BRANDFORSK
2017:1

Fire Stops in Buildings

Alar Just och Daniel Brandon

Brandforsk

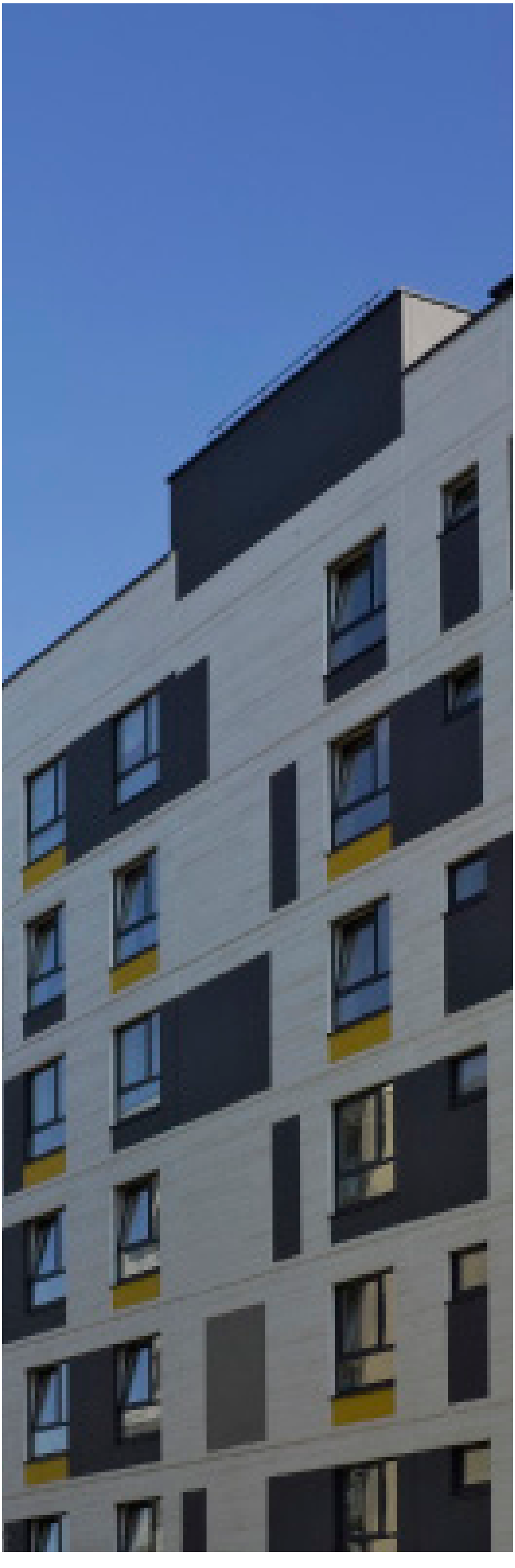
PROJECT TECHNICAL PARTNER

Anders Johansson Boverket
Viktor Wahlsten Brandskyddslaget
Håkan Pettersson LF Västerbotten
Matilda Svensson MSB
Johan Andersson SP Fire Research
Robert Jansson SP Fire Research
Daniel Brandon SP Hållbar Samhällsbyggnad
Alar Just SP Hållbar Samhällsbyggnad
Birgit Östman SP Hållbar Samhällsbyggnad

Keywords

Fire stops, cavity barriers, model scale fire tests

BRANDFORSK 2017:1
ISSN 0284-517



Contents

1 Introduction

In a statistical study performed by the London fire brigade in the Real Fires Database it was found that out of 30 086 fires occurring between 2009 and 2011, fire spread beyond the floor of origin through gaps or voids occurred in 92 cases. This illustrates that the phenomenon is relatively rare. However, it can lead to severe property damage. Fires can spread invisibly within cavities of the structure, which has led to problems concerning the extinguishment of the fire. Cavity barriers function is to stop the fire spread through cavities. However, these cavity barriers have not always been effective.

This report is the result of a study that aimed to:

1. Develop a robust testing method for cavity barriers for cavities with combustible materials within walls, floors and other elements in buildings.
2. Provide guidelines for the materials, installation, positioning, detailing and location of the cavity barriers.

Additionally, a preliminary study is performed to assess some extinguishing strategies.

Based on a study of characteristics of cavity fires, current standard fire tests for cavity barriers were revised for the use in cavities with combustible materials. From tests following the revised methodology, guidelines regarding the dimensions, installation and fire stopping design are provided.

2 Preliminary study

A first test series was performed in order to make a first assessment of a method that includes combustible materials in the cavity. In the test series called test series 1, cavity barriers were placed between two particle boards. The cavity barriers were glued on one of the cavity walls before the second cavity walls were placed (see Figure 1). Specimens were placed on top of a furnace (Figure 2) and then they were exposed to a standard fire in accordance with EN1363 for one hour.

Figure 1 - Single-barrier specimen of test series 1

Figure 2 - Positioning of 2 specimens on top of a furnace.

Test series 1 included four different cavity barriers, of which an overview is given in Table 1. The brands of the cavity barriers are kept anonymous as this is an ad hoc procedure, but a description of the different barriers is given in Table 1 and Table 2. Common methods to install cavity barriers are illustrated in Figure 3. The aim of this first test series was to identify weaknesses of an initial test method. Therefore, it was chosen to install the cavity barriers differently, using the most practical way considering the dimensions and compressibility.

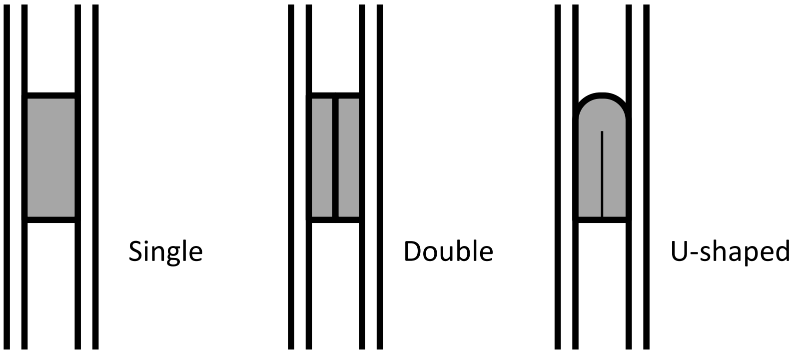
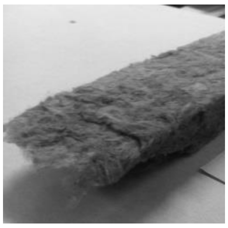


Figure 3 - Single, Double and U-shaped positioning between two cavity walls

Table 1 - Dimensions, density and description of the cavity barriers of test series 1

Specimen	**FS1**	**FS2**	**FS3**	**FS4**
Cavity barrier	Plastic covered HTE mineral wool	Stone wool	Plastic covered glass wool	Plastic covered HTE mineral wool
Dimensions, b x h [mm]	15x120	65x25	50x160	35x95
Appearance				
Unpressed density [kg/m^3]	20	28	20	20
U-shape (U) / single (S) / double (D)	U	S	U	D

Twelve thermocouples were positioned in each specimen in order to record relevant temperatures. Appendix A gives an overview of the thermocouple locations and the dimensions of the specimens. The failure criterion of the specimen is defined using the temperature measurements at the unexposed side. The cavity barrier is considered successful if the temperature on the unexposed side remains lower than 300°C, as this indicates that wood on the unexposed side would not char. Some of the test results will be shown in this report. However, a more complete overview of the test setup and test results is given in Appendix 2.

Figure 4 shows temperatures measured on the unexposed side of cavity barriers. It can be seen that the best performance was achieved with plastic covered glass wool of 50 x 160mm, which also had the largest volume. The stone wool did reach the failure criterion as the temperatures on the unexposed side were over 300°C. The method seems to be able to differentiate between performances of different materials. However, it can be questioned whether the specimens are exposed to conditions that are severe enough, so that the fire stops can be used to avoid high damage cavity fires. For an assessment of weaknesses of the preliminary test method a review of real cavity fires is performed. This is discussed in the next chapter.

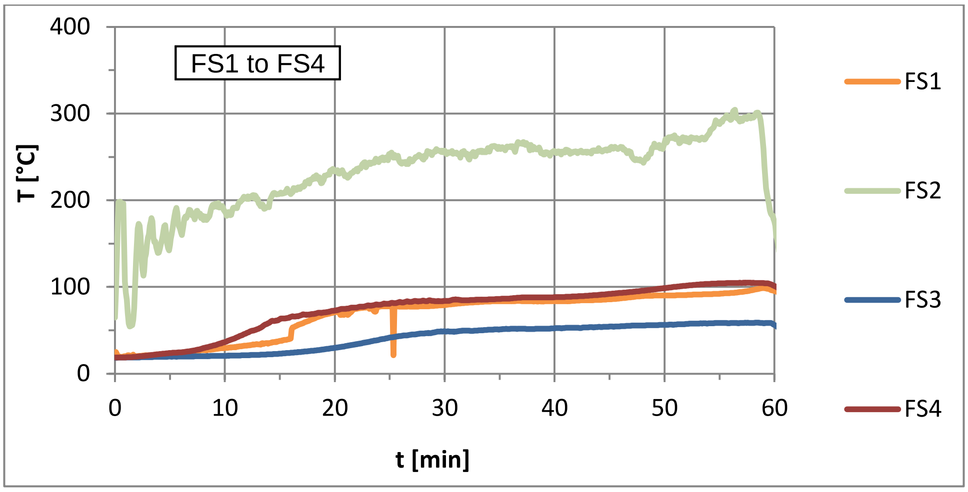


Figure 4: temperatures on the unexposed side of the cavity barriers

3 Review of real cavity fires

For the identification of causes of high fire damages and the nature of the fire exposure to cavity barriers, a number of known cavity fires is analysed in this report.

Two Swedish examples are the fires in Luleå, Klintbacken in 2013 (Umeå Kommun Brandförsvar och Säkerhet, 2013; Ostman and Stehn, 2014) and in Umeå, Ålidhem in 2008 (Umeå Kommun Brandförsvar och Säkerhet, 2009). The building in Luleå was a light timber frame structure constructed from prefabricated modules. The modules were transported to the building site and assembled. In the cavities between the modules, mineral wool was used as cavity barriers. However, according to the accident report, the insulation was covered in combustible plastic and the fire managed to spread past the cavity barriers.

The fire originated in a kitchen due to ignited oil in a saucepan. The fire brigade arrived quickly at the fire and managed to extinguish the fire in the original compartment (see Figure 5). However, the fire spread through the ventilation shaft and ignited combustible material in the attic. The attic burned out after approximately 1.5 hours, at which the visible fire stopped. However, within the cavities the fire spread downward (see Figure 6) and caused re-ignition of the fire in lower floors. The fire brigade struggled to extinguish the fire and had to demolish building elements in order to find and reach the fire. After the fire, the building had to be demolished as the fire damage was too severe for recovery.

The building consisted of three buildings parts adjacent to each other (see Figure 6), each part consisted of four floors and an attic. The building had a concrete structure and a masonry façade. The attic ranged over the whole building without fire walls (Umeå Kommun Brandförsvar och Säkerhet, 2009). The building in Umeå had a non-combustible structure, but had combustible material in the cavities.

Figure 4 - Fire damage after extinguishment of the fire in the ignited compartment[2]

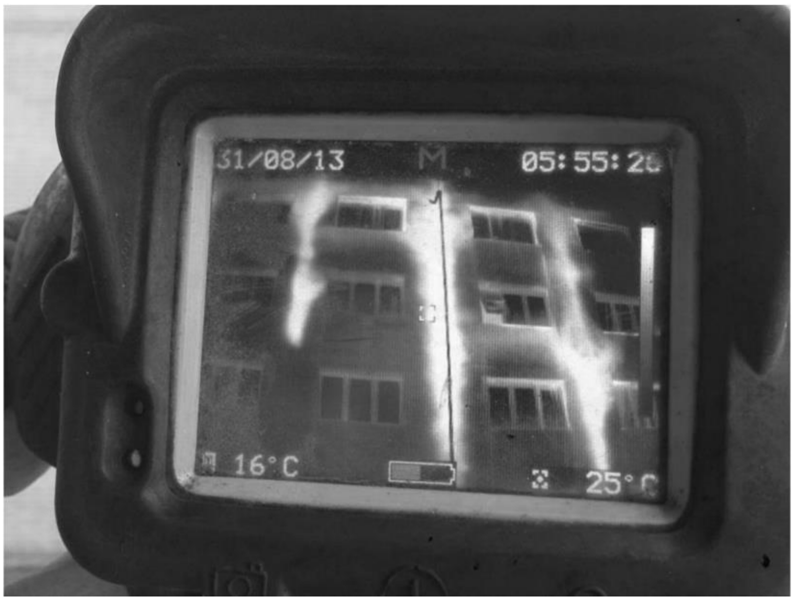


Figure 5 -Infrared camera picture indicating a downwards fire spread through cavities[2]

The fire ignited in a pan with oil in the kitchen and spread to the cupboard above the kitchen range. The fire was extinguished quickly by the fire brigade, after which the situation was assessed to be safe. However, after a few hours the fire re-ignited in the attic and the fire spread down to several apartments. Investigation of the fire showed that the fire spread through the cavity in the external wall, where any cavity barrier was absent.

Figure 6 - Building fire in Umeå, Ålidhem (Umeå Kommun Brandförsvar och Säkerhet, 2009).

In 2000, the Building Research Establishment performed a full scale fire test on a 6-storey timber framed building in a former airship hangar in Cardington (Lennon *et al.*, 2000). The test ran just more than one hour and was extinguished. From the study it was concluded that the structure was able to withstand an one hour of fire and that the fire spread outside of the ignited compartment was prevented for one hour. However, the fire re-ignited in a cavity (Pearson and Lane, 2002), despite the presence of cavity barriers, two-and-a-half hours after the test. The fire brigade had to return to the facility to extinguish the fire. However, the fire was difficult to extinguish as the cavity fire could not be located. It took the fire brigade five-and-a-half hours to extinguish the re-ignited fire and the damage was severe.

The three fires discussed above have the following in common (among other aspects):

- The fire spread through cavities in which the airflow may have been limited.
- The cavity contained combustible materials.
- The cavity fires outlasted the compartment fires by several hours.
- The cavity fires led to re-ignition of compartments after several hours.
- The fires were difficult to extinguish and led to high damages.

A method to assess cavity barriers should include a period after a fully developed fire, combustible materials within the cavity and potential heating of the air within a cavity. Therefore, preliminary cavity barrier tests should be revised. Using a revised test method should lead to more reliable guidance for the use of cavity barriers.

4 Test methodology for cavity barriers

A draft European test standard EN 1364-6 (2016) describes standard procedure for fire testing of cavity barriers. The test involves a cavity barrier exposed to a standard fire, similarly to the preliminary tests performed for this study. However, the test does not consider combustible cavity walls and the air within the cavity on the unexposed side of the cavity barrier, is in direct contact with ambient air. Therefore, the air temperatures in the cavity cannot significantly rise and there is no assessment of combustion of the cavity walls on the unexposed side of the cavity barrier. Also the duration of the fire test can be questioned as the duration of analysed cavity fires significantly exceeds the duration prescribed in the test standard.

4.1 Test series 2

In test series 2, an enclosed cavity is tested by using two fire barriers in a single specimen (Figure 7, right). These specimens are here simply referred to as double-barrier specimens. In contrast with the single-barrier specimen (Figure 7, left), which is in accordance with the draft of EN 1364-6 (2016), the double-barrier specimen contains an enclosed cavity. Both specimens contain a fire barrier between the cavity (B) and the furnace (A, Figure 7), which limits the temperature rise and air flow in the cavity during the heating phase of a fire. However, the temperatures in the cavity of the double-barrier (B, Figure 7) specimen can be significantly higher than those in the single-barrier specimen, as there is a barrier between the cavity and the ambient air (C, Figure 7, right). As buildings generally have multiple fire barriers and enclosed cavities, it is, as a worst case scenario, important to consider double-barrier specimens instead of single-barrier specimens.

The cavity walls comprised of 10mm thick particle board with 15mm gypsum board screwed on the unexposed sides. The density of the particle board was 812 kg/m^3. The cross-section of the specimens is shown in Figure 8. Seven different cavity barriers were tested, in order to evaluate the testing method. An overview of these cavity barriers is given in Table 2 and Table 3.

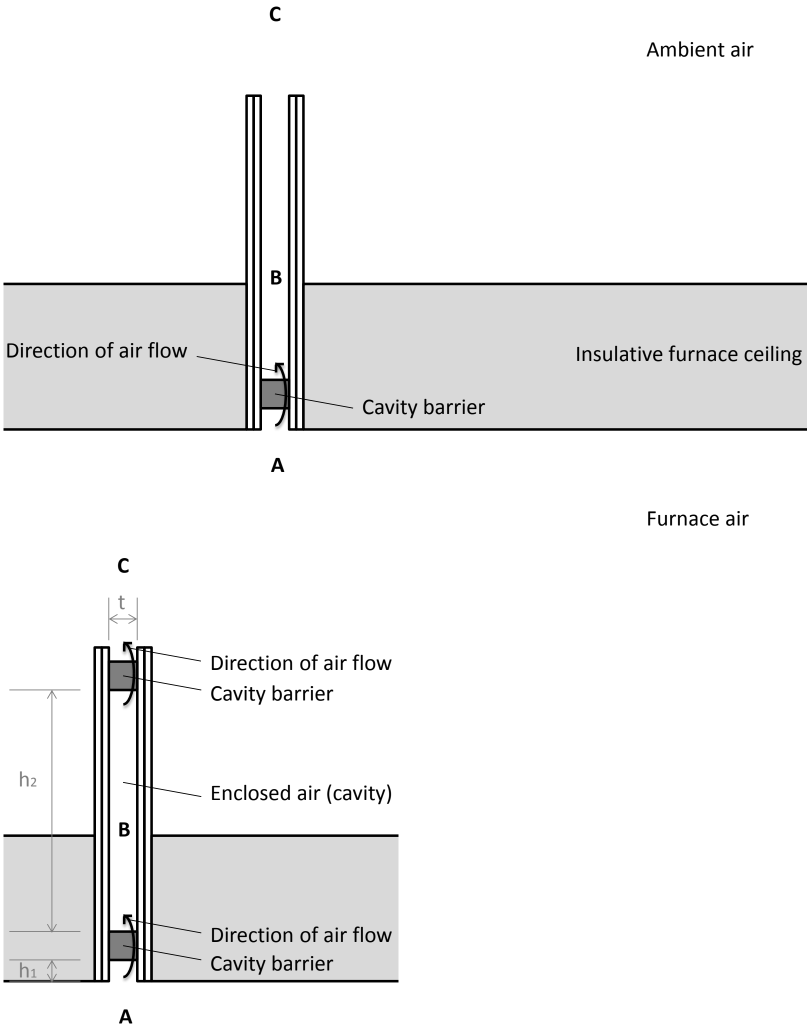


Figure 7 - Single-barrier (left) and double-barrier specimens (right), schematic

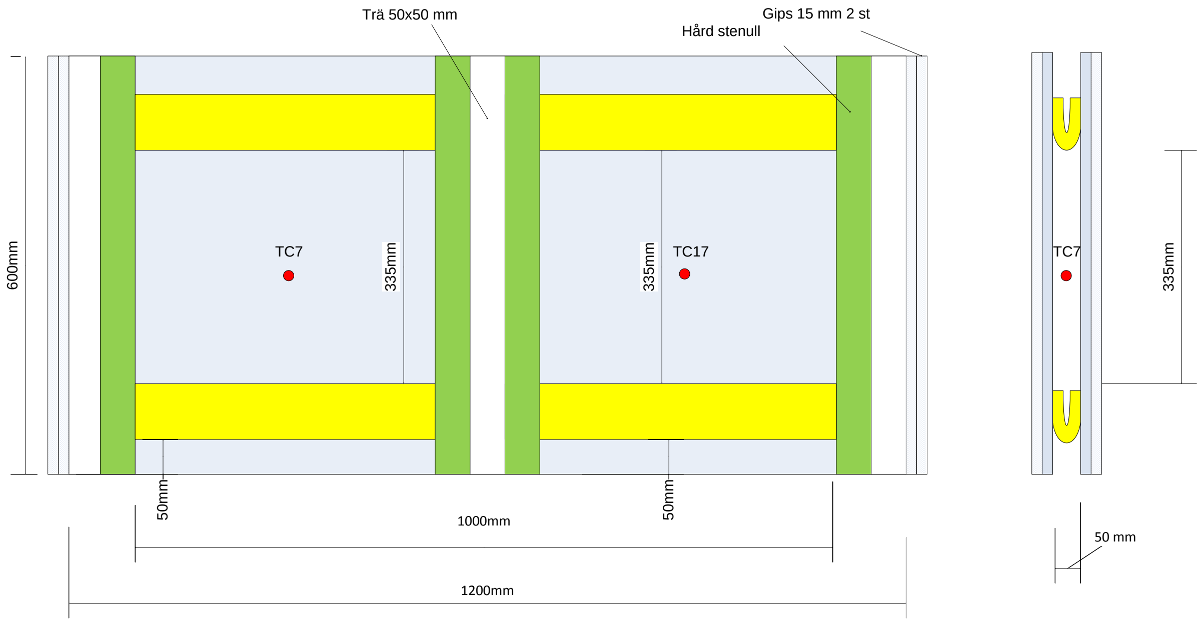


Figure 8 - Cross-sections of specimens of test series 2, exposed from the bottom

Table 2 - Dimensions, density and description of the cavity barriers of test series 2

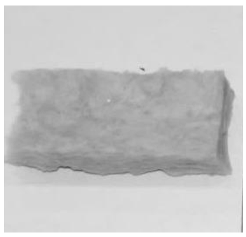
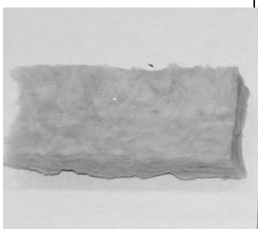
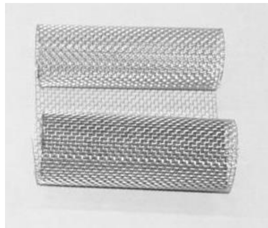
Specimen	**FS5.1 & FS6.1**	**FS5.2**	**FS6.2**
Cavity barrier	Plastic covered HTE mineral wool	HTE mineral wool	Plastic covered glass wool
Dimensions [mm]	30x95	30x95	50x160
Appearance			
Unpressed density [kg/m^3]	21	22	26

Table 3 - Dimensions, density and description of the cavity barriers of test series 2 (part 2)

Specimen	**FS7.1**	**FS7.2**	**FS8.1**	**FS8.2**
Cavity barrier	Plastic covered glass wool	Glass wool	Plastic covered Intumescent (ventilated cavity at room temperature)	Intumescent in rolled wire mesh* (ventilated cavity at room temperature)
Dimensions [mm]	20x60	20x100	4x73	roll: 40Ø intumescent: 4x44
Appearance				
Unpressed density [kg/m^3]	20	26	650	1310

* An additional 10mm thick stone wool strip was used to fill the 50mm cavity as the system could not cover the chosen width.

Barriers made of High Temperature Extruded (HTE) mineral wool or glass wool for closed cavities as well as self-expanding intumescent barriers for ventilated cavities were tested. The cavity barriers of all specimens except FS8.1 and FS8.2 were glued to the particle board wall using flued silicate based glue for fire insulation. These cavity barriers were attached so, that the largest dimension of the barrier's cross-section was spanning the smallest dimension of the cavity. The barriers were folded along their length into a V-shape, which was positioned vertically in the cavity. The barriers of the, at room temperature ventilated, specimens (FS8.1 and FS8.2) were stapled on the particle board. The dimensions of the enclosed cavity were 50x335x425mm and the total height of the specimens was 600mm. Four double-barrier specimens were tested simultaneously. Ten glass fibre insulated thermocouples of type K were positioned in each specimen. Appendix 2 describes the test setup and results in more detail. Appendix 1 is a paper that was presented at Interflam 2016, which discusses the same tests.

4.1.1 Fire curve

Following the introduction of this paper, the following phases of a fire are considered important:

- Phase 1: the heating phase
- Phase 2: the cooling phase
- Phase 3: the re-ignition phase

For this study, the heating phase (Phase 1) was performed in accordance with the standard fire curve defined in EN 1363-1 (see Figure 9). The pressure in the furnace was controlled and was 19 Pa +/- 4 Pa, 100 mm from the top of the furnace. Phase 1 was maintained for 1 hour. Subsequently, Phase 2 considered the cooling phase as shown in Figure 10, while the furnace remained closed. A cause of re-ignition was stimulated during Phase 3 by removing 1 wall of the furnace, which resulted in rapid cooling and an increase of air flow driven by buoyancy through the specimens. This phase was used to assess the presence of combustion within the enclosed cavity, as discussed in the next section. Phase 2 and Phase 3 lasted for two and one hours, respectively.

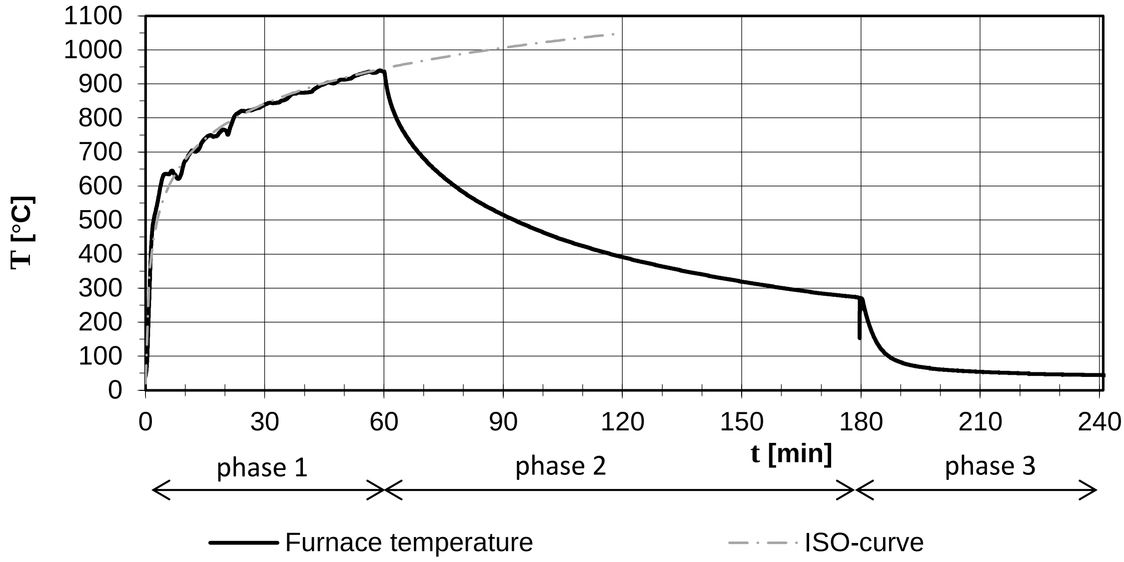


Figure 9 - Average heat exposure measured using two plate thermometers (test 1)

4.1.2 Failure criteria

As fire barriers aim to stop the fire spread, any sign of sustained combustion within the cavity barriers cannot be accepted. Wood based products generally have a combustion temperature of approximately 300°C. Therefore, a sustained temperature over 300°C cannot be accepted.

A second criterion is based on Phase 3 of the test, in which the furnace test rapidly decreases but the air velocity through the barrier increases. An increase of temperature in the cavity while increasing the oxygen content by buoyancy driven flow indicates that there is combustion in the cavity. Therefore, a temperature increase of 10°C or more is considered unacceptable.

4.1.3 Results

The temperatures measured in the centre of the enclosed cavities are shown in Figure 10. The curves corresponding to, at room temperature closed cavities, (all curves except for FS8.1 & FS8.2) showed a large variation. The temperature in specimen FS7.1 increased rapidly during the heating phase. After approximately 80 minutes visible flames started leaving the top of specimen FS7.1, after which the cavity was filled with stone wool to stop the fire. According to the two failure criteria mentioned before, the cavity barriers corresponding to specimens FS5.1, FS7.1, FS7.2, FS8.1 and FS8.2 fail the test, as the temperatures remained higher than 300°C. The barriers of specimen FS5.2 and FS6.1 fail the test as well, because they show a significant temperature increase during Phase 3. It should be noted that the specimens FS5.1 and FS6.1 are identical, but show significantly different temperatures. Whether this is caused by, (i) variations in the product, (ii) variation in the mounting or (iii) something related to the chosen test method we do not know, further investigations will show that. This indicates that more than one model scale specimen is needed to evaluate the effectiveness of a cavity barrier. According to the criteria defined, specimen FS6.2 showed acceptable behavior.

A clear correlation between performance of the cavity barriers and their size has been observed. Without exception, larger cavity barriers resulted in lower cavity temperatures throughout the entire test. The only cavity barrier that was considered successful according to the criteria had a smallest dimension that was equal to the cavity width (t, Figure 7). Additionally, in order to be able to fold the sheets of protection material into a U-shape that is compressed into the cavity, it is recommended that the largest dimension of the cross-section of the cavity barrier should be at least three times as large as its smallest dimension. Therefore, the minimum cross-section of a cavity barrier made of glass wool with a density higher than 25 kg/m^3 is recommended to be:

t x $3t$

where t is the cavity width as denoted in Figure 7

Additionally it is recommended that the compressed density of the glass wool after installation is 50 kg/m^3 or higher.

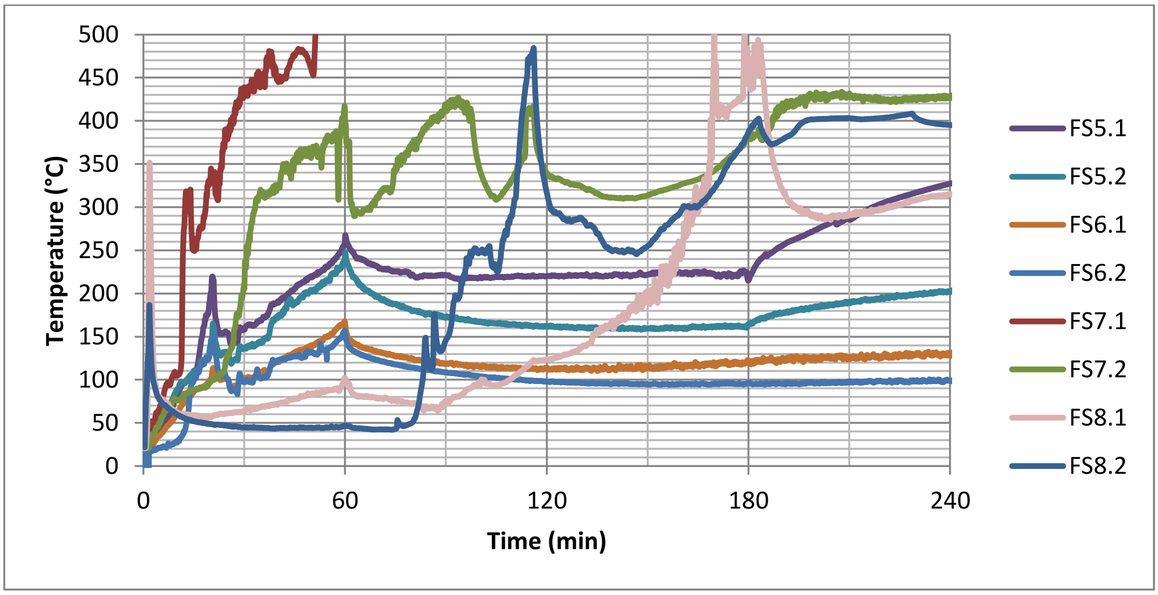


Figure 10 - Temperatures measured in the centre of the cavities

The two curves in Figure 10 that correspond to ventilated cavities (FS8.1 and FS8.2) show a peak at the very beginning of the test which is logical as this is cavity barriers that are open at room temperature. However, the temperature decreased rapidly afterwards, which indicates that the lower intumescent cavity barrier expanded. The temperature in the center of the cavity did not significantly increase for the first 80 minutes, indicating that the upper barrier was not fully activated during this period. During this period the test could, thus, be considered as a single-barrier test (see Figure 7A). Therefore, the applied method should be questioned for ventilated cavities. The increase of the temperature observed after 80 minutes could be caused by potential expansion of the upper barrier or possible degrading of the lower barrier.

As combustible material in the cavity, particle boards and plywood are commonly applied in cavities of existing buildings. Therefore, both materials were included in the test program.

4.1.4 Discussion of test method

Based on the review of real cavity fires, it was earlier concluded that a method to assess cavity barriers, should include:

- a period after a fully developed fire,
- combustible materials within the cavity
- potential heating of the air within a cavity.

These aspects were included in the test method of test series 2. The method involved a test duration of four hours. In the first hour the specimen was exposed to a standard fire. Subsequently, burners of the furnace were shut for two hours, exposing the specimens to decreasing temperatures. In the last hour the furnace was opened up, increasing the oxygen flow which allowed an assessment of combustion in the cavity.

In the next series an adjustment is made regarding the cooling phase. In order to achieve a repeatable test method, it is important the same test in other furnaces would get the same results. However, the decay phase of test series 2 is dependent on the insulation properties of the furnace, which differs per furnace. Therefore, the decay phase of test series 3 is made independent of the furnace, by removing the specimens from the furnace and continuing the measurements while the specimen is placed in ambient conditions. The ambient conditions after the fully developed phase resemble the conditions in the real fires reviewed earlier in this report.

4.2 Test series 3

In test series 2 a correlation was shown between the size of the cavity barrier and its fire performance. Test series 3 aims to indicate the influence of the following parameters:

- connection details between cavity barriers
- type of combustible material of the cavity wall
- the influence of plastic coating of the cavity barriers

In order to study these parameters it was decided to consider only one type of insulation, which is shown in Table 4. This is the cavity barrier that did not exceed the failure criteria of test series 2. More detailed information about test series 3 is given in Appendix 2.

Table 4 - Cavity barrier used in test series 3

Specimen	**FSJ 1 to 3**
Cavity barrier	glass wool with or without cover
Dimensions [mm]	50x160
Appearance	
Unpressed density [kg/m^3]	26

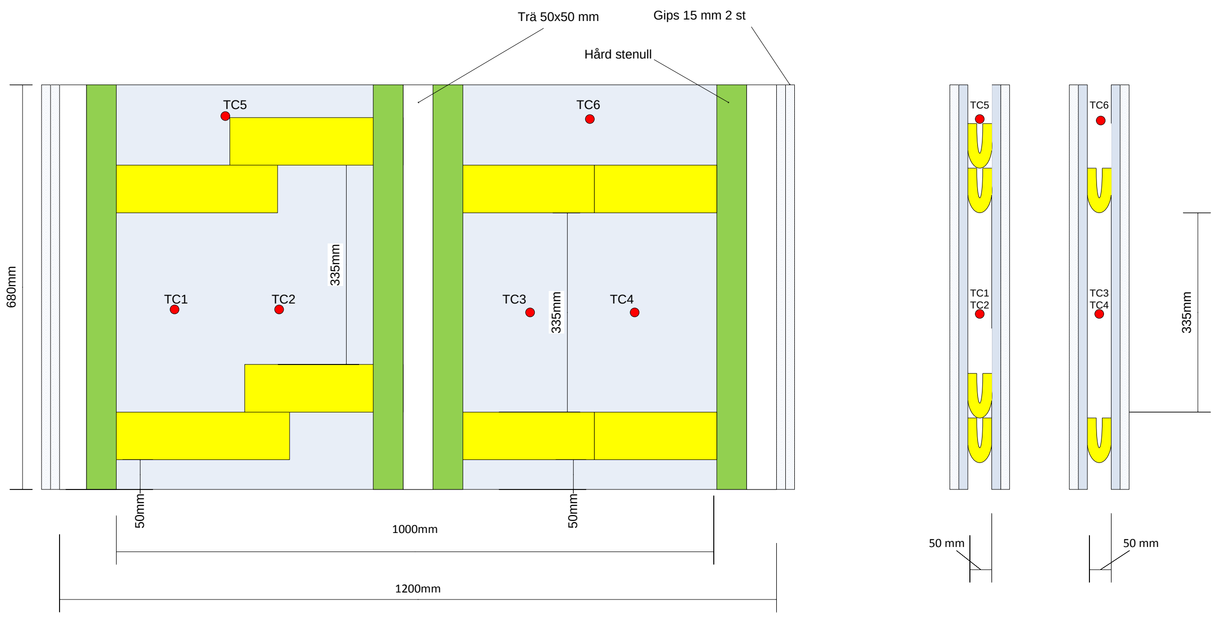


Figure 11 - Cross-sections of specimens with overlapping joints (left) and butt joints (right), exposed from the bottom

Table 5 gives an overview of the performed tests of test series 3. The performance of overlapping joints and butt joints between cavity barriers, as shown in Figure 11 was studied. Test FSJ1.1 and FSJ1.2 comprised of plastic covered cavity barriers which were positioned in a cavity with walls made of particle board. The unexposed sides of the particle board were covered by gypsum plaster boards similar to the specimens of the previous test series. Tests FSJ1.1 and FSJ1.2 functioned as reference tests for the other tests. Tests FSJ2.1 and FSJ2.2 were similar tests, without plastic covering of the cavity barriers. The difference between FSJ3.1 and FSJ3.2 compared with FSJ 1.1 and FSJ 1.2 was the combustible wall material of the cavity, as FSJ3.1 and FSJ3.2 were made using plywood with a density of 680kg/m^3 instead of particle board.

Table 5 - Matrix of performed tests in test series 3

Name of specimen	Overlapping joint	Butt joint
Plastic covered cavity barrier & particle board cavity wall material	*FSJ1.1**	*FSJ1.2**
Cavity barrier **without plastic covering** & particle board cavity wall material	*FSJ2.1*	*FSJ2.2*
Plastic covered cavity barrier & **plywood** cavity wall material	*FSJ3.1*	*FSJ3.2*

*Reference tests

4.2.1 Results and discussion

Temperatures measured in the centre of the cavities are shown in Figure 12. Test FSJ 1.2 showed the highest temperatures in the cavity after one of the cavity barriers fell into the furnace. It can be seen that FSJ2.1 and FSJ2.2 showed the best performance. These correspond to tests of cavity barriers without plastic. Observations of the test specimens after the tests, indicated that there was a significant air flow across the cavity barriers (Figure 13). Air channels are indicated by dark lines in the wooden surface at the position of the barriers. In contrast, the specimens of FSJ 2.1 and FSJ 2.2 (Figure 14), which correspond to cavity barriers without plastic, did not show these lines. The temperatures measured in the cavity were also significantly lower during the test. This indicates that cavity barriers without plastic covering are more suitable to limit the air flow into the cavity.

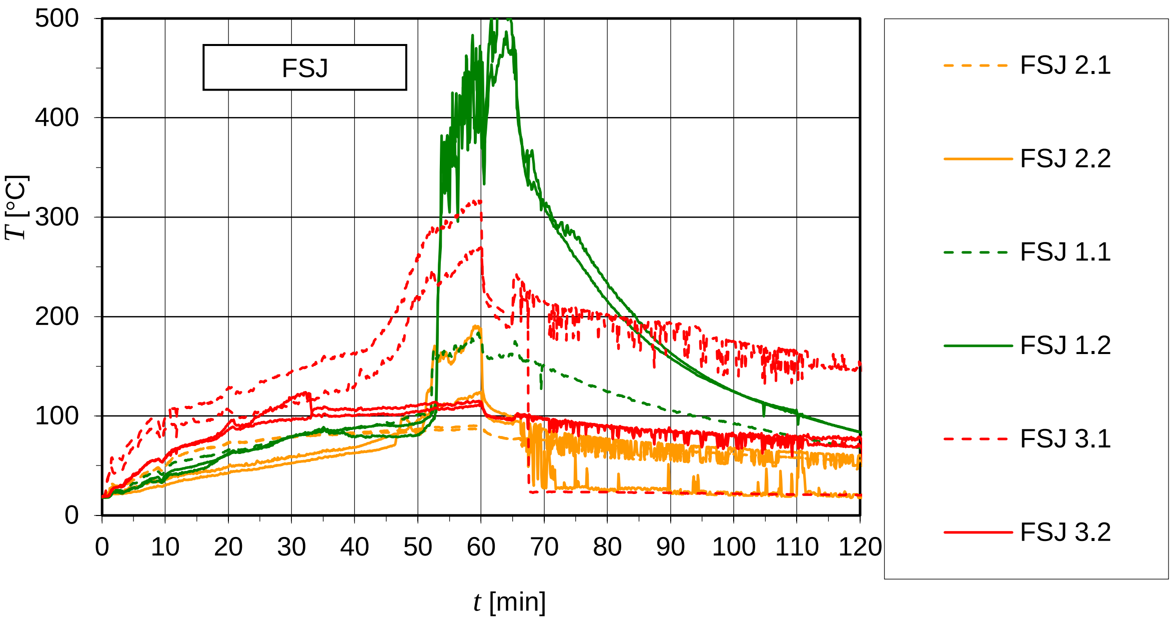
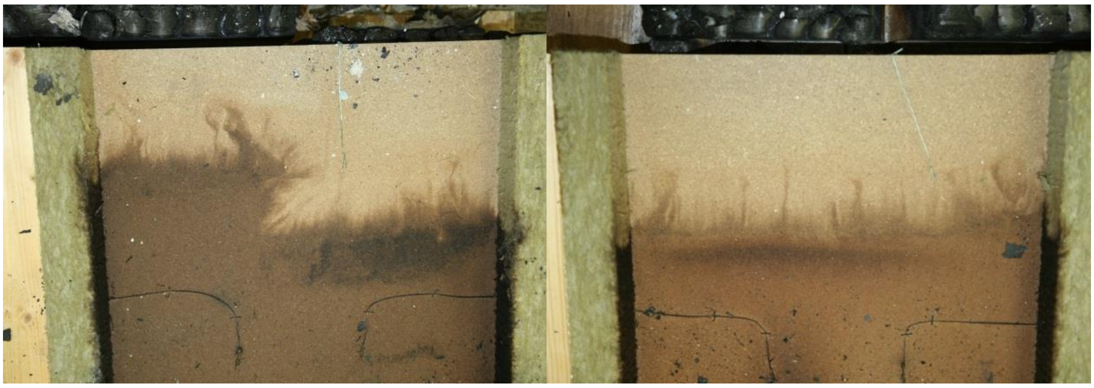


Figure 12 - Temperature measured in the center of the cavities

(a) (b)

Figure 13 - Cavity walls of FSJ1.1 (a) and FSJ1.2 (b) after the test



(a) (b)

Figure 14 - Cavity walls of FSJ2.1 (a) and FSJ2.2 (b) after the test

Figure 15 shows the specimen of FSJ2. The arrows indicate the direction of most significant air flow in the joints. Both cavities did not have to be extinguished after the fire test.

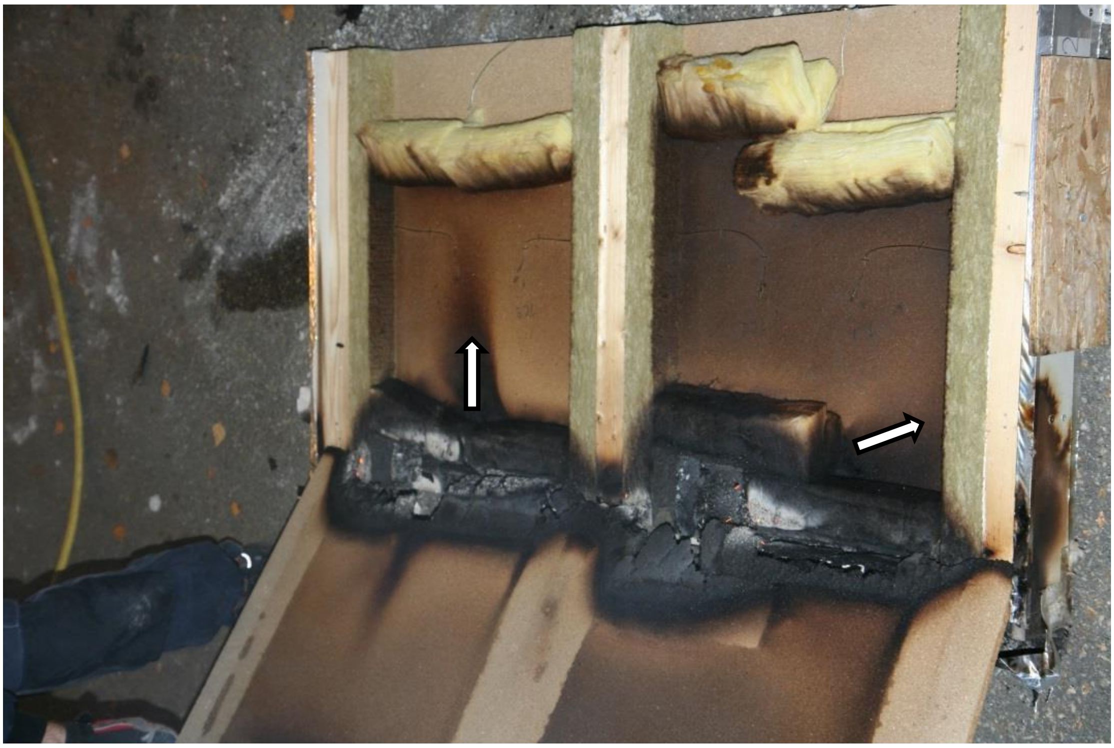


Figure 15 - Inside of the cavities FSJ2.1 (right) and FSJ2.2 (left) after the test

The second highest temperatures were measured in FSJ3.1. Observation of the specimen after the test (Figure 16 a) showed that the overlap joint was not entirely tight as the cavity barriers were inclined with different angles. This created an undesirable air channel. The test specimen of FSJ3.2 did not show an air channel at the location of the joint. During the installation it was considered easier to make the butt-joint tight.

(a) (b)

Figure 16 - Cavity walls of FSJ3.1 (a) and FSJ3.2 (b) after the test

5 Preliminary study of extinguishing methods

After the test of series 3 there was still combustion in the cavities of specimen FSJ1 and FSJ3. For the extinguishments a hole was drilled through the cavity wall and CO2 and/or powder extinguishers were used (see Figure 17). The consumed weight of the substance used for extinguishments is reported in Table 6.

Figure 17 - Extinguishing of specimen FSJ1.

Table 6 - Consumed weight of substance for extinguishment

Specimen	Extinguishment with	
	CO2	Powder
FSJ1 (left)	62 g	
FSJ1 (right)	96 g	
FSJ3 (right)		1324 g
FSJ3 (left)	157 g	724 g

Extinguishment using powder was only successful if a large amount of powder was used. Only one cavity was successfully extinguished using powder. This cavity required an equivalent of 9.5 kg/m^2. Extinguishment using CO_2 required 440 to 1100 g/m^2. However, the amounts used were close to the minimum amount of CO_2 that could be injected with one shot of the extinguisher. Therefore, it is possible that extinguishment required less CO_2 than used.

6 Conclusions

This report presents alternative tests to assess the ability of different cavity barriers to prevent fire spread in cavities with combustible walls. The specimens of these tests comprise of an enclosed cavity in which the temperatures can rise significantly during the test. This test involves a heating phase following the EN1363 standard fire curve for one hour. Subsequently, a cooling phase was considered to assess the development of the temperatures in the cavities after the fully developed phase. During the cooling phase, the availability of oxygen was increased by opening the furnace to assess the presence of combustion in the cavities.

Based on an analysis of cavity fires in timber constructions, it is considered important to assess presence of combustion beyond fire barriers in enclosed cavities with combustible walls during the decay phase of a fire. It is concluded that this can be done by closing the unexposed side of the cavity to illustrate the influence from heat accumulation in the cavity.

Regarding non-ventilated cavity barriers the following was concluded:

- The use of compressible (soft) insulation material which is installed firmly in the cavity, will limit the air flow. The tests showed that cavity barriers with a minimum compressed density of 50 kg/m^3 for glass wool can successfully prevent a cavity fire, under 1 hour of standard fire exposure and an additional decay phase. However, more tests are needed to confirm whether this rule is generally applicable for different insulation materials.
- Gluing specimens to the cavity walls successfully prevented falling of the cavity barriers
- Cavity barriers that are not glued should be kept in place, by for example gluing or, by robust designing.
- More air and smoke travels past cavity barriers with plastic covering, as the wrinkles in the plastic material formed channels for the air to flow through.
- Dripping of plastic materials of the cavity barriers was observed, which is theoretically not allowed.
- Air channels through connections of cavity barriers can be significant and should be avoided
- A overlapping joint between two parallel cavity barriers can potentially involve undesired air channels, which stimulate the temperature development in the cavity.
- The experiments showed that there is a correlation between the size of cavity barriers and the maximum temperatures within enclosed cavities.

7 Resulting Guidelines

Based on indications of this study, guidelines and recommendations are provided for the use of non-ventilated cavity barriers in cavities with combustible surface materials. These include recommendations for materials, design and installations. Additionally, advice for extinguishing of closed cavities is given. The aim of these guidelines is to increase the fire safety of buildings with cavities with combustible surface materials.

The recommendations given in this chapter could be used in case there is a fire resistance requirement up to 60 minutes, as they are based on tests with at least a standard fire exposure of 60 minutes.

7.1 Materials

Cavity barriers should preferably be non-combustible and made of a soft compressible low density insulation material. After installation a compressed density of 50 kg/m^3 is recommended for mineral wools, such as glass wool, stone wool and high temperature extruded mineral wool.

The materials should have no plastic covering as can cause small air channels, which increase the amount of hot air flowing into the cavity. Furthermore, it may melt and form drops.

7.2 Dimensions

There are several methods of installation recommended for cavity barriers. As shown in Figure 18 potential placement of the cavity barriers could be single double or U-shaped. In case mineral wools are used as cavity barriers, the minimum dimension is recommended to be chosen, so that its compressed density after installation is 50kg/m^3 or higher. Additionally, its height after installation, h, should be at least equal or larger than the maximum of 75mm and 1.5t, where t is the cavity width. For a U-shape placement of the cavity barrier the cross-section should be at least t x 3t. Additionally, the minimum density of the uncompressed material should be 25 kg/m^3.

In case wood is used as a cavity barrier, the minimum height for of a cavity barrier should be calculated using a one-dimensional charring rate in accordance with EN1995-1-2:2004. The remaining uncharred height should be 25mm after the required insulation time (for example 60 minutes). It should also be ensured that the fasteners maintain their function for the required insulation time in a standard fire. The wooden cavity barrier should be placed tight against both opposing surfaces of the cavity and air channels across or along the wood should be avoided.

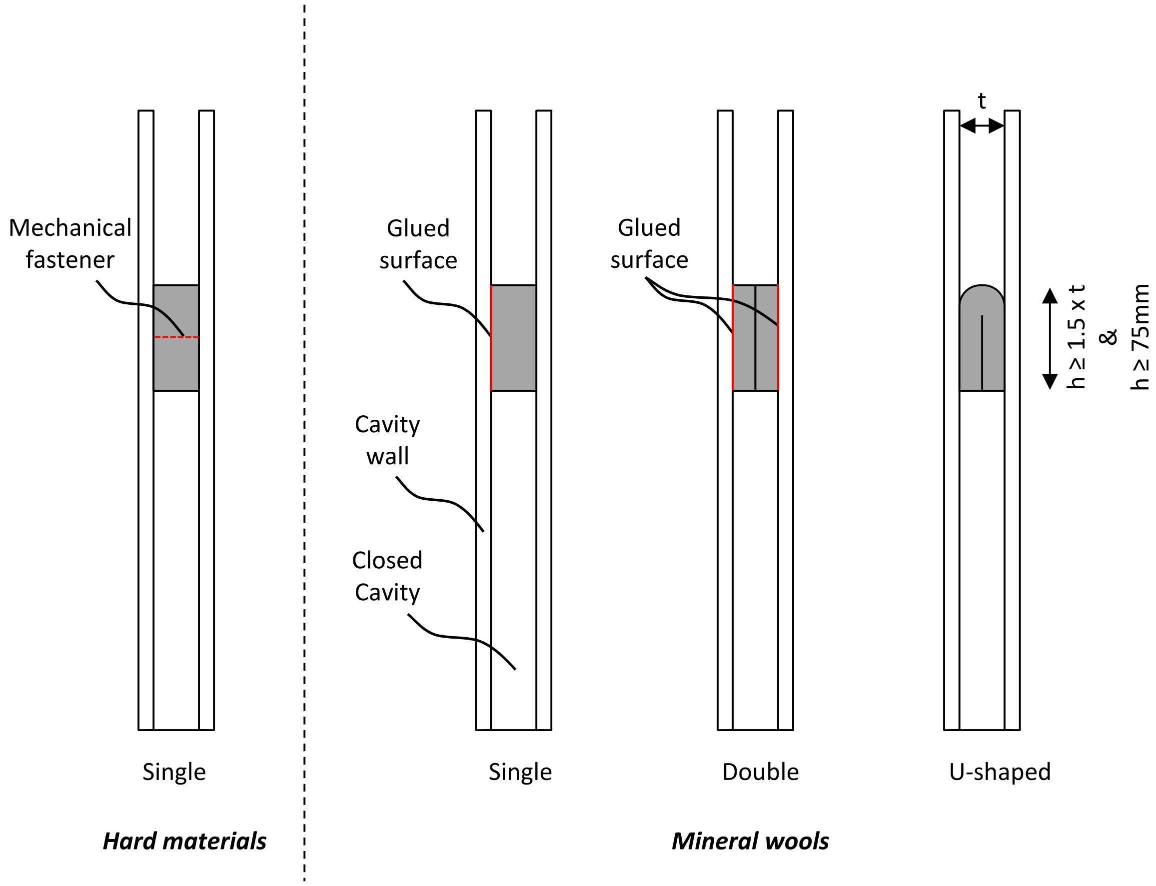


Figure 18 – Cross-sections of single double and U-shaped cavity barriers

7.3 Design

The design of cavity barriers should aim to (1) avoid falling of the cavity and (2) avoid air channels across and along the cavity barriers. Falling of the specimens can be avoided by appropriate fixation methods and, if possible, by robust design. Using robust design, falling of the barrier can be avoided, even if the primary fixation method (using glue, fasteners or by clamping) fails. An example of a robust solution that prevents falling of highly exposed cavity barriers is shown in *Figure 19*.

Example of robust design of cavity barriers around a wall opening

A fire leaving a compartment through an opening will expose the upper side of the opening significantly more severely, than the lower side of the opening. Therefore, there is an increased risk that the cavity barrier above the opening falls, which would allow the fire to easily access the cavity. By letting highly exposed, horizontally positioned, cavity barriers within walls rest on the vertically positioned elements (Figure 19), the risk of falling becomes small.

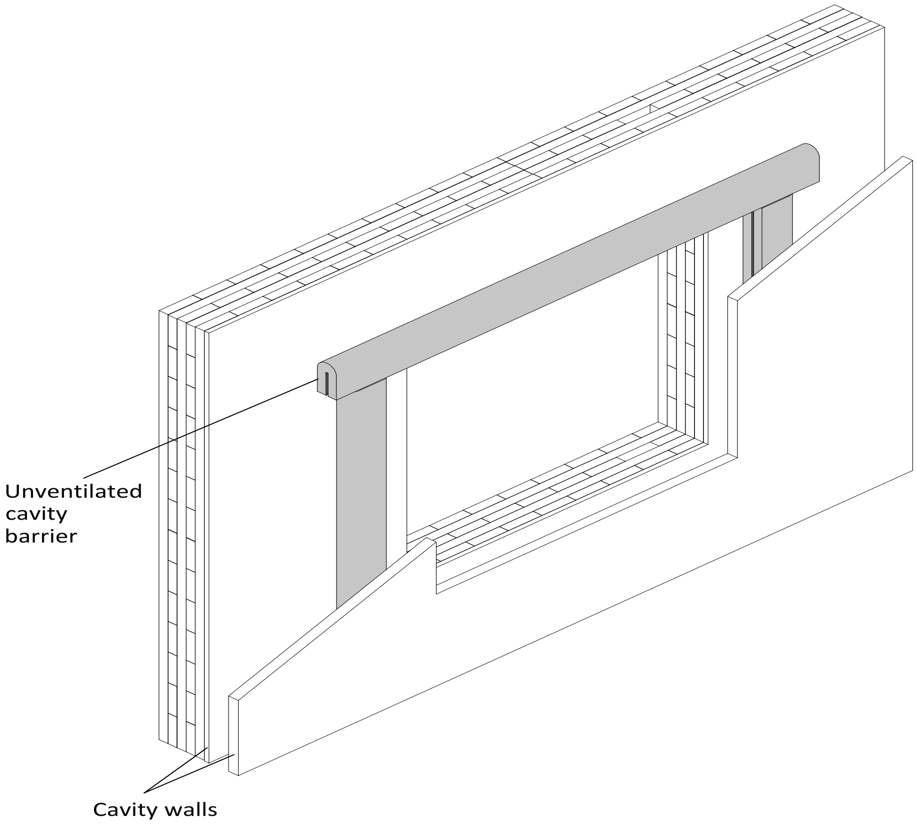


Figure 19 **-** *Prevention from falling of cavity barrier by robust design*

Undesired air channels can be avoided by design. Such undesired air channels could occur in corners and bends of the cavity barrier material, as shown in Figure 20. Solutions can be obtained by designing separate cavity barriers which are connected, instead of using bended cavity barrier in corners.

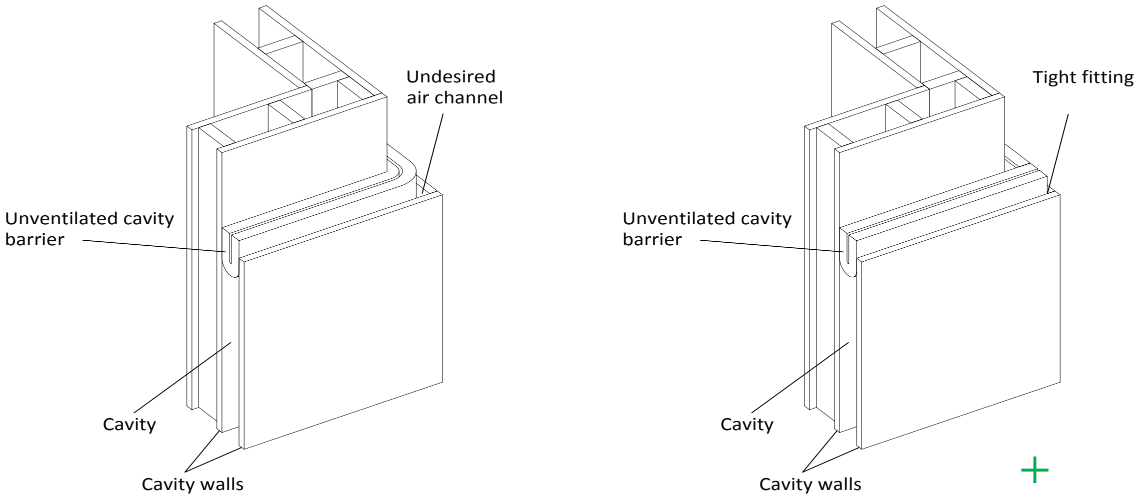


Figure 20 - Possible risk for undesired air channel in the outer corner

7.4 Installation

Third party control is recommended for the installation of cavity barriers in cavities with combustible materials.

A schematic drawing concerning the installation of single, double or U-shaped placed cavity barriers is shown in Figure 21. The single and double placement of cavity barriers is especially applicable for cavities between modules of modular buildings. In this case the cavity barriers should be fixed to the cavity wall before the cavity is closed. Gluing of the cavity with high temperature resistant adhesives is recommended. For cavity barriers with a double placement, misalignment is allowed as long as the height of the contact area between the cavity barriers is equal or higher than the maximum of 75mm and 1.5 x t (see Figure 22).

The U-shape placement should be done using an installation board, as shown in Figure 21 and Figure 23. The intended position should be ensured using this installation board, which is especially relevant at the locations of joints. The resistance of the board should be used to indicate whether the cavity barrier is installed firmly.

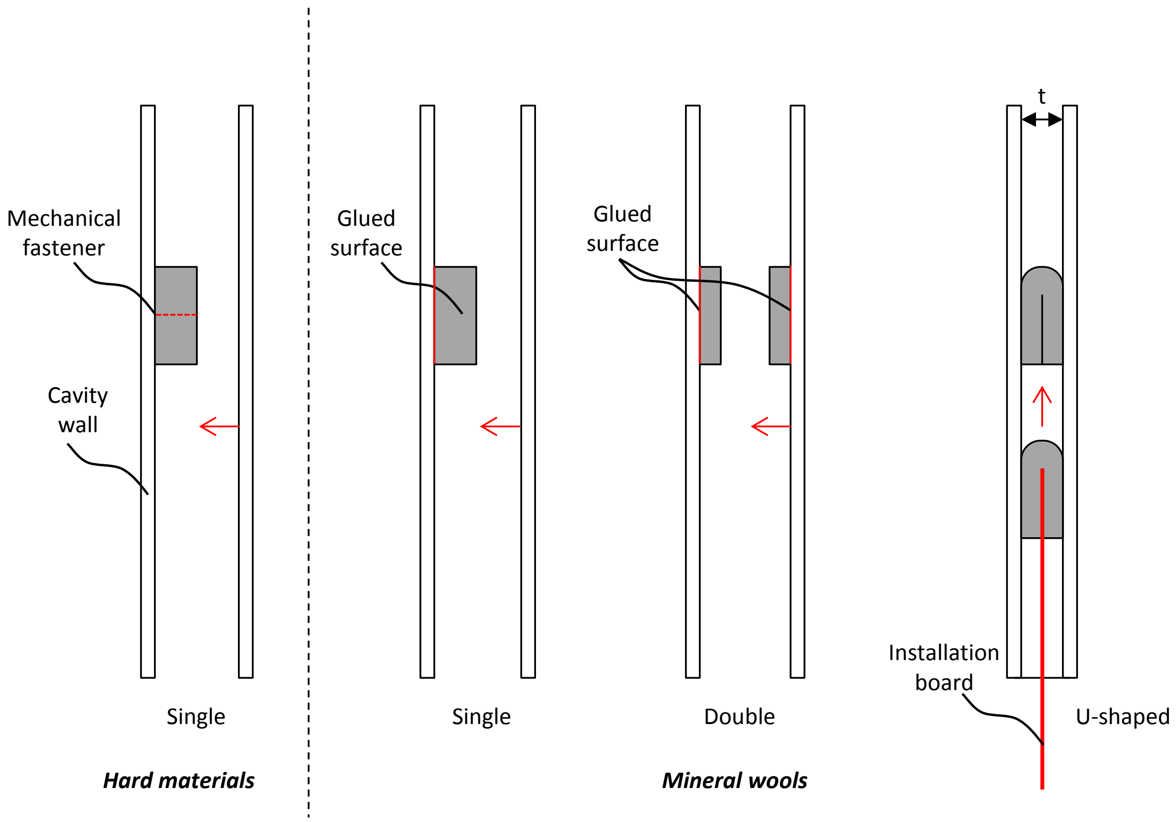


Figure 21 – Schematic drawing of installation

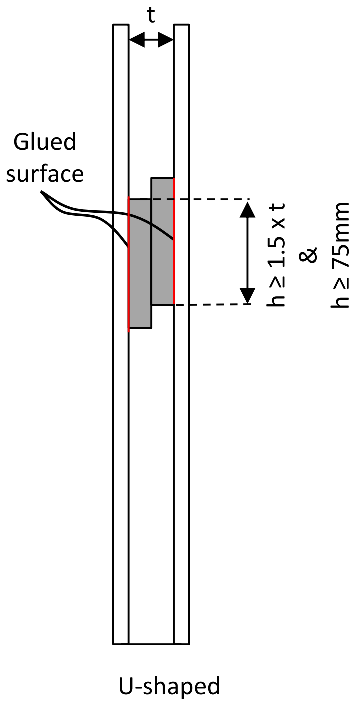


Figure 22 – Allowable geometrical misalignment

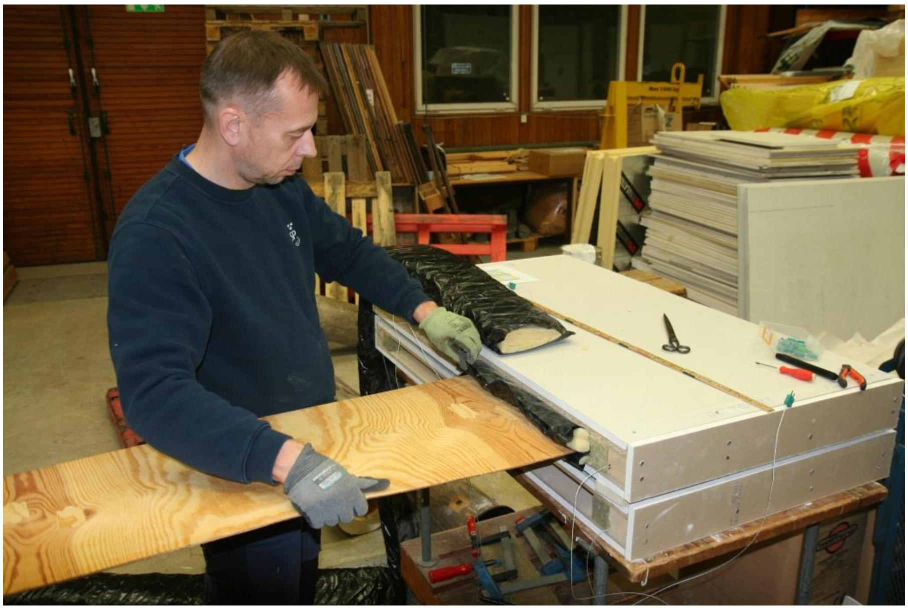


Figure 23 - Sliding cavity barrier into the cavity for a U-shaped placement

Joints between cavity barriers should be made, so that air channels in the joint are avoided. Using cavity barriers with a U-shaped placement could lead to undesired air channels in joints, as shown in Figure 24. Therefore, in-line and butt-joints are recommended for cavity barriers with a U-shaped placement. However, an overlapped joint, as shown on the left hand side of Figure 24, can be applied if (1) the length of the overlap is at least equal the height, h, of the cavity barrier and (2) the cavity is made of mineral wool without plastic covering. It must be ensured that both cavity barriers in one joint are place tightly against each other.

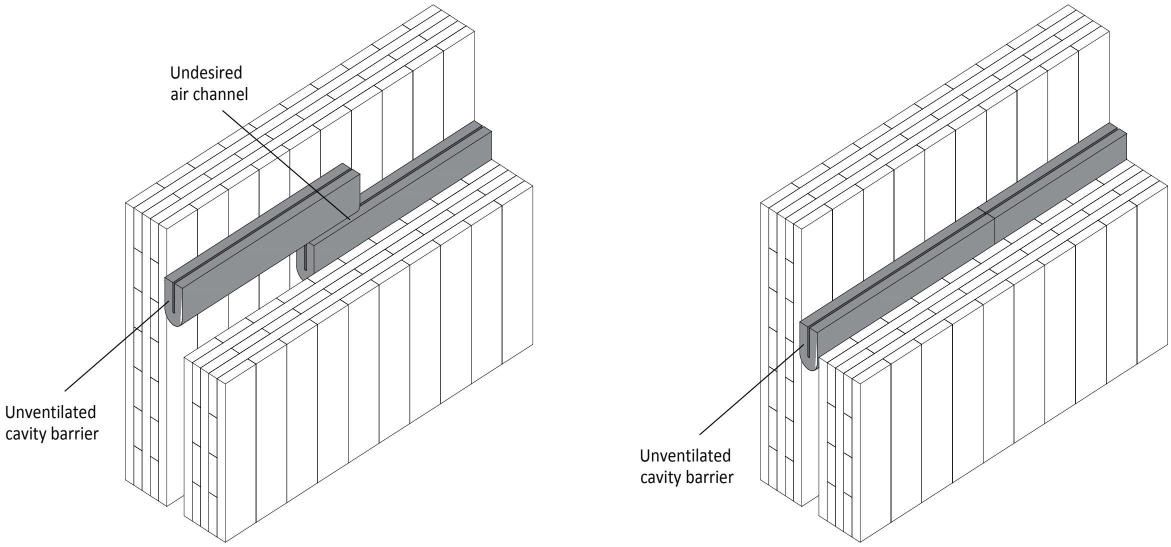


Figure 24 - Possible risk for undesired air channel with overlapped joint

7.5 Extinguishing

For locating cavity fires, the use of a thermal camera is recommended. If a fire is located, a hole could be made through the wall at the located cavity fire. The location of the hole should be traceable, also in the event of excessive smoke. The cavity fire could potentially be extinguished using water vapour or CO_2. *note: The use of CO_2 was shown to be effective for small scale cavity fires. However, no large scale tests have been performed to confirm this works for larger scale.*

8 Future and ongoing work

Future studies should further address methods for locating and extinguishing cavity fires

Acknowledgements

The authors acknowledge Robert Jansson McNamee and Petra Andersson for their valuable input.

The work reported here is supported by Brandforsk under contract BF 14-004.

References

Lennon T (2013) "Fires in cavities in residential buildings - The performance of cavity barriers in external walls with combustible materials" BRE Report NF 51, Watford, UK.

Umeå kommun Brandförsvar och Säkerhet (2013) Fördjupad olycksundersökning - Brand i flerbostadshus i Luleå Klintvägen, Umeå, Sweden.

Umeå kommun Brandförsvar och Säkerhet (2009) Fördjupad olycksundersökning Brand i byggnad Geografigränd 2 A-J i Umeå, Umeå, Sweden.

Östman, B., Stehn, L. (2014), Brand i flerbostadshus – Analys, rekommendationer och FoU-behov, SP Report 2014:07, Stockholm Sweden.

Lennon T., Bullock M.J., Enjily V. (2000) The fire resistance of medium-rise timber frame buildings. BRE Report No 79485-1, BRE, Watford, UK.

Pearson, A and Lane T (2002), Fire Alarm. Building.co.uk 2002:28.

EN 1364-6 (2016) Fire resistance tests for non-loadbearing elements – Part 6: Cavity Barriers.

EN 1363-1 (2012) Fire resistance tests – Elements of building construction – Part 1: General requirements.

Appendix 1: Interflam paper

Appendix 2: Test reports

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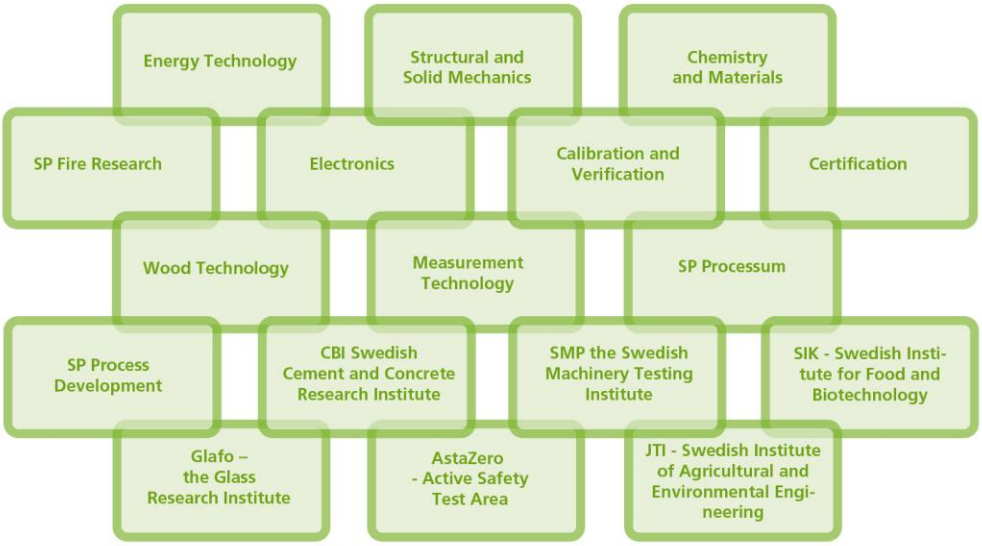

SP Technical Research Institute of Sweden

Box 857, SE-501 15 BORÅS, SWEDEN

Telephone: +46 10 516 50 00, Telefax: +46 33 13 55 02

E-mail: info@sp.se, Internet: www.sp.se

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SP Wood Technology

SP Report 2014:XX

ISBN 978-91-88001-12-2

ISSN 0284-5172

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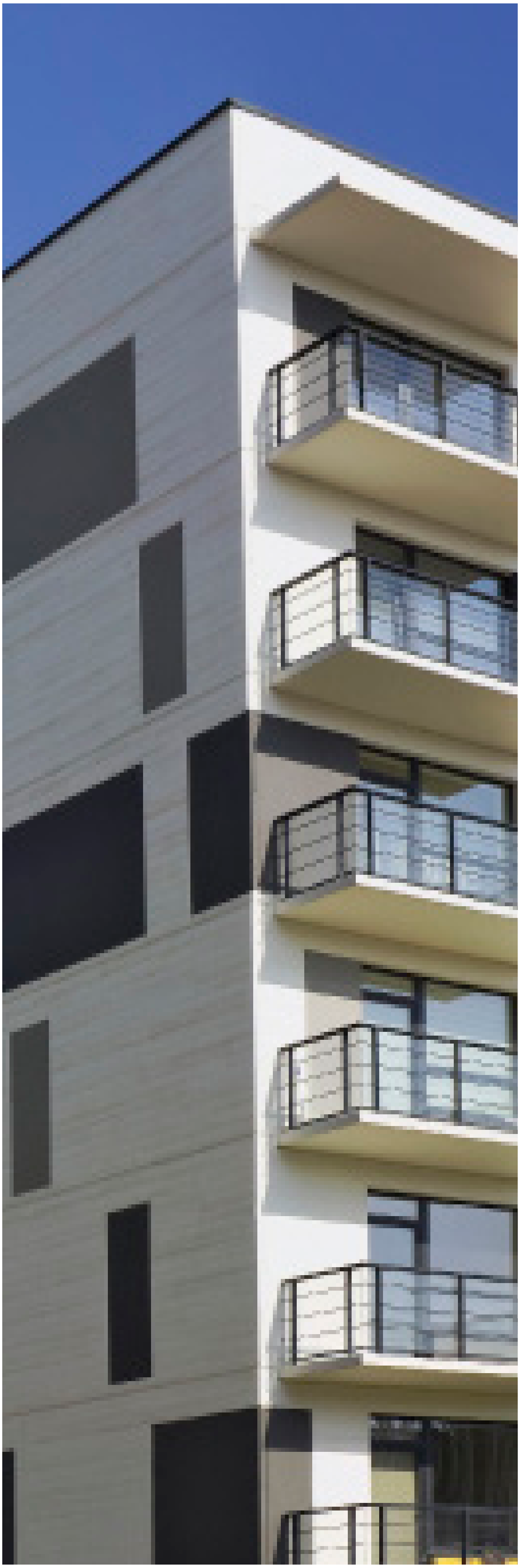

SP Sveriges Tekniska Forskningsinstitut
P.O. Box 857
SE-501 15 Borås, Sweden
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Årstaängsvägen 21 c
Box 472 44, 100 74 Stockholm
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