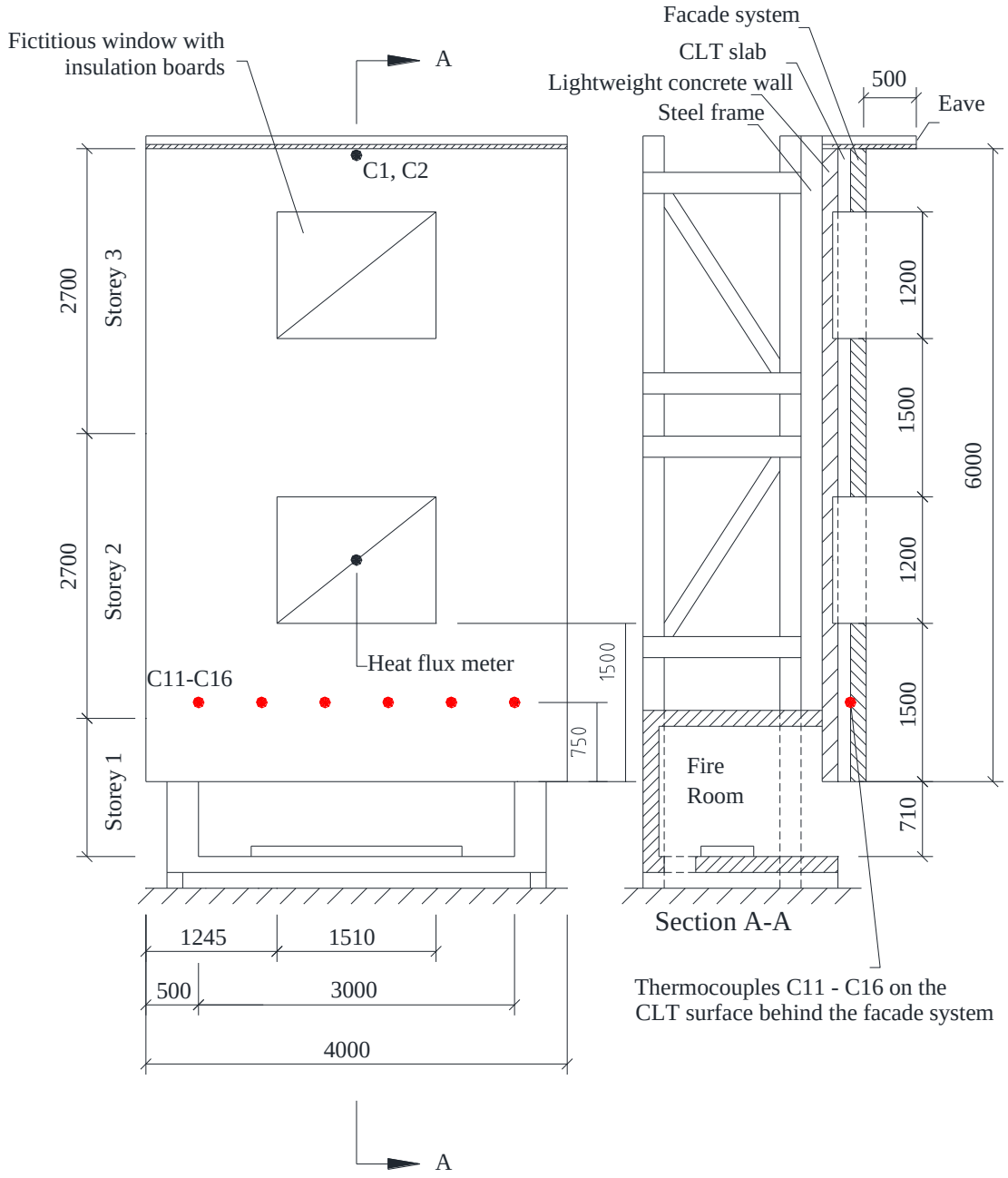

Figure 2: Setup of Test 1.

Figure 3: Photo before Test 1.

Figure 4: Photo during Test 1.

4.2 Results of Test 1

Only results of the test that are within the scope of this report are given in this sub-section.

The by SP Fire 105 (1994) required measurements of the temperature under the eave and the radiation towards the window on the first floor and the radiation towards the center of the first window are shown in Figure 5 and Figure 6, respectively. The allowable temperature and allowable heat flux are indicated in the figures. The tested façade fulfilled the requirements of the Swedish building regulations listed in the beginning of this chapter and the measurements remained well within the allowable range:

- The maximum temperature measured below the eave was 212 ˚C, which is well under the allowable temperature of 500˚C during a continuous period longer that 2 minutes or 450˚C during a continuous period longer than 10 minutes.
- The heat radiation towards the test specimen in the center of the fictitious window one floor above the fire room did not exceed 80 kW/m² during the test. Maximum measured heat radiation was measured to 30 kW/m².
- During the test, there was no drop-off from the test specimen.
- The fire spread on the surface of the test specimen and inside the test specimen did not reach above the lower edge of the fictitious window two floors above the fire room.

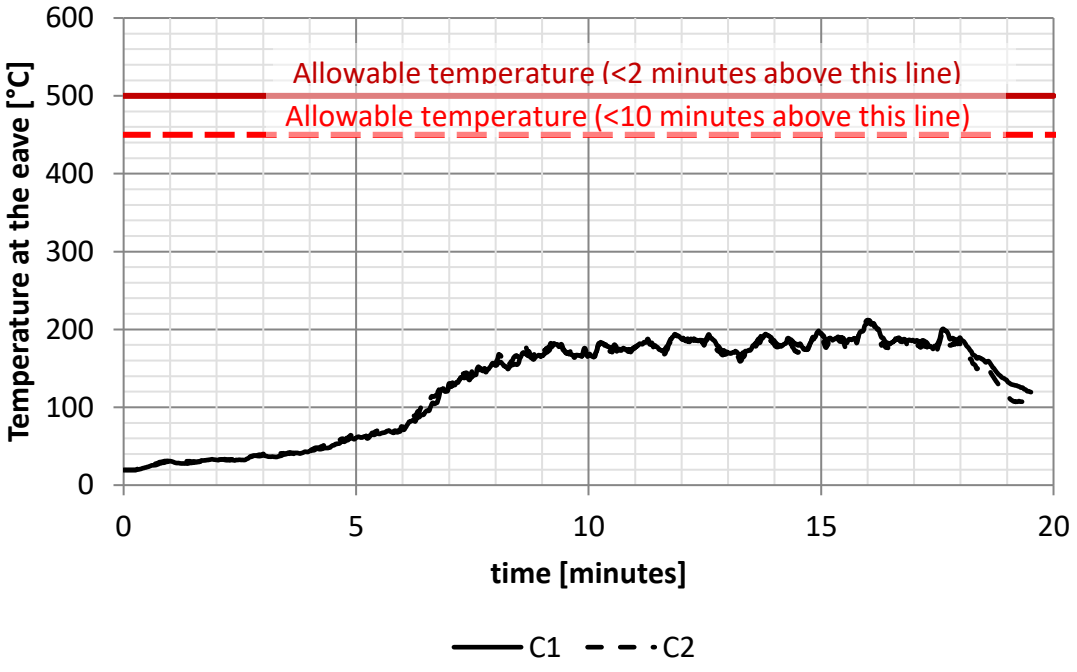

Figure 5: Temperatures at the eave during Test 1 together with the allowable temperatures at that location

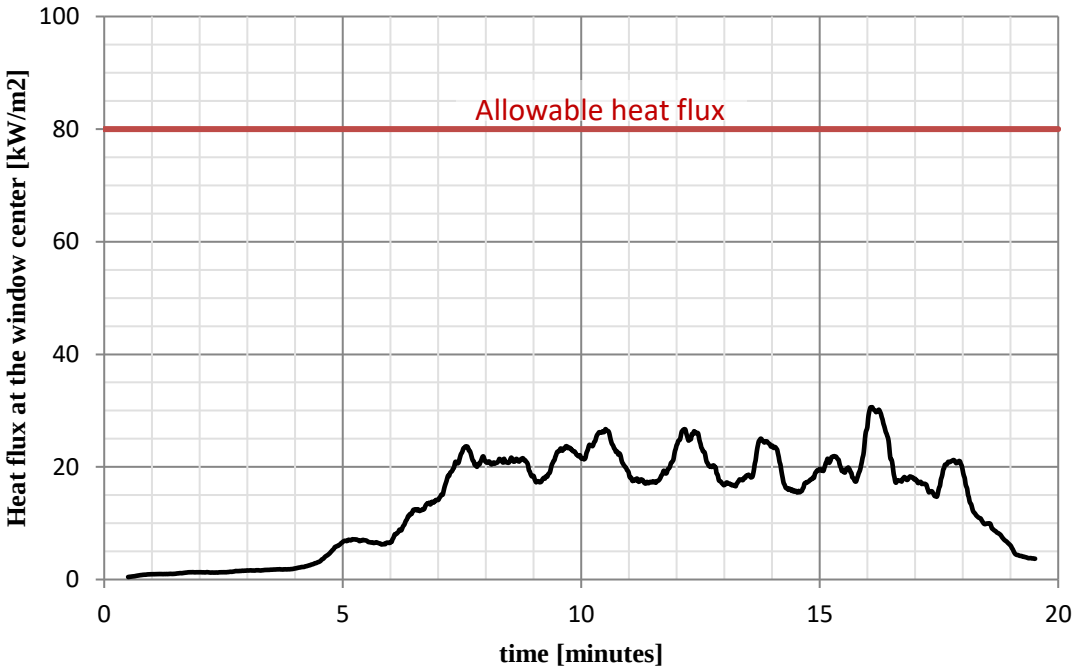

Figure 6: Heat flux at the window center on the first floor during Test 1 and the allowable heat flux

Figure 7 shows the temperatures measured on the surface of the CLT on the side of the fire exposure, together with the temperature ranges indicating the wood's contribution to the fire development. The maximum temperature measured on this surface was 48˚C, which is well under the pyrolysis temperature, which indicates that the structural timber did not contribute to the fire as a fuel.

Figure 8 shows the surface of the CLT, after the test, on side of the fire exposure, at the location that was positioned right above the fire room during the test. Figure 9 shows the total surface of the CLT on the side of the fire exposure after the test. No coloring or charring of the CLT member was observed. The minor black areas visible in Figure 9 are smudges of char that fell from the facade system.

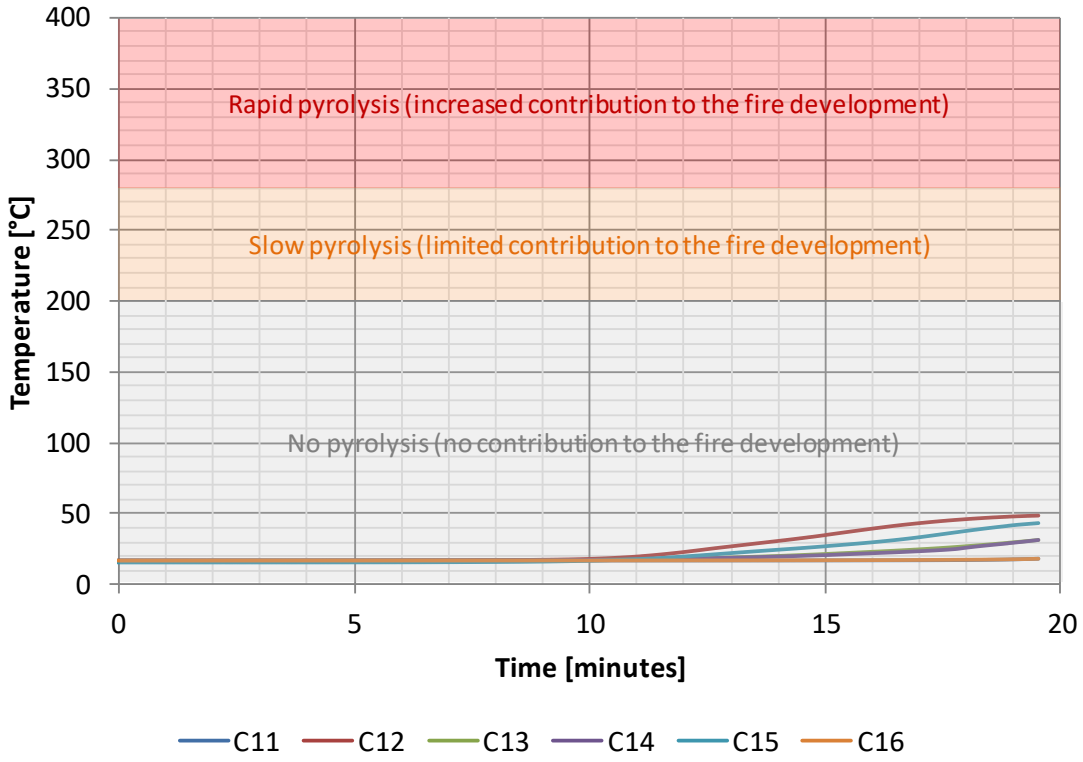

Figure 7: All temperatures measured at the surface of the CLT slab on the side of the fire exposure of Test 1 (locations shown in Figure 2)

Figure 8: The surface of the CLT slab behind the exposed façade system after Test 1.

Figure 9: The surface of the CLT slab after Test 1 on the side of the fire exposure

5 Test 2: SP Fire 105 façade test of an external wall with backing particle board

This chapter summarizes test results of a façade fire test according to SP Fire 105.

Similar to Test 1 discussed in Chapter 4, Test 2 was performed to assess compliance with three requirements by the Swedish Building Regulations (BFS 2011:6) for external walls of buildings of building class BR1. These three requirements have already been discussed in chapter 4.

According to the assessment report by RISE (RISE report 9P02285-01-2), the external wall of Test 2 meets these requirements.

The information given in this section is obtained from the official test report (RISE report 9P02285-2) by RISE and from raw data made available by ISOVER Saint Gobain and Moelven, the owners of this information. No detailed information of the façade system is given as that is confidential information.

5.1 Setup of Test 2

The setup is in accordance with SP Fire 105, Issue No: 5 (1994). This method was described earlier in Section 4.1.

The test specimen discussed in this section was a façade system with a 10 mm thick particle board with a nominal density of 680 kg/m^3 on the cold side, as shown in Figure 10. The purpose of the particleboard was to indicate any fire impact behind the complete façade. The façade system comprised of a waterproof fire-impregnated wooden façade of fire class B-s2,d0 according to EN 13501-1 and an 80mm glass wool insulation layer of fire class A2-s1,d0 according to EN 13501-1, with the particle board on the unexposed side, among other things not detailed in this report because of confidentiality. The façade system was ventilated between the façade panels and the insulation.

For the same reasons as discussed in Section 4.1, the temperature measurements at the particle board surface have been included in this report. The locations of the thermocouples on the particle board surface (C11-16), the thermocouples under the eave (C1 and C2) and the heat flux meter are shown in Figure 10. Figure 11 and Figure 12 show photos taken before and during the test, respectively.

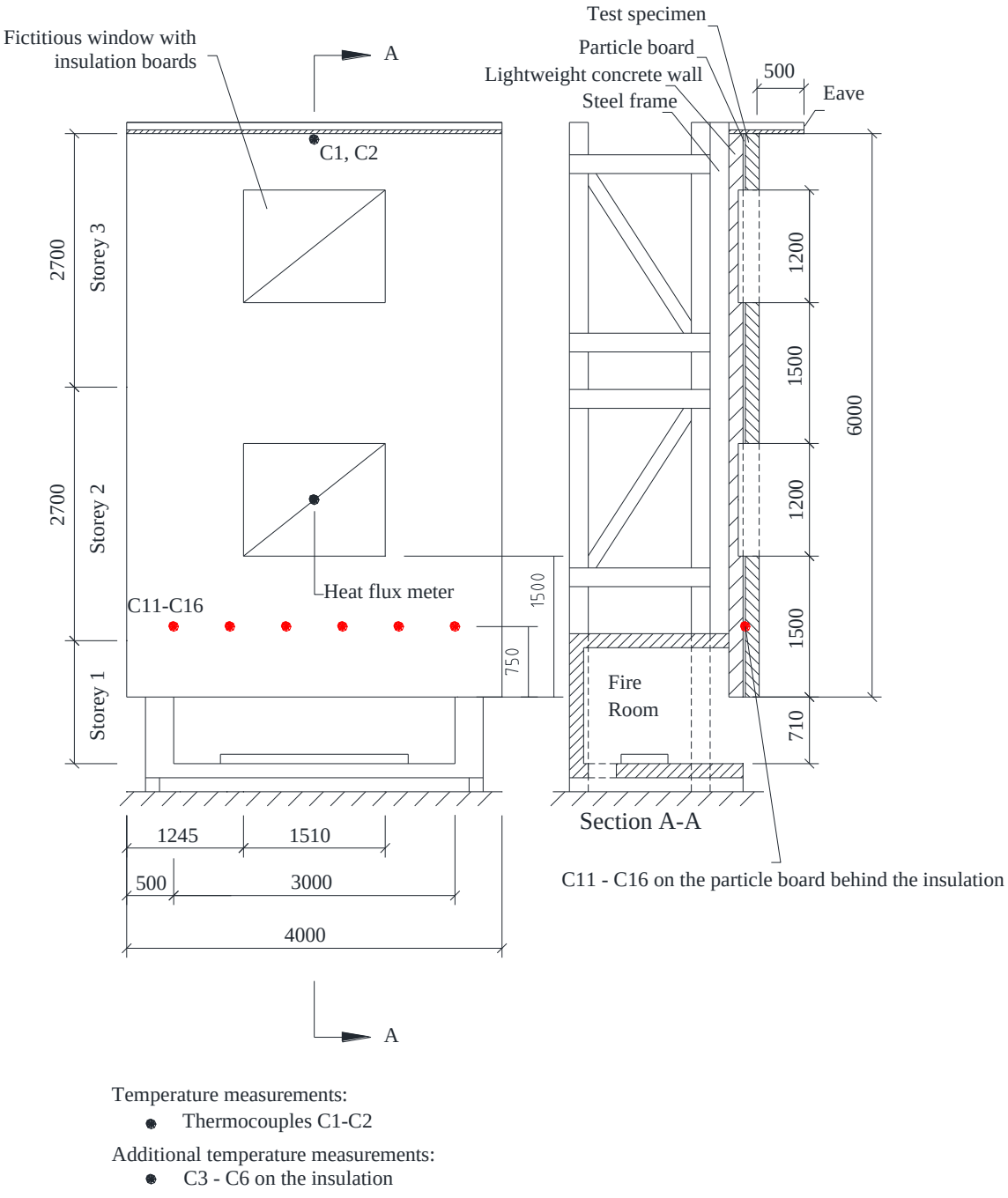

Figure 10: Setup of Test 2.

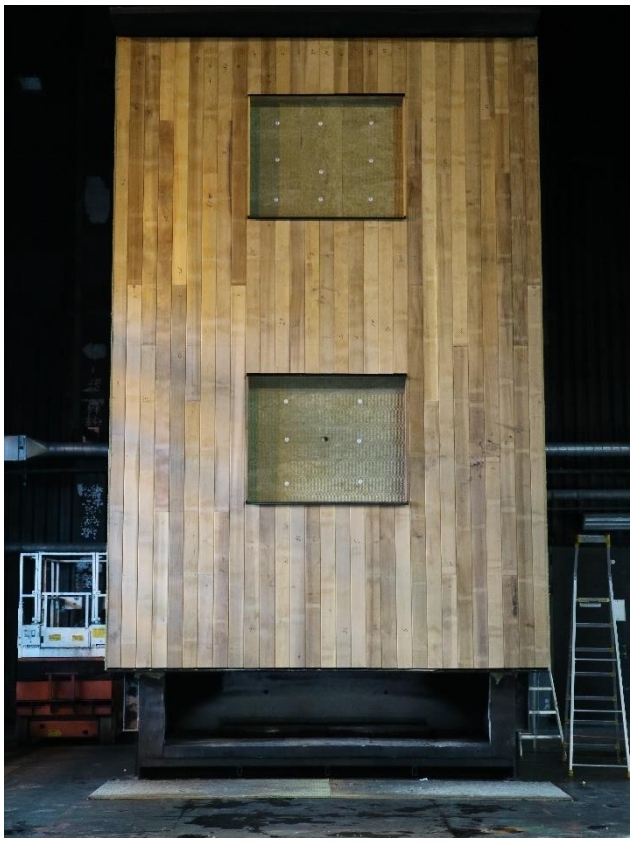

Figure 11: Photo before Test 2.

Figure 12: Photo during Test 2.

5.2 Results of Test 2

Only results of the test that are within the scope of this report are given in this sub-section.

The by SP Fire 105 (1994) required measurements of the temperature under the eave and the radiation towards the window on the first floor and the radiation towards the center of the first window are shown in Figure 13 and Figure 14, respectively. The allowable temperature and allowable heat flux are indicated in the figures. The tested façade fulfilled the requirements of the Swedish building regulations listed in the beginning of this chapter and the measurements remained well within the allowable range:

- The maximum temperature measured below the eave was 280 °C, which is well under the allowable temperature of 500°C during a continuous period longer that 2 minutes or 450°C during a continuous period longer than 10 minutes.
- The heat radiation towards the test specimen in the center of the fictitious window in the floor above the fire room did not exceed 80 kW/m² during the test. Maximum measured heat radiation was measured to 50 kW/m².
- During the test, there was a drop-off from the test specimen. The drop-off consisted of charred pieces of facade panel. The pieces had a separate maximum size of approx. 15 x 15 cm and did not burn on the floor in front of the test specimen. The total weight was estimated to less than 5 kg in total.
- The fire spread on the surface of the test specimen and inside the test specimen did not reach above the lower edge of the fictitious window two floors above the fire room.

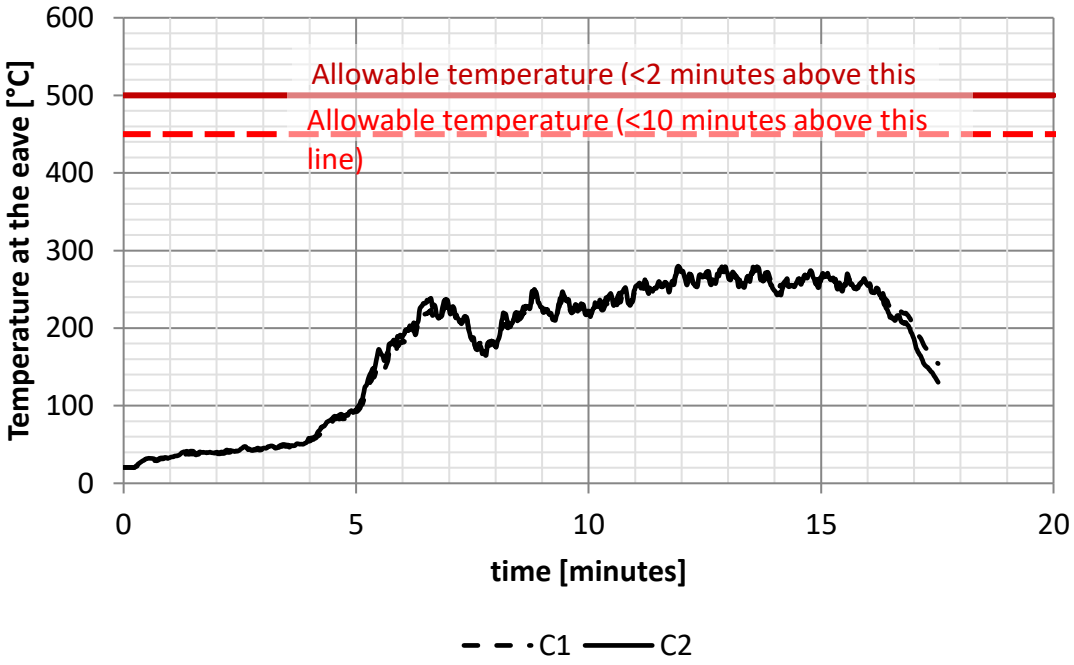

Figure 13: Temperatures at the eave during Test 2 together with the allowable temperatures at that location

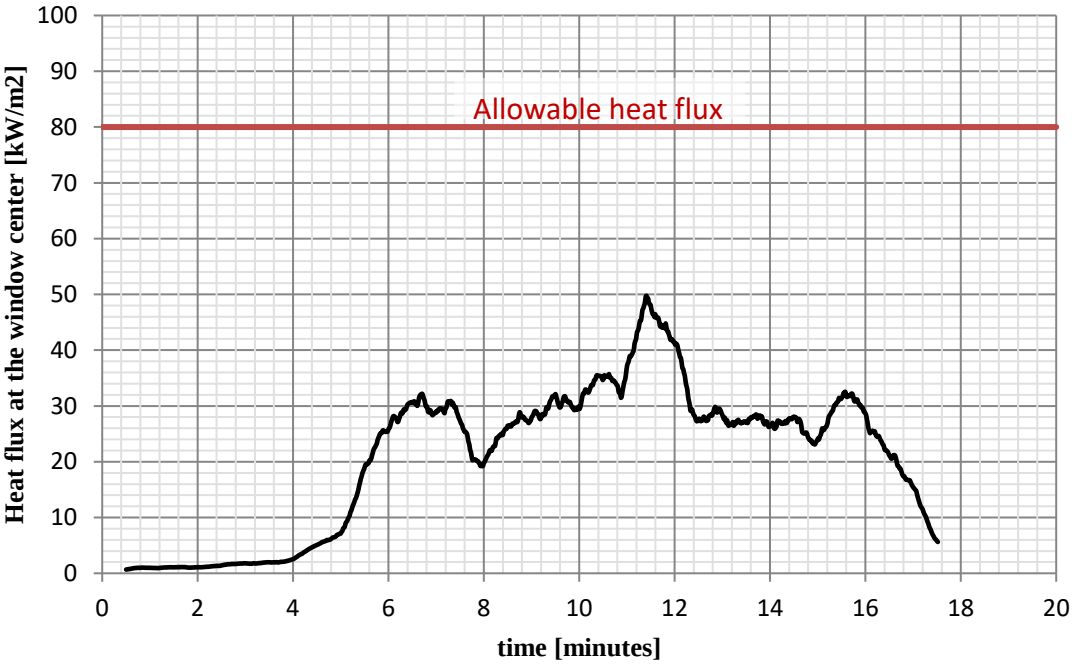

Figure 14: Heat flux at the window center on the first floor during Test 2 and the allowable heat flux

Figure 15 shows the temperatures measured on the surface of the particle board on the side of the fire exposure, together with the temperature ranges indicating the particleboard's contribution to the fire development. The maximum temperature measured on this surface was less than 35˚C, which is well under the pyrolysis temperature.
Photos of the particle board surface were not included in the test report. However, the test report stated that the particleboard was unaffected after the test.

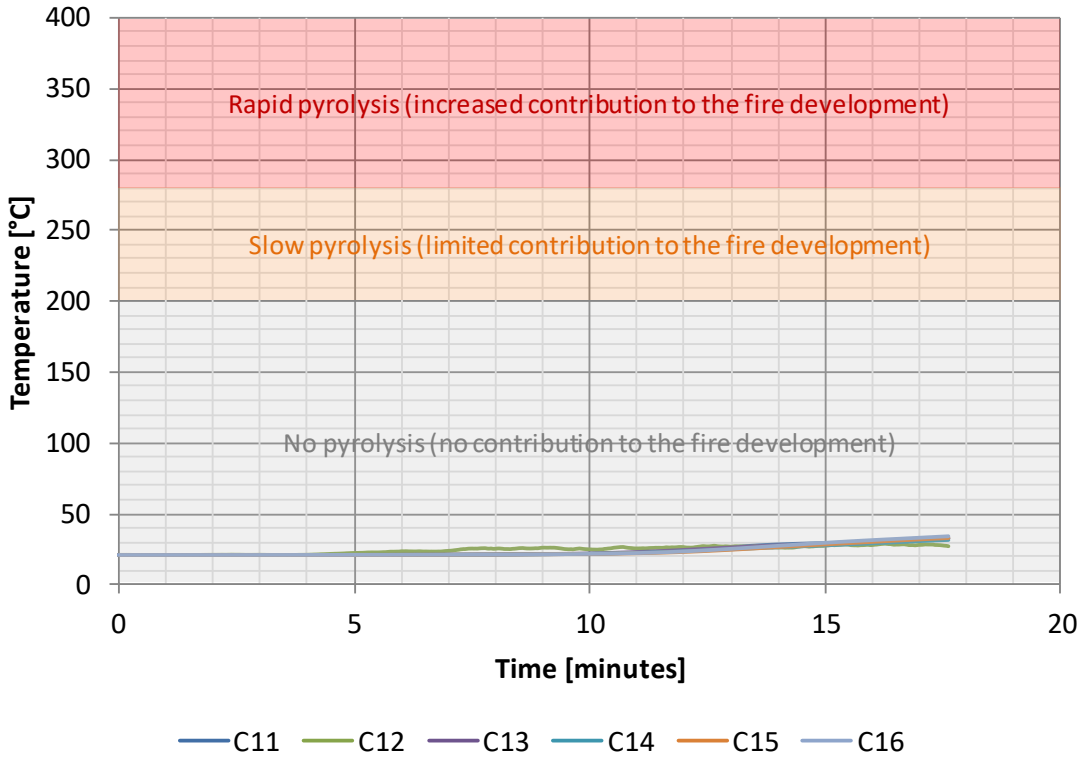

Figure 15: All temperatures measured at the surface of the particle board on the side of the fire exposure of Test 2 (locations shown in Figure 10)

6 Test 3: Fire resistance test of an external wall exposed on the external side

In contrast with the first two tests discussed in this report, Test 3 is a furnace test of a load bearing wall in accordance with EN 1365-1:2013 in connection with EN 1363-1:2012. The external wall tested consisted of a 5-layer, 120 mm thick CLT panel. The layer thicknesses were 20, 30, 20, 30 and 20 mm in order from surface to surface. The façade system on the fire exposed side consisted of a wooden façade and a 40mm cavity for ventilation, stone wool insulation, timber studsand a fire protection board. The fire protection board was fastened to the CLT panel. The specific details of the façade system are left out of this report because of confidentiality.

The information given in this section is obtained from the test report (Prüfbericht Nr. PB 3.2/18-423-1) written by MFPA Leipzig GmbH, with permission of, Knauf, the owner of this report.

6.1 Setup of Test 3

The setup and exposure of Test 3 was in accordance with EN 1365-1:2013 and EN 1363-1:2012. The dimensions of the external wall were 3.0 m x 3.0 m and the test was performed for 99 minutes. Figure 16 shows the exposed side (i.e. façade side) of the test specimen prior to the test.

Figure 16: Exposed side of the test specimen prior to the test.

Temperature measurements have been made in on the surface of the CLT on the side of the fire exposure. The locations of the thermocouples for these measurements are shown in Figure 17.

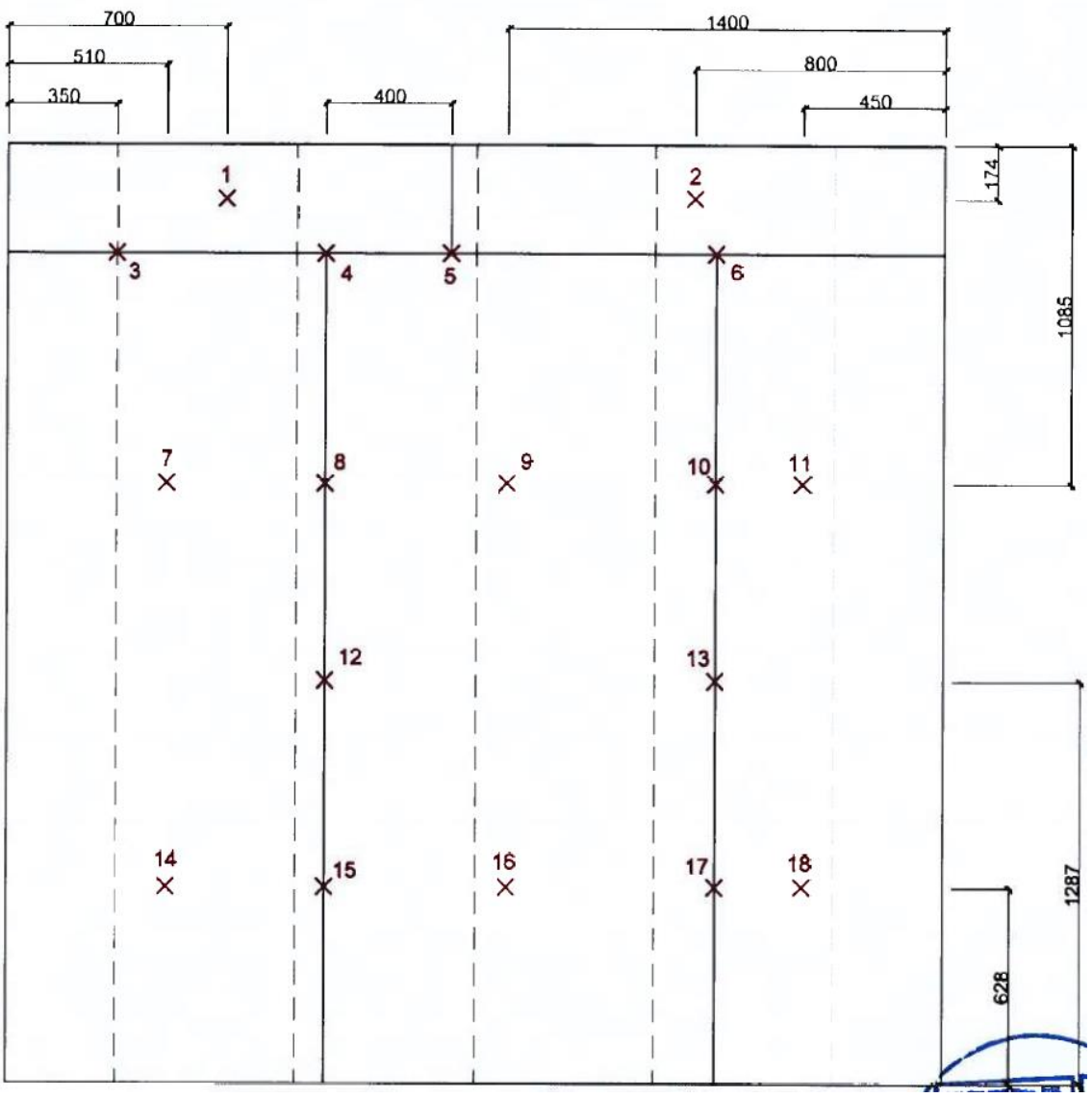

Figure 17: Thermocouple locations at the interface of the CLT and the fire protective board.

6.2 Results of Test 3

The test setup passed all fire resistance criteria of EN 1363-1 2012 for the full duration (99 minutes) of the test. Temperatures measured at the interface of the CLT and the fire protective board are shown in Figure 18. The maximum temperature measured at the timber surface was 92˚C, which is lower than the pyrolysis temperatures of >200˚C, discussed in Chapter 3.

The surface of the CLT panel on the side of the fire exposure, after the 99 minutes long fire resistance test, is shown in Figure 19. Aside from local coloring on the left side of the panel, the panel was largely undamaged. The total volume of charred material was minimal.

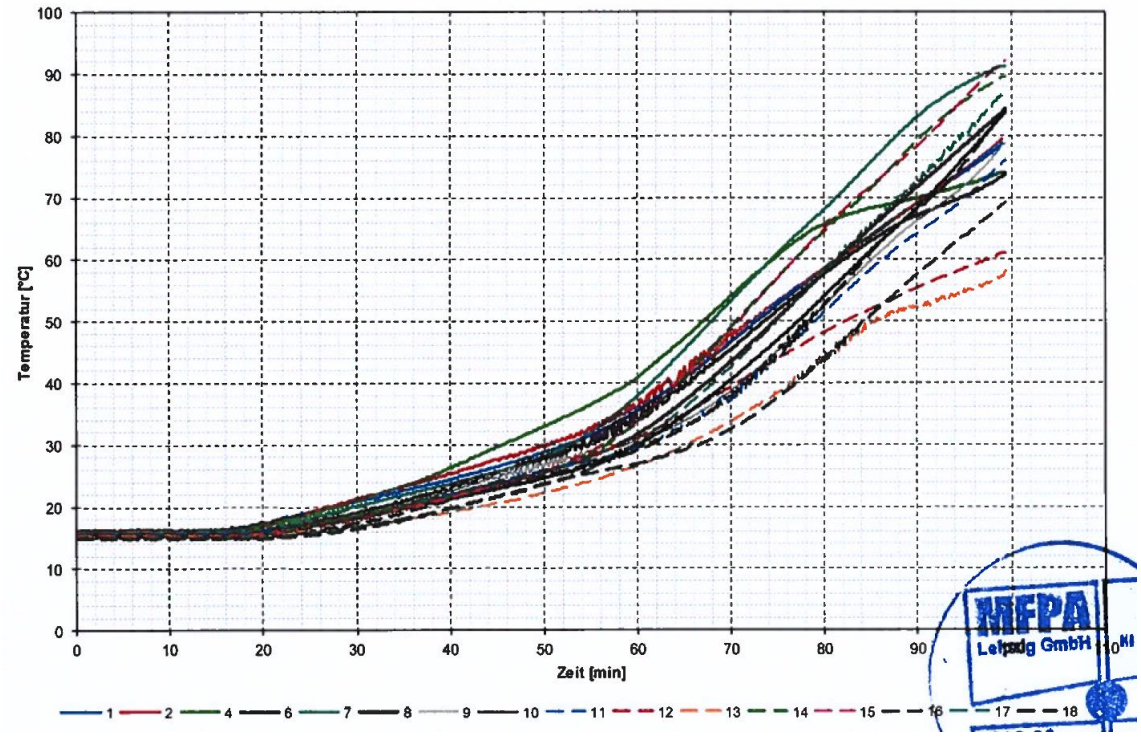

Figure 18: Temperatures at the interface between the CLT panel and the fire protection board.

Figure 19: surface of the CLT panel on the side of the fire exposure, after the 99 minutes long fire resistance test.

7 Discussion

The two façade fire tests discussed in chapters 4 and 5 included timber members to allow assessment of the fire impact on the structural timber in the external wall. The façade system consisted of a combustible cladding and a non-combustible insulation layer. Temperature measurements on the timber surface at the interface with the façade system were made at locations with relatively high exposure by the fire plume. The temperatures at these locations were in all cases lower than 50˚C during the whole test, which is considerably less than the temperatures at which slow pyrolysis occurs. In addition, visual observations of the wood surface after the test indicated that the timber was unaffected, and no coloring or charring occurred. Both the temperature observations and the visual observations indicate that there was no contribution of the structural timber members to the development and spread of the fire.

Chapter 6 shows the results of a 99 minutes long fire resistance test of an external wall exposed on the external side. The external wall included a CLT slab which was positioned behind a façade system, which consisted of non-combustible insulation and combustible battens within the insulation layer. Maximum temperature measured at the interface of the CLT and the façade system was 92˚C, which is well below the temperature range that corresponds to slow pyrolysis (200 - 280˚C) and far below temperatures that correspond to rapid pyrolysis (>280˚C). Visual observation after the fire test indicated two locations of local superficial coloring and charring in a mostly unaffected panel. As the charring was only superficial the volume of pyrolyzed wood is insignificant and the total resulting combustion energy is considered to be negligible in comparison to the combustion energy released by the fire source and façade panels.

It should be noted that the tested façades are being implemented in practice. All tests that were made available to the author in relation with this assignment were included in this report.

8 Conclusion

This report summarizes and discusses three fire tests of external walls with a timber structure or a part of a timber structure. The facades tested are used in practice. All fire tests that were made available to RISE in relation with this assignment were included in the report.

In the three case studies of this report, the temperature measurements at the surface of the structural timber at highly exposed locations and visual observations, indicated:

- No contribution of the structural timber to the fire development and fire spread, during the standard façade fire tests according to testing method SP Fire 105.

- No structural damage of the structural timber, during the standard façade fire tests according to testing method SP Fire 105.

- Insignificant contribution of the structural timber to the fire development, during a 99 minutes long fire resistance test of an external wall exposed from the external side.

- Insignificant structural damage, during a 99 minutes long fire resistance test of an external wall exposed from the external side.

Both standard façade fire tests, which were in accordance with the Swedish façade fire testing standard SP Fire 105, were assessed by the accredited testing institute to meet the requirements set by the Swedish Building regulations that: (1) the fire spread inside the external wall shall be limited; (2) the risk for fire spread along the façade surface shall be limited and; (3) the risk for injuries as a consequence of falling parts from the external wall shall be limited. The structural timber of these tested external walls did not contribute to the fire development and the fire spread on the façade. These findings are in line with an experiment by Gibbs and Su (2015), who have tested an external wall with CLT in the standard Canadian façade fire test, with fire exposure that differs of that of the Swedish test and concluded that the CLT was unaffected.

The case studies showed that external fire spread along and through external walls can be limited in certain external walls with façade panels of fire class B-d2,s0 (classification according to EN 13501-1), glass or stone wool insulation and a timber construction with fire class D.

References

Browne, F.L. 1958. Theories of the combustion of wood and its control. A survey of the literature. Report 2136. Madison, Wisconsin: Forest Products Laboratory, US Department of Agriculture.

BFS 2011:6 (2011) Boverkets byggregler – föreskrifter och allmänna råd (Swedish). Boverket, Karlskrona, Sweden.

EN 13501-1 (2019) Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests.

EN 1363-1 (2012) Fire resistance tests. General requirements

EN 1365-1 (2013) Fire resistance tests for loadbearing elements – Part 1: Walls

Gibbs, E. and Su, J.Z. (2015) Full scale exterior wall test on Nordic cross-laminated timber system. National Research Council Canada (https://nrc-publications.canada.ca/eng/view/fulltext/?id=78f47a7e-0cc5-418f-bb43-461a6c102ffd)

Prüfbericht Nr. PB 3.2/18-423-1 (2019) MFPA Leipzig GmbH, Leipzich, Germany.

RISE report 8P09453-01-1rev2 (2020) Fire technical assessment of façade cladding system. Research Institutes of Sweden, Borås, Sweden

RISE report 8P09453-01-2rev2 (2020) Fire technical assessment of façade cladding system. Research Institutes of Sweden, Borås, Sweden

RISE report 8P09453-1rev1 (2020) Fire test of façade cladding. Research Institutes of Sweden, Borås, Sweden

RISE report 9P02285-01-2 (2019) Fire technical assessment of façade cladding system. Research Institutes of Sweden, Borås, Sweden

RISE report 9P02285-2 (2020) Fire test of façade cladding. Research Institutes of Sweden, Borås, Sweden

SP Fire 105, Issue No: 5 (1994) Method for fire testing of façade materials, Dnr 171-79-360 Department of Fire Technology, Swedish National Testing and Research Institute.

RISE Research Institutes of Sweden AB
Box 5604, 114 86 STOCKHOLM
Telefon: 010-516 50 00
E-post: info@ri.se, Internet: www.ri.se

Safety
RISE Rapport 2020:50
ISBN: 978-91-89167-33-9