FIRE RESEARCH & INNOVATION CENTRE

Technical Report

Upgrading heritage escape route doors – Mounting of glass, protective boards and sealing lists

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Contents

1 Preface

This document has been prepared within *Task 3 Escape route doors* of *Project 4.3 Fire safety measures for dwellings* within FRIC - Fire Research and Innovation Centre. It is a continuation of the first part of the project, which resulted in the report *Fire performance of escape route doors in cultural heritage buildings A state-of-the-art review [9]*. Older wooden escape route doors are often a week point in the fire safety in apartment buildings, and this project seeks to find solutions for upgrading such doors.

SINTEF and NIKU – Norsk institutt for kulturminneforskning has had a close collaboration in this project. We would like to thank the following FRIC-partners for contributing to discussions and input in several project meetings during the autumn of 2020:

- Morten Pedersen, Trøndelag fylkeskommune
- Robert Olofsson, RISE Fire Research
- Christian Widén-Björk, Trøndelag Brann- og Redningstjeneste IKS
- Torgeir Brurok, Trøndelag Brann- og Redningstjeneste IKS
- Brynhild Garberg Olsø, SINTEF

The solutions given in this report are preliminary solutions and will later be used as basis for small-scale and full-scale testing. The results from the fire testing will be given in a report describing finally necessary upgrading solutions in detail.

Trondheim/Oslo, 06.01.2021

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2 Background and premises

This report presents possible solutions for mounting of glass, protective boards and sealing lists when upgrading older wooden escape route doors with a cultural heritage value. The report deals with intervention on the door itself in cases where this is necessary.

Hardware such as door closer, door fittings, hinges and handles are not considered in this report.

Recommended solutions subjected for small-scale and full-scale testing are described in chapter 7 Conclusion.

These types of doors normally have a thickness of 45-50 mm, with glass on the upper part, and a thinner wooden door-panel on the lower part. For antiquary reasons the interventions on the doors should be as little intrusive and as reversable as possible [10]. It is desired to retain the old glass, but if this is not possible due to lack of space it may be removed. Aperture and mouldings should be modified as little as possible. If mouldings must be loosened from their original position they should be kept and preferably reused on the door leaf.

When securing an escape route, the building must be seen as a whole, and compensatory solutions must be considered. See SINTEF Byggforsk 720.315 *Fire technical upgrading of brick apartment buildings from the period of 1870-1940*.

3 Mounting of glass

3.1 Technical solutions for mounting of glass

3.1.1 Existing solutions for old wooden doors

Typical ways of mounting glass in old wooden doors are shown in Figure 3.1.1:

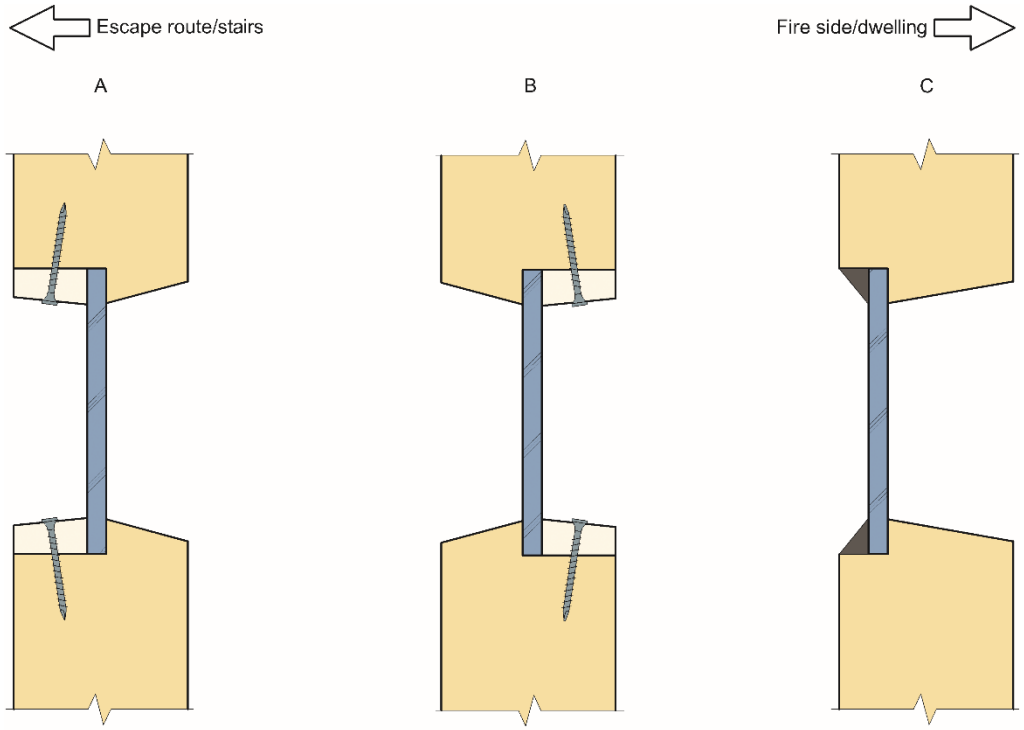

Figure 3.1.1 Typical ways of mounting glass in existing solutions. The figure is based on a sketch by Morten Pedersen

- Alternative A: Glass mounted in the aperture (NO: fals) on the stairway side of the door, fastened with wooden battens
- Alternative B: Glass mounted in the aperture on the apartment side of the door, fastened with wooden battens
- Alternative C: Glass mounted in the aperture on the stairway side of the door, fastened with glazing putty (NO: kitt)

3.1.2 Findings from SINTEF Technical Approval

SINTEF Technical Approval has been reviewed for two anonymous manufacturers. Test reports forming the basis for the approvals showed detailed drawings of how the glass was mounted to the doors' window frame. Based on this, Figure 3.1.2 shows a suggestion for how fire rated glass can be mounted as a replacement of original glass or, if possible, as a supplement on the inside of the original glass:

- If possible, the existing aperture in the door window frame should be used. If there is too little space, a deeper aperture must be milled out. The aperture should be at least 20 mm in height to ensure that the fire rated glass is held in place on the non-fire exposed side of the door. The thickness of the wood on the non-fire exposed side is not critical since it will not be exposed to fire.

- A glazing gasket in silicone (NO: gummipakning) is placed close to the aperture, on all four sides
- 15x1 mm expanding tape is mounted on all four sides
- The fire rated glass is placed on the tape, and pushed against the glazing gasket
- 15x15 mm steel angles or steel clips are placed on the fire exposed side of the glass, to hold it tight. The steel angles and clips are fixed using steel screws. The steel angles or steel clips are placed approx. 100 mm from each corner, then max 300 mm from one another. The screws must be fastened tilted inwards.
  For aesthetic matters, the steel angles or steel clips may be covered with wooden battens. The battens will not have a function when it comes to fire resistance.

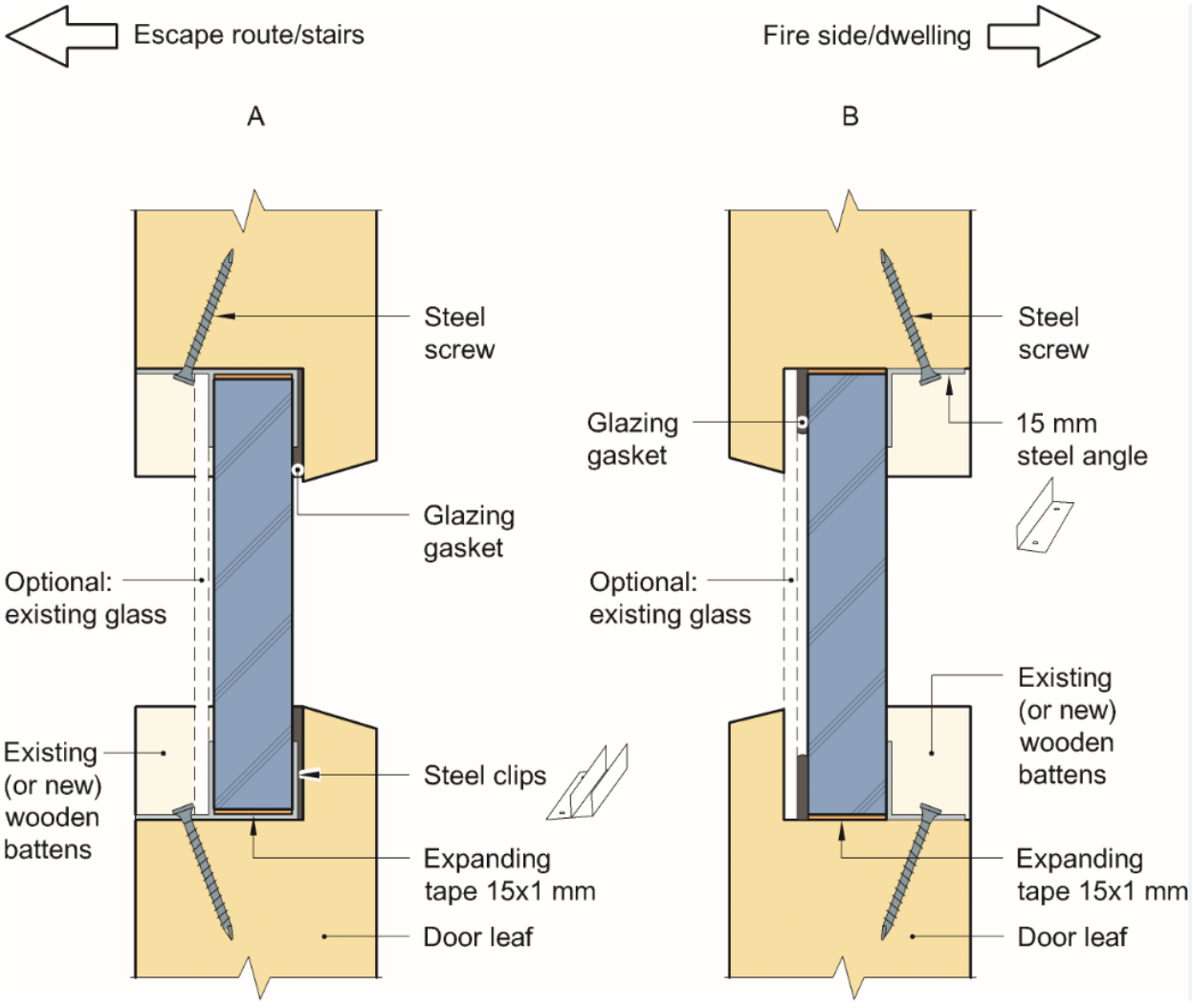

Figure 3.1.2 Possible ways of mounting fire rated glass. Figure A is based on a sketch by Morten Pedersen and figure B by Anne-Marit Haukø

- Alternative A: Fire rated glass mounted in the aperture on the stairway side of the door, fastened with wooden battens (new or existing) and steel clips. When the wood on the fire side of the door has burned away, the steel clip will still hold the glass in place.
- Alternative B: Fire rated glass mounted in the aperture on the apartment side of the door, fastened with wooden battens and steel angles (same solution as in Figure 3.1.2)
- In doors where the existing glass is fastened with glazing putty, both alternative A and B can be used.

If there is not enough space available inside the door window frame for the 15x15 mm steel angles, it is a possible solution to mount the fire rated glass flush with the inside of the door. Figure 3.1.3 shows the solution. The glass must be held in place with a 30 mm steel frame. This solution is not from SINTEF Technical Approval, it has been developed during discussions in project meetings. The size of the steel frame supporting the glass will be equal to 15x15 mm steel angles.

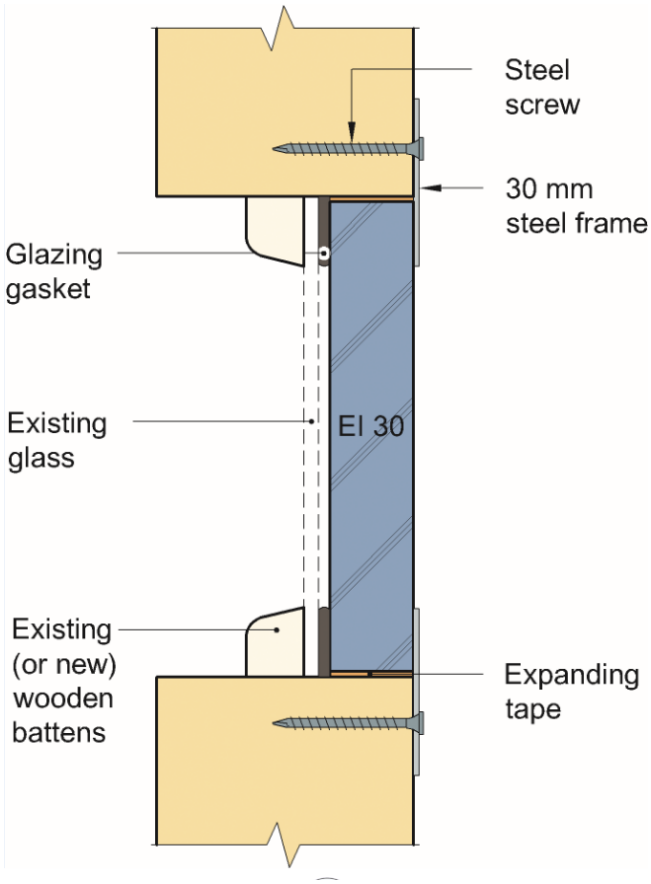

Figure 3.1.3 Mounting of fire rated glass inside aperture with steel frame. The figure is based on a sketch by Anne-Marit Haukø

If there are several small glass-frames in the door, and there is not enough space available inside the door window frame, it is a possible solution to mount the fire rated glass on the outside and letting a gypsum board take the weight of the glass. Figure 3.1.4 shows the solution. The glass must be held in place with

a 30 mm steel frame. This solution is not from SINTEF Technical Approval, it has been developed during discussions in project meetings.

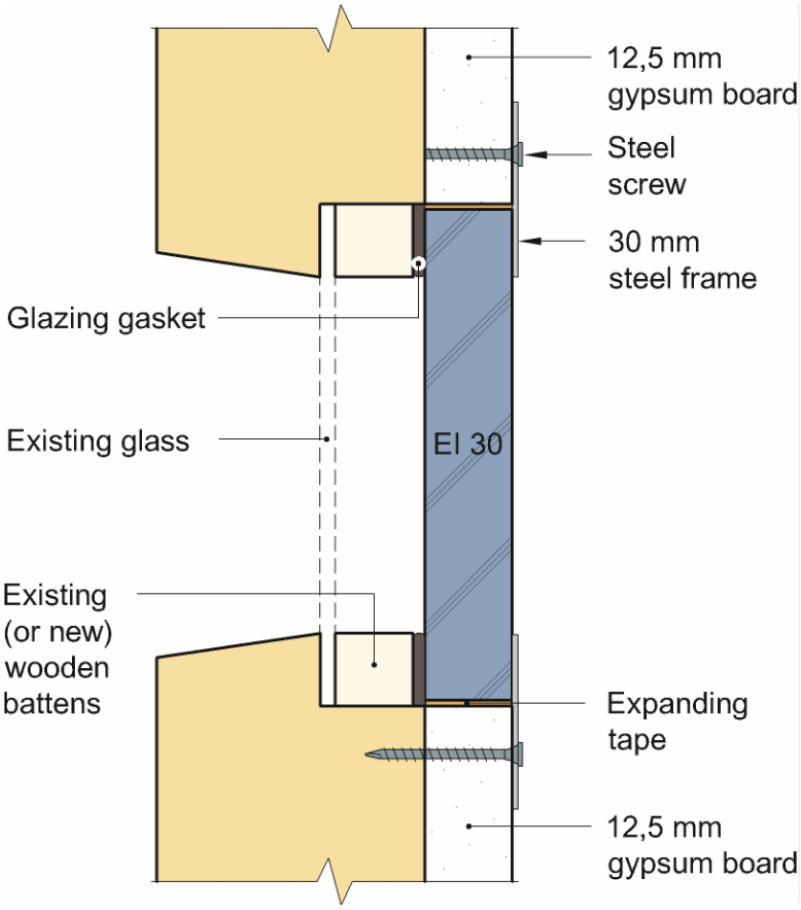

Figure 3.1.4 Mounting of fire rated glass outside aperture with steel frame. The figure is based on a sketch by Anne-Marit Haukø

3.1.3 Findings from SINTEF Byggforskserien

SINTEF Byggforsk *571.957 Windows and glass walls with fire resistance* [6] has been reviewed, and gives the following information:

The glass is placed on load-bearing blocks and possibly support blocks in hardwood, for example oak or pine (density approx. 500 kg/m^3), against the frame. Fire sealing between the glass and the frame is done with an expanding fire gasket, also called ceramic tape. The fire gasket expands and seals the transition during heat stress.

The solution is shown in Figure 3.1.5.

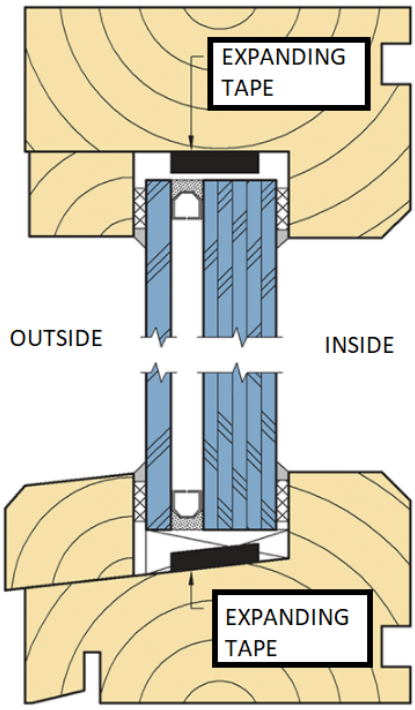

Figure 3.1.5 Fire rated window from Byggforsk 571.957 [6]

Some people want more privacy when the glass in the door goes from colored/uneven to clear. For privacy a half opaque film may be mounted on the inside of the glass. The film may however restrain the development of the fire isolating layer during fire, and this must be clarified with the manufacturer. Type of film and mounting should be chosen and done in collaboration with the manufacturer.

3.1.4 Findings from English heritage guideline

Gives no information on glass mounting.

3.1.5 Findings from supplier

AGC is a supplier of fire rated glass with product name Pyrobel, which comes in different classes for fire resistance. Figure 3.1.6 shows Pyrobel 16 with fire resistance EI 30 mounted in a wooden frame (https://www.agc-pyrobel.com/system/files/2019-10/TF.pdf.).

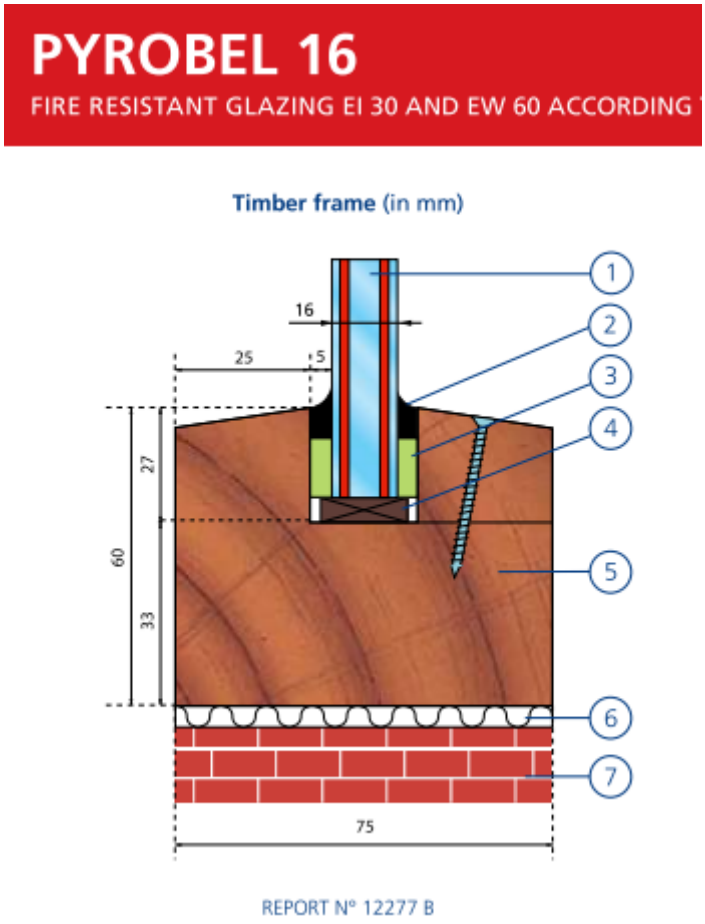

Figure 3.1.6 Fire rated window from AGC

The following parts are included:

1. Pyrobel 16 fire rated glass EI 30
2. Neutral sealant
3. Ceramic fibre paper: Superwool X607 20x5 mm
4. Setting block
   1-4 is held in place by a 25x27 mm wooden frame
5. Hardwood partition
6. Ceramic or mineral wool
7. Partition

3.2 Assessment of reaction to fire classification for glass panes

Requirements for glass panes in doors in escape routes in dwellings is EI 30, according to the guideline to TEK17.

The starting point for this project is that stairwell doors in older apartment buildings often have poor fire resistance, and the glass will usually be the weakest point. The goal must therefore be to upgrade the doors to be significantly better. Fire resistance EI 30 as tested in a fire laboratory and classified according to EN 13501-2 is not possible to achieve, but we must strive to get as close to fire resistance EI 30 as possible.

Time is a critical factor during fire and escape. Provided that fire is detected by a fire alarm system, it will be possible to start evacuation early. It is likely that the building will be evacuated after 15 minutes. But it must also be taken into consideration that failure in the fire alarm system can occur, and that evacuation may take longer. This type of doors is normally found in apartment buildings in larger cities or densely populated areas. After 15 minutes, it is therefore likely that the fire brigade will be in place.

During the early stages of the fire, smoke in the escape route will be the biggest problem. Later, heat radiation, and eventually flames, will also be a challenge.

[5] gives that people should not be exposed for more than 10 kW/m^2 for max 4 seconds during escape.

Table 1 shows radiative heat flux and effects on different parameters. When exposed to a heat flux of 16 kW/m^2, human skin will feel sudden pain and develop second-degree burn blisters after 5 seconds. [7]

Table 1 Radiative heat flux and effects [7]

kW/m^2	Effect
170	Maximum flux measured in a post-flashover compartment
80	Thermal Protective Performance test for personal protective equipment
52	Fiberboard ignites at 5 seconds
29	Wood ignites, given time
20	Typical beginning of flashover at floor level of a residential room
16	Human skin: sudden pain and second-degree burn blisters after 5 seconds
12.5	Wood produces ignitable volatiles by pyrolysis
10.4	Human skin: Pain after 3 seconds, second-degree burn blisters after 9 seconds
6.4	Human skin: second-degree burn blisters after 18 seconds
4.5	Human skin: second-degree burn blisters after 30 seconds
2.5	Human skin: burns after prolonged exposure, radiant flux exposure typically encountered during firefighting
1.4	Sunlight, sunburns potentially within 30 minutes. Sunburn is NOT a thermal burn. It is caused by cellular damage due to ultraviolet radiation.

Possible fire ratings of glass:

- EI 15 / EI 30
Laminated multilayer glass which in principle stops all heat radiation from a fire. In the event of a fire, the layer expands between the glasses and builds an opaque barrier. [1] The mean temperature and the surface temperature of the glass must satisfy the maximum requirements given in EN 13501-3 [6].

- EW 30
Laminated fire glass, which partly limits the heat radiation in the event of a fire. Allows a heat radiation of 15 kW/m^2, measured at a distance of one meter from the fire glass on the side that is not exposed to fire. [1] [6]

- E 30
Tempered glass, replacing wire glass that was widely used in the past. The purpose is to stop flames and smoke spread [1].

3.3 Discussion on mounting and type of glass

After reviewing SINTEF Technical Approval, SINTEF Byggforsk, the English heritage guideline and supplier AGC, the findings from SINTEF Technical Approval is the most suitable solution for this project because it is the most detailed. It is critical that the fire rated glass is held in place from both sides, and Figure 3.1.2 - 3.1.4 shows solutions that will hopefully be successful in small-scale and large-scale fire tests. Since the outer wooden layer will char, the screws fastening the steel angles must be tilted inwards, angle appr. 45 degrees. The size of the screws must be adapted to the width of the door leaf.

The solution requires space for the glazing gasket, glass pane and steel angles. The space available inside the door window frame will differ from door to door. If there is lack of space, it is an alternative solution to use a steel frame around the glass on the fire side of the door, as shown in Figure 3.1.3 – 3.1.4.

A heat radiation of 15 kW/m^2 from EW rated glass is high and can cause skin burn after short time, as shown in Table 1. Also, we will try to upgrade the doors as close to EI 30 as possible. It is therefore considered necessary to use fire rated glass EI 30.

4 Mounting of gypsum boards

4.1 Findings from SINTEF Technical Approval

Technical Approval no. 20081 Norgips Skilleveggsystem requires the use of gypsum screws in accordance to EN 14566. Gypsum boards shall be fastened with screws in a distance of max c/c 250 mm along the edges, and in distance max c/c 250 mm inside the boards. The distance from the side edges shall be at least 10 mm, and the distance from the top and bottom edges shall be at least 15 mm. The size of the screws is not mentioned.

4.2 Findings from SINTEF Byggforskserien

SINTEF Byggforsk *734.503 Fire technical improvement of old wooden doors* gives the following guidelines:

One-sided protective board cladding is an alternative when you want to keep the door leaf's appearance on one side, for example towards stairwells. If the wood filling (NO: Dørspeil) is at least 21 mm thick,

you can fill in the thinner parts of the wood filling with pressure-resistant rock wool which is cut and glued with wood glue and fastened as shown in Figure 4.2.1.

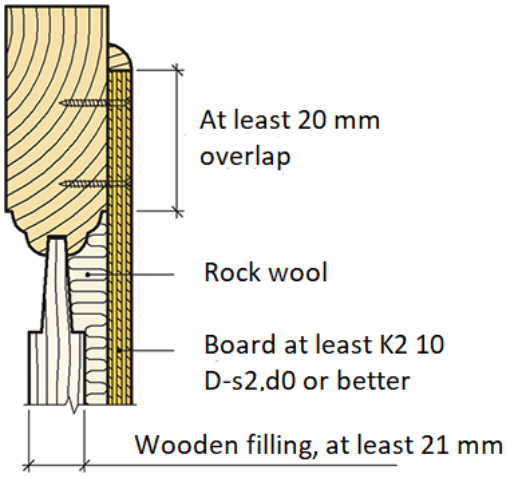

Figure 4.2.1 One-sided cladding on door leaves when the wood filling is at least 21 mm [4]

If the wood filling is thinner than 21 mm, at least 20 mm of rock wool must be inserted between the filling and the cladding. See Figure 4.2.2. At the thinnest, the wood filling must be at least 9 mm thick. If there is not enough space for the rock wool, a distance list must be mounted.

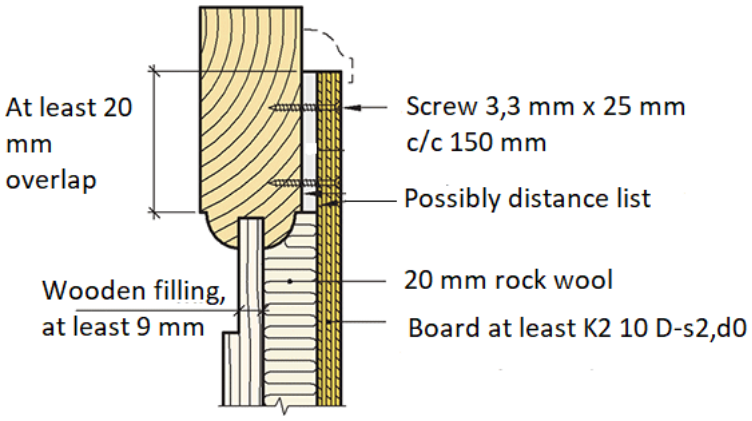

Figure 4.2.2 One-sided cladding on door leaves when the wood filling is less than 21 mm [4]

4.3 Findings from English heritage guideline

Chapter 5.5.2 in the English heritage guideline [3] gives numerous examples of possible solutions to upgrading the door leaves, see summary in Figure 4.3.1. Not all of the given solutions are tested. Method A is the only method suitable for this project, because method B-H requires dismantling of the thin wooden mirrors and is considered too complex.

Table 5.2 Summary of methods of upgrading the fire resistance of existing panels to joinery doorsets.
(This table should be read in conjunction with the contents of Section 5.5)

	Fire resistance performance of panels (minutes)							
Upgrading method	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***
Panel thickness (mm)								
6	20*	-	25*	30	25*	25*	-	20*
9	20*	15*	25*	30	25*	30	20*	20*
12	25*	20*	30	30	25*	30	20*	20*
20	30	25*	30	30	25*	30	20*	30

**** Fire resistance performances below 30 minutes may be acceptable as part of a fire engineered solution.***

Figure 4.3.1 Summary of methods for upgrading timber panels [3]

Upgrading method A is shown in Figure 4.3.2, and describes mounting of a gypsum board on the thinnest part of the door, and a 6 mm calcium silicate board on the rest of the door. For example, if the panel thickness of the thinnest part is 20 mm, the door will obtain a fire resistance of 30 minutes.

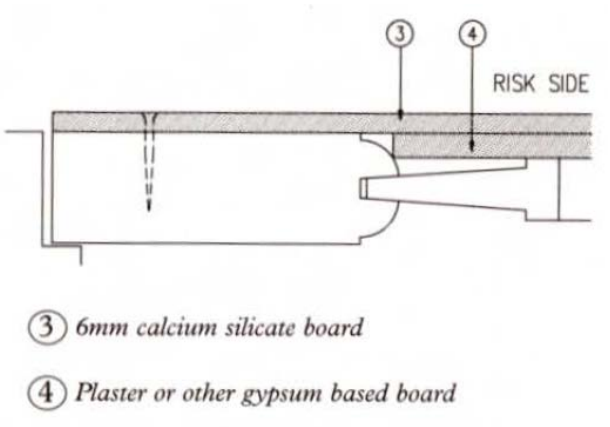

Figure 4.3.2 Upgrading method A [3]

4.4 Types of gypsum boards

The main types of gypsum boards used in buildings are:

- 9 mm outdoor gypsum boards
- 12,5 mm standard gypsum boards type A
- 15 mm fire gypsum boards type F
- 12,5 mm Fermacell Fibre Gypsum board
- 12,5 mm Robust gypsum boards

Since the doors are located inside and not subjected to moisture, the 9 mm outdoor gypsum board is considered not suitable. Based on experience from fire tests, the 12,5 mm standard gypsum board will burn through and fall down after approximately 15-20 minutes. 15 mm fire gypsum board and 12,5 mm Fermacell Fibre Gypsum board will last longer, approximately 30 minutes or more. Robust gypsum boards will possibly have a fire resistance equal to fire gypsum boards, based on its high density. SINTEF has access to test-reports from an anonymous manufacturer of robust gypsum boards, which shows that the boards have not collapsed after 50 minutes.

4.5 Discussion on upgrading wooden fillings

Previous fire tests using fire retardant paint has shown that the paint has limited effect. It is also an insecure solution because the properties of the paints vary, and there is great uncertainty when it comes to quality of the workmanship and how to control the achievement of correct thickness. [9, 10] The most robust solution is therefore to use gypsum boards on the thinner parts of the wooden doors.

After reviewing SINTEF Byggforsk and the English heritage guideline, the solution in SINTEF Byggforsk *734.503 Fire technical improvement of old wooden doors* is the most suitable solution for this project. The gypsum board must overlap the thicker part of the door with 20 cm, and the gap between the filling and the board must be filled with stone wool.

If using 12,5 mm standard gypsum boards, the stone wool will be exposed after appr. 15-20 minutes. To prevent the stone wool from falling down, it must be fastened with a steel net properly attached to the door. It is then possible to obtain 30 minutes fire resistance to the door, but the safety margin is small.

If we want to be on the safer side, 15 mm fire gypsum board or 12,5 mm Fermacell Fibre Gypsum board must be used. The stone wool will most likely be protected for 30 minutes, and there is no need to use a steel net to prevent the stone wool from falling down. The downside with this solution is that 15 mm fire gypsum board and 12,5 mm Fermacell Fibre Gypsum board have a higher density, making the door heavier.

However, with the heavy use of an entrance door the previously mentioned gypsum boards will most likely be damaged after short time. It is therefore recommended to use 12,5 mm Robust gypsum boards.

For aesthetic reasons it may be used wooden battens/mouldings to cover the gap between the gypsum board and the original door. The battens/mouldings will not have a function during fire.

5 Expanding sealing lists and silicone gaskets

Requirements in VTEK: Doors classified according to NS 3919:1997 [B 30, A 60 etc.] must have ledge, thresholds and sealing lists on all sides to achieve sufficient smoke tightness. This does not apply to doors and hatches that have been tested and meet the criteria for S_a classification according to NS-EN 1634-3: 2004 (including correction sheet AC: 2006).

In this case, the doors will not be classified according to NS 3919, nor will they be tested according to NS-EN 1634-3. We must nevertheless strive to achieve as smoke-tight doors as possible.

5.1 Findings from English heritage guideline

The English heritage guideline gives the following general advice for choosing cold smoke sealants [3]:

• *Durability*
Doors in constant use should be fitted with seals capable of withstanding extended cycling tests without significant damage. Some generic types, by the nature of their design, are more durable than others. However, seals of the same generic type will vary from one brand to another.
• *Ability to accommodate variable gaps between the door edge and frame and distortion of the door*
This is most important in retrofit situations where doors tend to be less well fitting. Frequently the gaps vary significantly around the door edge and the door is warped to some degree.
• *Effect on the door's ability to self-close*
Where the building design prevents the movement of air, for instance because of sealed windows, etc. smoke seals can make it more difficult at times to open and close a door. This is because the action of closing a door can cause an atmospheric pressure difference between the rooms on either side. Certain generic types of seal have a greater effect on this factor than others. If a seal is to be truly effective it must make contact with both adjacent surfaces. This introduces friction inhibiting the door-closing action. Some seals have a lower frictional resistance than others, thus minimising the effect.
• *Interruption by items of ironmongery*
Hinges, lock mechanisms and edge-mounted flush bolts are examples of items of ironmongery which may interrupt some generic types of smoke seal.

5.2 Findings from other literature

The report "*Upgrading the fire resistance of floors and doors in heritage buildings*" [2] indicates that expanding sealing lists can be used to prevent failure of the door's integrity (E) and insulation capacity (I). The solution provides sufficient tightness, i.e., that the space between the frame and the door leaf is not greater than approx. 3 mm. Expanding lists alone will not prevent the spread of cold smoke, and where this is important the solution should be combined with smoke seals. Figure 5.2.1 shows expanding sealing lists placed in a groove in the door and frame.

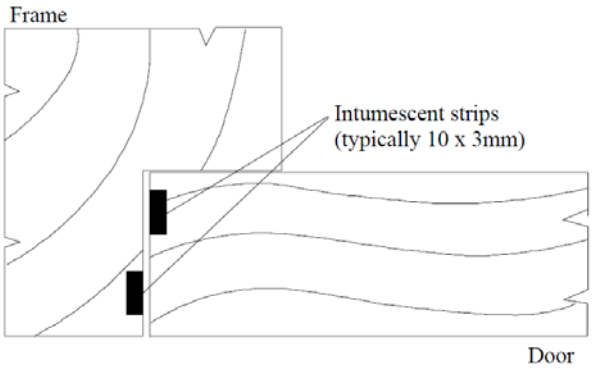

Figure 5.2.1 Expanding sealing lists in door frame and door leaf. Figure is from [2].

5.3 Discussion on lists and gaskets

There are two alternatives for smoke sealing; expanding lists or smoke lists. Expanding lists expands on heat and will only work after a while, when the temperature in the fire room has become high enough. Cold smoke early in the fire development will escape the expanding list. Therefore, a smoke list must be mounted in addition, which will stop the cold smoke. Both types of lists must be milled into the frame or the door leaf to ensure that they sit properly and provide a robust solution.

The smoke lists should be made of silicone that does not melt during the early stages of fire.

6 Door frame

The area between the door frame and the wall can be a weak point in the construction. An example of how to make a fireproof connection between the door frame and the wall is taken from a fitting instruction for Gilje fire rated door EI 30 [8]. The following steps must be executed:

- Take the door blade out of the frame, and make a temporary fastening point for the frame
- The threshold must be levelled and laid on expanding fire sealant, both on the inner and outer edge of the threshold
- Adjust and fasten the door frame and replace the door blade
- Stop up (NO: dytt) with mineral wool around the edges (e.g. Rockwool Flexi-A board)
- The size of the joint between the frame and the wall can be min. 10 mm and max 20 mm
- Finish by adding expanding fire sealant along the joint on both sides

7 Summary and input to fire testing

- Fire rated glass EI 30 must be used in the fire testing.

- The glass must be mounted as shown in fig. 2, 3 or 4, with 15x15 mm steel angles or steel clips. If there is not enough space available inside the door window frame for the 15x15 mm steel angles, it is a possible solution to mount the fire rated glass flush with the inside of the door. Figure 3.1.3 shows the solution. The glass must then be held in place with a 30 mm steel frame.

- If there are several small glass-frames in the door, and there is not enough space available inside the door window frame, it is a possible solution to mount the fire rated glass on the outside and letting a gypsum board take the weight of the glass. Figure 3.1.4 shows the solution. The glass must be held in place with a 30 mm steel frame.

- Because of the heavy use of an entrance door, it is recommended to use 12,5 mm Robust gypsum boards. These boards have a fire resistance equal to 15 mm fire gypsum board and 12,5 mm Fermacell Fibre Gypsum board, 30 minutes or more.

- Expanding lists and silicone gaskets must be mounted. Both types of lists must be milled into the frame or the door leaf, so that they sit properly and provide a robust solution.

- The area between the door frame and the wall can be a weak point in the construction. The method described in chap. 6 using mineral wool and expanding fire sealant will most likely be a good solution.

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