

Post-protection behaviour of wooden wall and floor structures completely filled with glass wool

Alar Just



Abstract

This report presents a design method for post-protection behaviour of glass wool insulation in timber-frame assemblies. It is based on non-load-bearing small-scale tests at SP Träteck and full-scale tests at TÜV Estonia of standard fire exposure in accordance with EN 1363-1.

Recession of glass wool insulation was measured during tests as a basic parameter of the described method. According to the method described in this report, the fire resistance of glass wool-insulated walls and floors should be calculated in the same way as for stone wool-insulated structures, using existing rules during the protected phase. The new design model takes into account the delay of charring along the wide sides of studs, although recession of glass wool occurs during the post-protection phase after the failure of the cladding. After complete recession of the glass wool insulation, the design procedure is similar to that for floor and wall assemblies with void cavities. The residual cross-section shape is treated as trapezoid.

Calculation of load-bearing capacity requires not only the residual cross section to be taken into account, but also the reduced material properties of heated wood. The reduced cross-section method with zero-strength layer or reduced properties method should be used for structural design.

Key words:

Glass wool, post-protection, timber frame, fire design

SP Sveriges Tekniska Forskningsinstitut
SP Technical Research Institute of Sweden

SP Report 2010:28
ISBN 978-91-86319-66-3
ISSN 0284-5172
Stockholm 2010

Contents

Abstract	2
Contents	3
Preface	4
Summary	5
1 Introduction	6
1.1 Symbols	6
2 Glass wool	7
3 Charring of wall and floor studs	8
3.1 The EN 1995-1-2 method for insulated wall and floor assemblies	8
3.2 The EN 1995-1-2 method for wall and floor assemblies with void cavities	9
3.3 The ETH method for wall and floor assemblies with void cavities	10
4 Investigation of post protection effect by tests	11
4.1 Test results	11
4.2 Conclusions from test results	14
5 Design method for timber wall and floor members protected by glass wool	15
5.1 Trapezoidal model	15
5.2 Rectangular models	17
5.2.1 Simplified model for bending elements	17
5.2.2 Simplified model for compression elements	18
5.3 Strength and stiffness properties	18
5.4 Examples	19
6 Conclusions	22
7 References	22

Preface

This report describes a proposal for a design method for timber-frame assemblies completely filled with traditional glass wool insulation. The method is needed for complementing the design rules in EN 1995-1-2 for wall and floor structures insulated by glass wool.

The author of this report would like to thank Jürgen König, Joachim Schmid (SP Trätek), Jan Goor (Saint-Gobain Isover) and Elar Vilt (AS Kodumaja) for their great help.

Summary

The use of glass wool insulation in timber-frame buildings is popular because of its light weight and good insulation properties. Since fire design is an important part of the design procedure, EN 1995-1-2 gives rules for the structural design of timber buildings exposed to fire. Based on experience of fire tests, design rules are different for stone wool and glass wool, although the differences are not specified in standards for mineral wool. Hence it is well known that glass wool insulation does not provide long protection for timber studs once the fire protective cladding has fallen off.

Annex C of EN 1995-1-2 gives design rules for walls and floors insulated by mineral wool. While a post protection phase is considered for stone wool-insulated construction, structures filled with glass wool are counted as having failed immediately after failure of the cladding. There is also a design method for wall and floor assemblies with void cavities.

This report presents a design method for post-protection behaviour of glass wool insulation in timber-frame assemblies. It is based on non-load bearing small-scale tests at SP Träteknik and full-scale tests at TÜV Estonia with standard fire exposure in accordance with EN 1363-1. Considering the start of charring at 300 °C, recession of glass wool insulation was measured during tests as a basic parameter for the method described in this report. Frangi et al [4] introduced a post-protection study of floors with void cavities to complete the calculation model in EN 1995-1-2 [1].

According to the method described here, the fire resistance of glass wool-insulated walls and floors during the protection phase should be calculated similarly to that of stone wool-insulated structures, i.e. in accordance with existing rules. This is when studs and insulation are protected from direct fire exposure by cladding.

The new design model takes into account the delay of the start of charring along the wide sides of studs, although recession of glass wool occurs during the post-protection phase, after the failure of the cladding. After complete recession, the design procedure of timber-frame constructions is similar to that for floor and wall assemblies with void cavities. The residual cross-section shape is treated as trapezoid.

Calculation of load-bearing capacity requires not only the residual cross-section to be taken into account, but also the reduced material properties of heated wood. The reduced cross-section method with zero-strength layer, or the reduced properties method, should be used for structural design.

In the future, this method can be foreseen as applicable for other recessive insulation materials, such as cellulose fibres, wood wool and wood fibre and other natural insulation products for which the recession rate can be defined by fire tests.

1 Introduction

Timber-frame assemblies are normally built up from the timber frame (floor joists or wall studs) and a cladding attached to each side of the timber. The cavities may be void, or partially or completely filled with insulation. Since the timber frame is sensitive to fire exposure, it must be effectively protected against fire.

The design and optimisation of a timber frame assembly with respect to maximising fire resistance employs a hierarchy of contribution to fire resistance of various layers of the assembly. The greatest contribution to fire resistance is obtained from the membrane (layer) on the fire-exposed side first directly exposed to the fire, both with respect to insulation and to failure (fall-off) of the membrane. In general, it is difficult to compensate for poor fire protection performance of the first membrane by improved fire protection performance of the following layers.

In small-sized timber frame members, e.g. floor joists or wall studs in assemblies with void cavities, increased charring takes place after failure of the cladding. However, the timber member will normally collapse before reaching the consolidation phase with a char depth of 25 mm. Such conditions are described in Annex D of EN 1995-1-2.

For small-sized timber frame members in assemblies with cavity insulation, charring mainly takes place on the narrow, fire-exposed side. Since there is a considerable heat flux through the insulation to the sides of the member during the stage after failure of the lining (provided that the cavity insulation remains in place), the effect of increasing arris rounding becomes dominant and no consolidation of the charring rate is possible.

For the stage before failure of the cladding (protection phase $t \leq t_f$), both stone wool and glass wool insulation perform approximately equally. However, once the cladding has fallen off and the insulation is directly exposed to the fire (post-protection phase $t \geq t_f$), glass wool insulation will undergo decomposition, gradually losing its protecting effect for the timber member by surface recession. Stone wool insulation, on the other hand, provided that it remains in place, will continue to protect the sides of the timber member facing the cavity.

Batt-type mineral wool insulation should always be secured mechanically, through the use of battens or steel channels or oversizing.

Immediate failure of the assembly with glass wool is a conservative assumption. From full-scale wall tests, it is known that it will take some time until the glass wool insulation has completely recessed once it has been directly exposed to the fire.

The aim of the report is to give design rules for the post-protection phase of wooden floor and wall assemblies insulated with traditional glass wool.

1.1 Symbols

d_{char}	charring depth;
$d_{\text{char},1,n}$	notional charring depth on wide side of cross-section;
$d_{\text{char},2,n}$	notional charring depth on narrow side of cross-section;
$d_{\text{char},1,\text{unexp}}$	notional charring depth on wide side on unexposed side of cross-section;
$h_{\text{char},3}$	height of charred zone of cross-section height;
t_{ch}	is the start time of charring;

t_f	is the failure time of cladding;
$t_{f,ins}$	is the failure time of insulation;
k_s	is the cross-section factor;
k_2	is the insulation factor;
k_{3a} , k_{p2b}	is the post-protection factor for Phase 3a; (k_3 in [1])
k_{3b} , k_{p2c}	is the post-protection factor for phase 3b
k_n	is a factor to convert the irregular residual cross-section into a notional equivalent rectangular cross-section;
β_0	is the one-dimensional design charring rate, (Table 3.1) at [1];
β_n	is the notional charring rate, (Table 3.1) at [1];
h_p	is a thickness of cladding on the fire-exposed side;
W_{fi}	is a section modulus of the charred cross-section;
W_{rec}	is a section modulus of the simplified equivalent rectangular cross-section;
A_{fi}	is a cross-section area of the charred cross-section;
A_{rec}	is a cross-section area of the simplified equivalent rectangular cross-section;
$v_{rec,ins}$	is a recession of insulation;

2 Glass wool

Glass wool is a mineral wool manufactured predominantly from natural sand or molten glass [2].

After the fusion of different raw mineral materials, mainly natural sand and recycled glass, at 1450 °C, the liquid glass that is produced is converted into wool (mixture of fibres). Stable dimensions, cohesion and mechanical strength of the product are obtained by the addition of a binder. Most of the fibre intersections are “blocked” by a drop of binder. This wool is then heated above 200 °C to polymerize the binder. During that stage, the wool is calendared to give it strength and stability. The final stage involves cutting the wool and packing it in rolls or panels (with or without compression) before palletizing the finished product for transport and storage.

Glass wool is a thermal and acoustical insulation products where 100 % of the glass content is fiberised, making a woolly structure able to decrease the air permeance. Depending of the applications and the property requirements, products from low, medium or high densities can be produced. It can be a loose fill material, blown into attics, or, together with an active binder sprayed on the underside of structures, rolls and panels that can be used to insulate flat or curved surfaces such as cavity wall insulation, ceiling tiles, curtain walls and ducting. It is also used to insulate piping and for soundproofing.

Densities of glass wool insulations, used in timber structures, are usually 14 to 20 kg/m³. The maximum service temperature of traditional glass wool is usually around 500 to 600 °C, which means that glass wool-insulated timber frame walls and floors have good fire protective properties as long as the protective cladding has not fallen off. When the temperature rises over 500 °C, there will be a rapid recession of glass wool insulation. This will occur usually after the cladding failure.

3 Charring of wall and floor studs

3.1 The EN 1995-1-2 method for insulated wall and floor assemblies

According to [1], the modified relations between charring rates and protective times of fire protective claddings for protected wall and floor members are as shown in Figure 1.

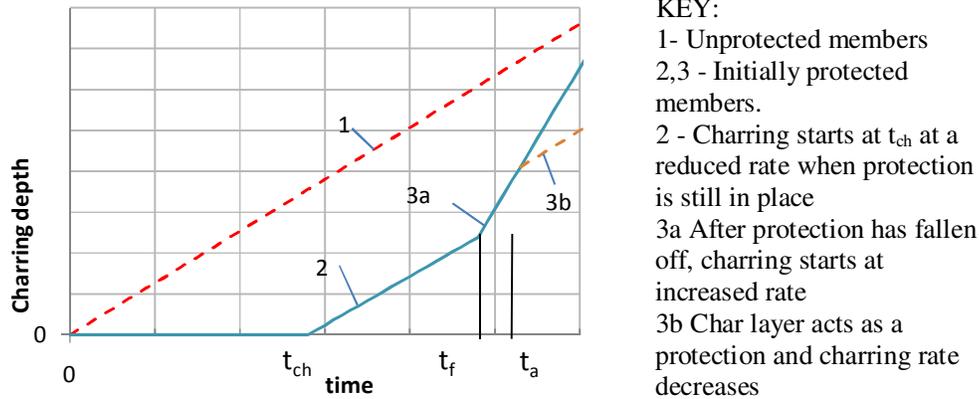


Figure 1 - Charring rates of timber

For larger (non-typical) cross-sections, there is a time limit t_a , after which the charring rate is similar to that of unprotected timber because of the protective properties of the char layer. Floor and wall studs are of too small size for the protective char layer to develop. There is also a heat flux from the sides, which means that the time limit cannot be applied, and the high charring rate applies until the end.

Different times of t_{ch} and t_f are used only for fire-rated gypsum boards (Type F according to [3]). For ordinary gypsum boards (Types A and H according to [3]) the start of charring time is also counted as the failure time of the board. $t_{ch}=t_f$

For timber members protected by claddings on the fire-exposed side, the notional charring rate is calculated as (Equations (C.1) and (C.2) in [1]):

$$\beta_n = k_s k_2 k_n \beta_0 \quad \text{for } t_{ch} \leq t \leq t_f \quad (1)$$

$$\beta_n = k_s k_3 k_n \beta_0 \quad \text{for } t \geq t_f \quad (2)$$

where:

$$k_n = 1,5$$

The cross-section factor is $k_s = 1,1..1,4$, depending on the width of the stud cross-section. k_2 and k_3 represent the reduced and decreased charring rates of Stages 2 and 3.

If all other factors are the same for studs, the difference in charring rates is the use of different factors k_2 or k_3 for different stages of protection.

During the protected Phase 2 as shown in Figure 1, the behaviour of wall studs in rock wool and glass wool-insulated walls and floors is similar. The protection coefficient is calculated as one of the two following, depending on the cladding joint configuration.

$$k_2 = 1,05 - 0,0073h_p \quad (3)$$

$$k_2 = 0,86 - 0,0037h_p \quad (4)$$

Provided that the cavity insulation is made of stone wool batts and remains in place after failure of the lining, the post-protection factor k_3 should be calculated as (Equation (6.12) in [1]):

$$k_3 = 0,036t_f + 1 \quad (5)$$

Where the cavity insulation is made of glass wool, failure of the member should be assumed to take place at the time t_f . (Subclause C.2.1 (6) in [1])

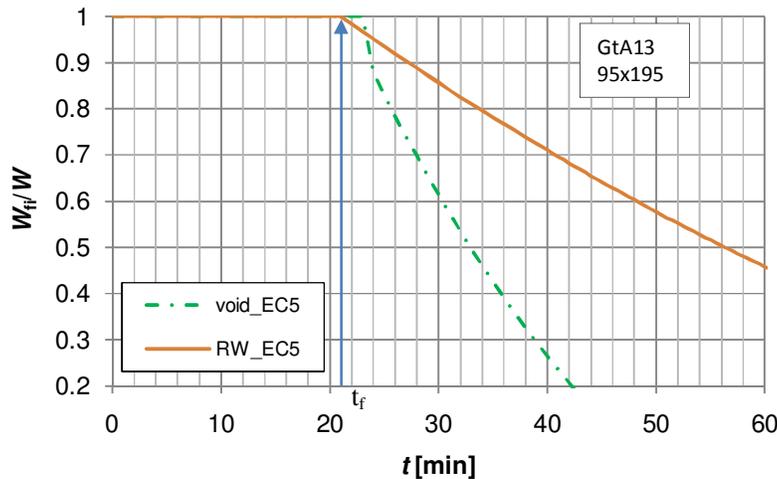


Figure 2 - Reduction of section modulus for structures insulated with stone wool and void cavities

Figure 2 shows the reduction of section modulus in fire design in accordance with [1]. Up to the failure time of gypsum cladding, the behaviour of stone and glass wool-insulated wall and floor structures is similar. The behaviour of structures with void cavities is different. After the failure of cladding, EN 1995-1-2 gives rules only for assemblies with stone wool and void cavities.

3.2 The EN 1995-1-2 method for wall and floor assemblies with void cavities

Charring of timber members during the protected stage is slower in the case of void cavities than of insulated cavities. There is no local heat increase.

At protection Stage 2, the notional charring of the narrow side of the timber member is taken into account by notional charring rate β_n and factor k_2 .

Charring rates of the timber member given in Table 3.1 in EN 1995-1-2 [1] should be multiplied by a factor k_2 .

The protection coefficient for gypsum claddings during the protected stage is:

$$k_2 = 1 - 0,018h_p \quad (6)$$

When the cladding has fallen off there will be charring of three sides of the timber studs.

The notional residual cross-section is shown on Figure 7. A notional charring rate β_n used for the narrow and wide side cross-sections.

For the stage after failure of the protection, the charring rates given in Table 3.1 in [1] should be multiplied by a factor $k_3 = 2$.

3.3 The ETH method for wall and floor assemblies with void cavities

Frangi et al (4) made a post-protection study of floors with void cavities to complement the calculation model in EN 1995-1-2 [1], coming up with increased charring rates compared to [1]. The reason for very fast charring is the missing protective char layer after cladding failure for protection against high temperatures.

The model is valid for cross-sections of 60 mm and greater. The method introduces also a Phase 2c (and 3b in Figure 1) which takes the protective char layer created within 5 minutes into account.

Coefficients for Phase 2b:

$$k_{p,2b} = 1 + \frac{8}{75}t_f \quad \text{for } 0 \leq t_f \leq 15 \text{ min} \quad (7)$$

$$k_{p,2b} = 1,9 + \frac{7}{150}t_f \quad \text{for } 15 \leq t_f \leq 60 \text{ min} \quad (8)$$

Coefficient for phase 2c:

$$k_{p,2c} = 1 + \frac{2}{225}t_f \quad \text{for } 0 \leq t_f \leq 60 \text{ min} \quad (9)$$

The post-protection charring depth on the narrow and wide sides of the cross-section from [4] is expressed as

$$d_{char,1} = d_{char,2} = k_{p,2b}\beta_0 t \quad (10)$$

Using the notional charring rate β_n instead of β_0 is recommended for cross-sections less than 60 mm wide.

For cross-sections less than 60 mm wide, the heating from the wide sides is so intensive that there is no Phase 2c (or 3b in Figure 1).

4 Investigation of post protection effect by tests

4.1 Test results

A series of small-scale tests at SP Trätec [5], [6] and large-scale tests at TÜV Estonia [7] were made to study the post-protection effect of glass wool insulation. All the tests were of non-load-bearing structures.

Studs with typical cross-section of 45x145 mm were used for timber framing. Standard fire conditions (EN 1363-1, ISO 834) [8] were used.

Test floors had a Type A gypsum board as cladding on the fire-exposed side. Test wall 2.1 had Type A gypsum board on the fire-exposed side, while test wall 2.5 had Type F gypsum board on the fire-exposed side.

Charring spread was measured by thermocouples, placed on the sides of the timber studs. The start of charring was defined as occurring at a temperature of 300 °C.

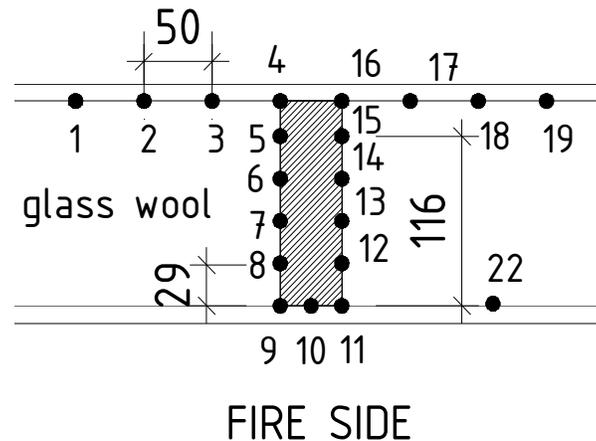
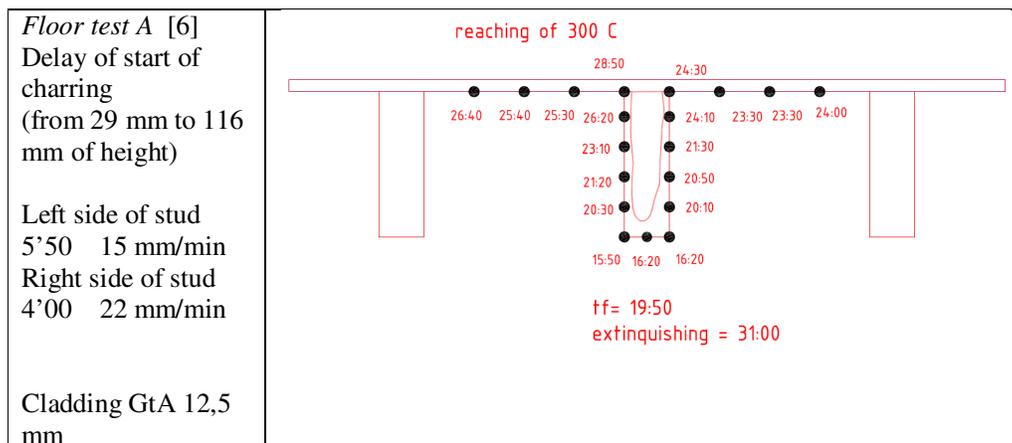


Figure 3 – Positions of thermocouples on test specimen

The following describes the start of charring times (in minutes) of glass wool-insulated studs.

t_f shows the fall-off time of cladding.



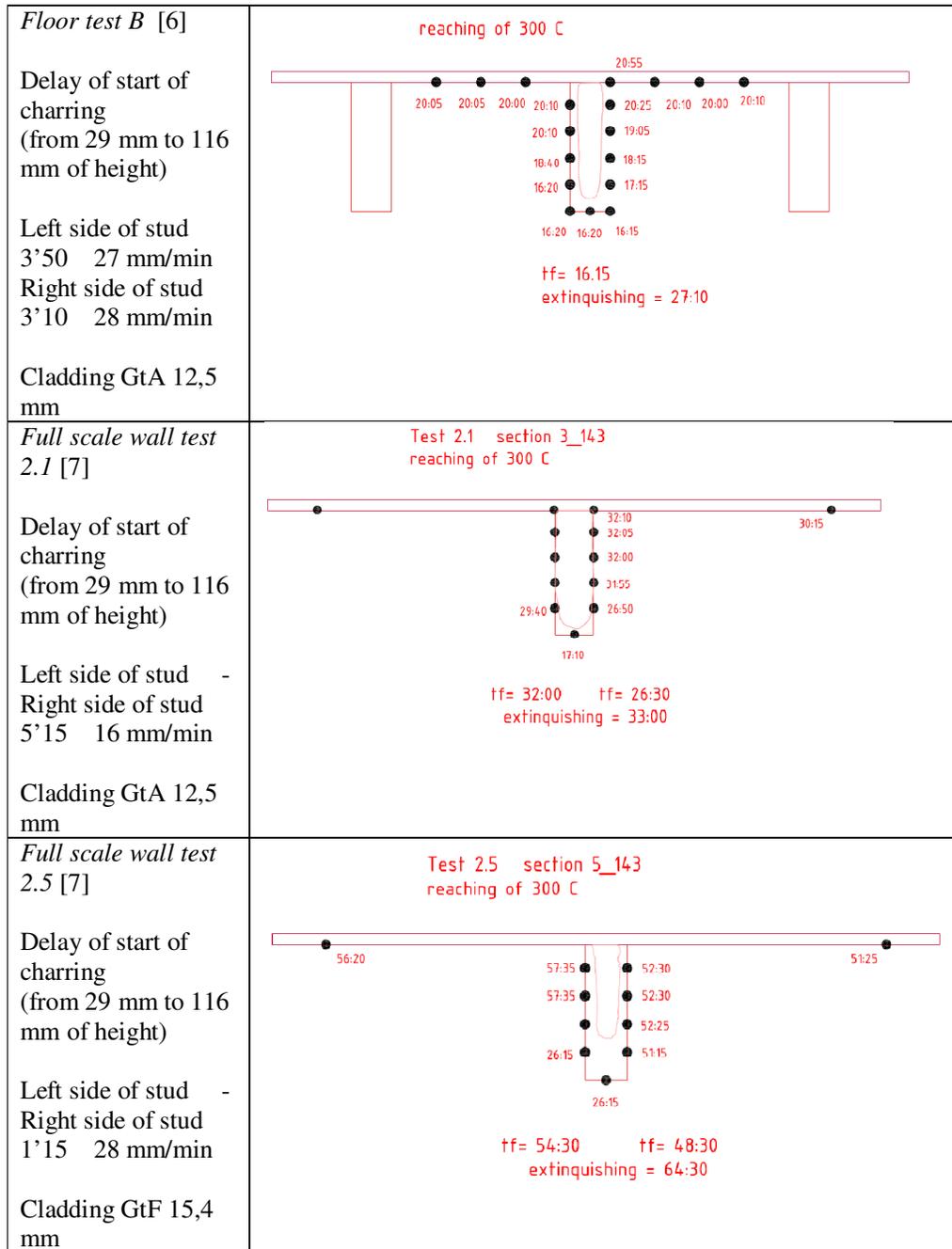


Figure 4 - Start of charring time in different tests

Table 1. Recession of glass wool insulation in tests.

Test	Cladding	t_f [min.sec]	Delay of start of charring (from 29 to 116 mm height) [min.sec]	Recession speed [mm/min]
Floor test A [5]	GtA 12,5	19.50	5.50 4.00	15 22
Floor test B [6]	GtA 12,5	16.15	3.50 3.10	27 28
Wall test 2.1 [7]	GtA 12,5	26.30	5.15	16
Wall test 2.5 [7]	GtF 15,4	48.30	1.15	28

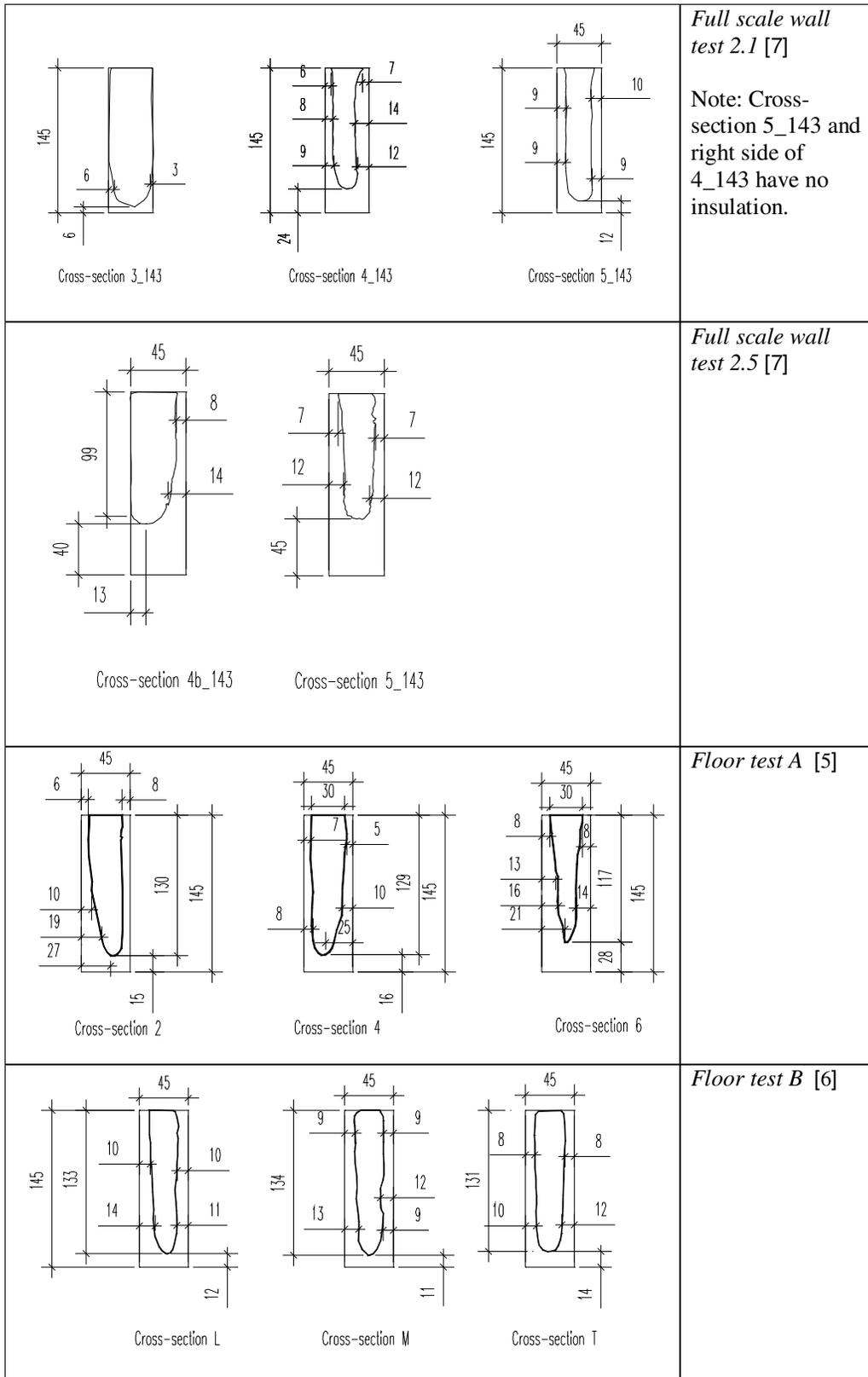


Figure 5 - Shapes of charred cross-sections after fire tests.

Delay of start of charring on the wide sides of cross-sections occurred due to recession of glass wool insulation. Test 2.1 [7] compared half of the wall insulated by glass wool insulation with the other half having void cavities. Shapes of cross-sections are shown on Figure 5.

The shapes of charred cross-sections are close to trapezoid because the charring starts later when insulation recesses.

4.2 Conclusions from test results

The volume of glass wool insulation decreases rapidly as the temperature rises. The post-protective behaviour of ordinary glass wool insulation is not comparable with that of stone wool insulation, although it does provide some small protection after cladding failure in comparison with structures with void cavities. The effect can be noticeable for greater cross-section heights.

As shown in Figure 4, start of charring time spread within 4 ..5 minutes from down to top of cross-section of timber stud. Floor and wall tests showed the same effect of charring due to recession of glass wool insulation.

Recession of glass wool insulation is proposed to design with 30 mm/min with sufficient safety margin.

When the glass wool insulation is melted, the timber frame burns in a similar manner to that of a structure with void cavities. The design method proposed by Frangi et al [4] should be used.

Because of different start of charring times in different cross-section heights, the shape of the notional cross-section is treated as trapezoidal.

Because of smaller typical cross-sections, studied in this report, Phase 3b is not used because of the inability to create a protective char layer on the 45 mm wide cross-section. Rapid heat transfer begins from the sides of studs before a char layer will forms.

5 Design method for timber wall and floor members protected by glass wool

5.1 Trapezoidal model

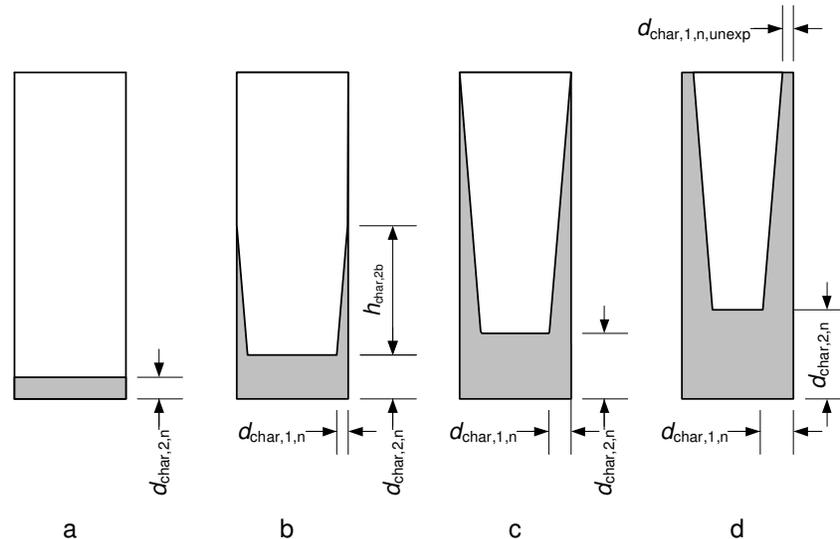
The following design procedure, based on test results and the method by ETH [4], is proposed for floors with void cavities,

The different charring phases are illustrated in Figure 1.

For the time before failure of the cladding, charring takes place. The design model in Annex C in [1] for Phase 2 is valid for this case. See Figure 6a.

Once the cladding has fallen off at time $t = t_f$, surface recession of the glass wool insulation takes place due to thermal decomposition, so that the wide sides of the timber member are increasingly exposed to the fire and start to char, see Figure 6 b.

When surface recession of the glass wool insulation has reached the unexposed side of the insulation at $t = t_{f,ins}$, (Figure 6c), charring on the wide sides of the timber member will take place over the whole depth of the cross-section (Figure 6d).



- Charring on narrow fire-exposed side before cladding has fallen off ($t_{ch} \leq t \leq t_f$)
- Charring on narrow side and wide sides during surface recession of glass wool insulation ($t_f \leq t \leq t_{f,ins}$)
- Recession of glass wool completed ($t = t_{f,ins}$)
- Charring on three sides after failure of glass wool insulation ($t \geq t_{f,ins}$)

Figure 6 – Illustration of charring phases

In the following, it is either assumed that the cladding remains in place after the start of charring of the timber member, i.e. , $t_{ch} \leq t_f$, or that the cladding falls off at the time of start of charring, i.e. $t_{ch} = t_f$.

Failure time of the insulation is counted as

$$t_{f,ins} = t_f + \frac{h}{v_{rec,ins}} \quad (11)$$

where

$v_{rec,ins}$ is the surface recession rate for glass wool insulation:

$$v_{rec,ins} = 30 \text{ mm/min}$$

h is the cross section height

Charring depth on different stages is calculated as

1) Phase 2. $t_{ch} \leq t \leq t_f$ (Figure 6a)

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) \quad (12)$$

2) Phase 3. $t_f \leq t \leq t_{f,ins}$ (Figure 6b):

$$d_{char,1,n} = k_3 \beta_0 (t - t_f) \quad (13)$$

$$h_{char,3} = v_{rec,ins} (t - t_f) \quad (14)$$

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) + k_3 \beta_n (t - t_f) \quad (15)$$

This stage is relatively short and could be replaced by linear interpolation of section modulus between times t_f and $t_{f,ins}$.

3) Phase 3. $t \geq t_{f,ins}$ (Figure 6d):

$$d_{char,1,unexp,n} = k_3 \beta_0 (t - t_{f,ins}) \quad (16)$$

where

k_2 is the insulation factor of the cladding from [1] expressions (C.3) or (C.4), given as:

$$k_2 = 1,05 - 0,0073 h_p \quad \text{for unjointed claddings} \quad (17)$$

$$k_2 = 0,86 - 0,0073 h_p \quad \text{for jointed claddings} \quad (18)$$

k_3 is the post-protection factor, given as

$$k_{3a} = 1 + \frac{8}{75} t_f \quad \text{for } 0 \leq t_f \leq 15 \text{ min} \quad (19)$$

$$k_{3a} = 1,9 + \frac{7}{150} t_f \quad \text{for } 15 \text{ min} \leq t_f \leq 60 \text{ min} \quad (20)$$

$$k_{3b} = 1 + \frac{2}{225} t_f \quad \text{for } 0 \leq t_f \leq 60 \text{ min} \quad (21)$$

If there is a risk of insulation falling off before completely recessed, the time

$$t_{f,ins} = t_f$$

The reduced cross-section method with zero-strength layer or reduced properties method should be used for structural design.

The design model described in [1] applies for $t_{ch} \leq t \leq t_f$.

For $t > t_f$, the reduced cross-section method given by [1], Clause 4.2.2 should be used, i.e. the charring depth should be increased by $d_0 = 7 \text{ mm}$.

The method presented in this paper could also be used for other recessive insulation materials, e.g. cellulose fibres.

5.2 Rectangular models

A further simplified model for calculations is that of the rectangular cross-section. Compared to the trapezoidal model, it is not universal for bending and compression members. Figure 8 shows the relationship between cross-sectional areas of trapezoidal and rectangular cross-sections to provide an equivalent section modulus of trapezoidal and rectangular cross-sections. For this reason, two different rectangular models should be used for the two basic cases.

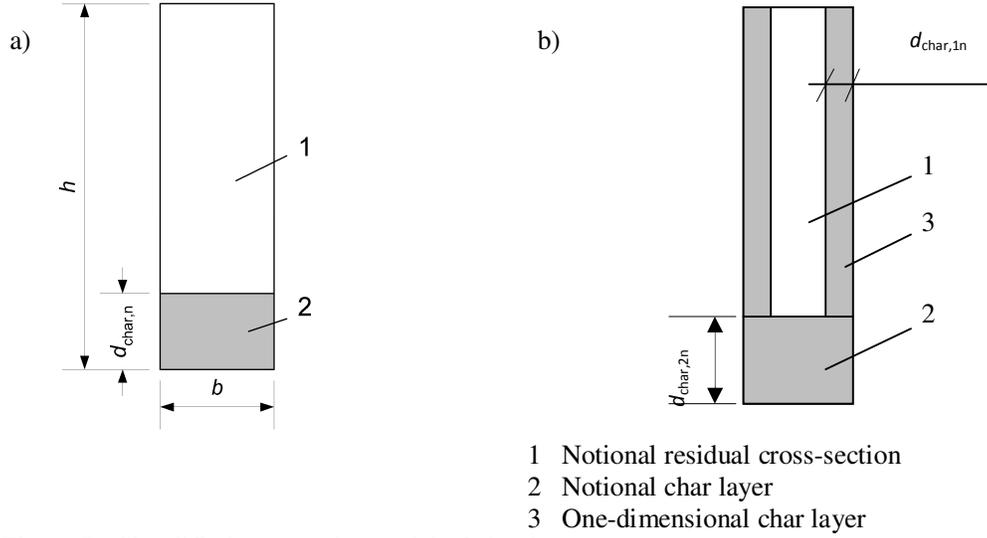


Figure 7 - Simplified rectangular model of charring

5.2.1 Simplified model for bending elements

We assume that the section modulus of a rectangular cross-section is similar to the section modulus of trapezoid cross section. (This is a safe approximation.)

$$W_{fi} = W_{rec}$$

Charring depth at different stages is calculated as

- 1) Phase 2. $t_{ch} \leq t \leq t_f$ (Figure 7a)

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) \quad (22)$$

- 2) Phase 3. $t_f \leq t \leq t_{f,ins}$:

Linear interpolation of A_{rec} should be used.

- 3) Phase 3. $t \geq t_{f,ins}$ (Figure 7b):

$$d_{char,1,n} = k_3 \beta_0 \left(t - t_f - 0,3 \frac{h}{v_{rec}} \right) \quad (23)$$

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) + k_3 \beta_n (t - t_f) \quad (24)$$

The rectangular model based on equal-section modulus of a trapezoid can give a corresponding rectangular cross-sectional area up to two times less, after only 5..10 minutes after cladding failure. See Figure 8.

We therefore introduce the alternative rectangular model for compression members.

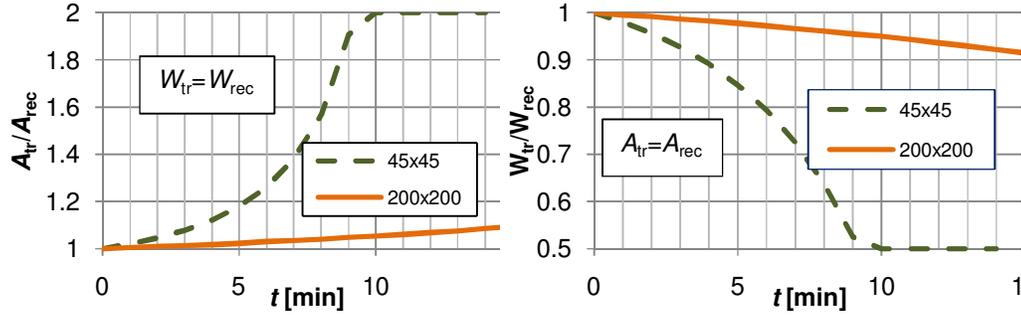


Figure 8 - Comparison of change of section properties of trapezoidal and rectangular cross sections during fire development

5.2.2 Simplified model for compression elements

We assumed that the cross-sectional area of the notional rectangular cross section is similar to the section modulus of a trapezoid. (This is a safe approximation.)

$$A_{tr} = A_{rec}$$

The charring depth at different stages is calculated as

- 1) Phase 2. $t_{ch} \leq t \leq t_f$ (Figure 7a)

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) \quad (25)$$

- 2) Phase 3. $t_f \leq t \leq t_{f,ins}$:

Linear interpolation of A_{rec} should be used.

- 3) Phase 3. $t \geq t_{f,ins}$ (Figure 7b):

$$d_{char,1,n} = k_3 \beta_0 \left(t - t_f - 0,5 \frac{h}{v_{rec}} \right) \quad (26)$$

$$d_{char,2,n} = k_2 k_s k_n \beta_0 (t_f - t_{ch}) + k_3 \beta_n (t - t_f) \quad (27)$$

5.3 Strength and stiffness properties

It is recommended that the reduced cross-section method should be used for calculating strength and stiffness.

The method of [1] for counting zero-strength layer should be used for structural design for $t_{ch} \leq t \leq t_f$.

For the time period $t > t_f$, the zero-strength layer should be taken as $d_o=7$ mm from three side of the cross-section.

Alternatively, the reduced properties method as given in [1] Annex C can be used, but the method is limited with necessary data.

5.4 Examples

Examples of charred cross-section (without counting d_0) are shown on the next diagrams for different studs and protection.

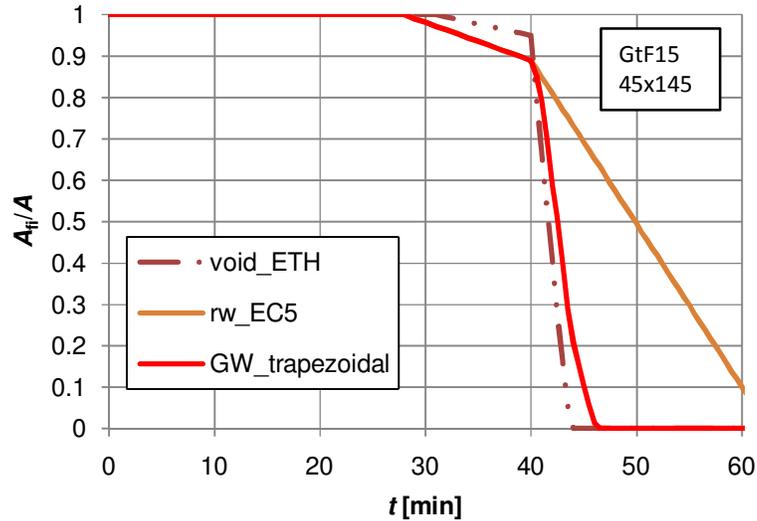


Figure 9 – Decreasing cross-sectional area. Example of existing and new design models for timber-frame assembly with Type F gypsum plasterboard and timber studs 45x145. Comparison with test results.

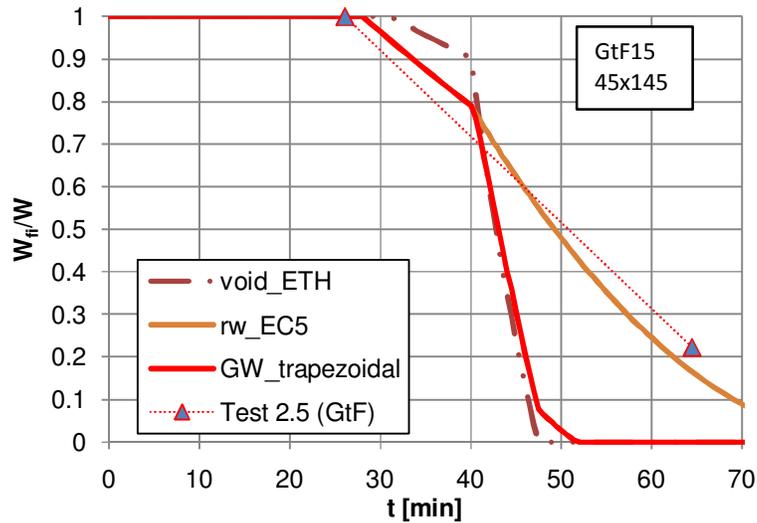


Figure 10 – Decreasing section modulus. Example of existing and new design models for timber frame assembly with Type F gypsum plasterboard and timber studs 45x145. Comparison with test results.

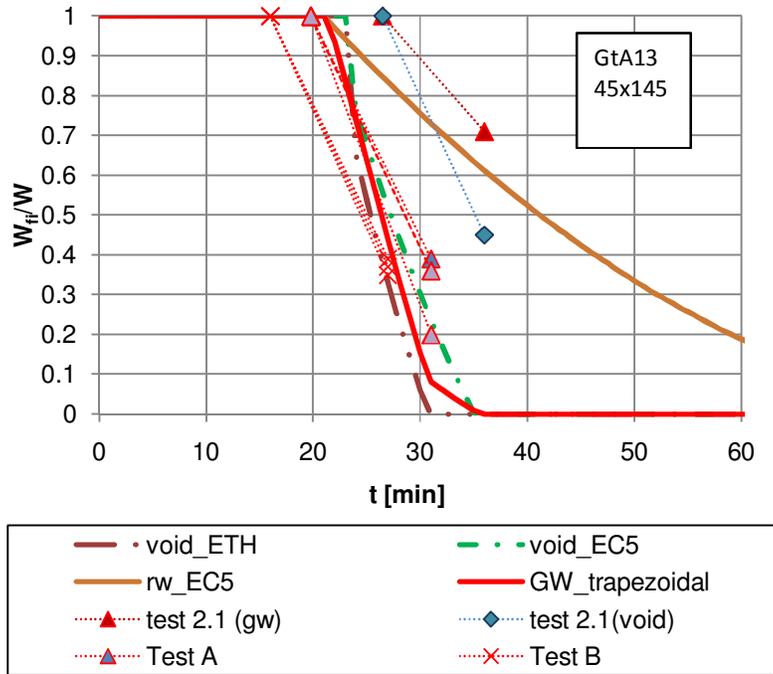


Figure 11 - Example of new design model for structure with Type A gypsum plasterboard and timber studs 45x195. Comparison with test results.

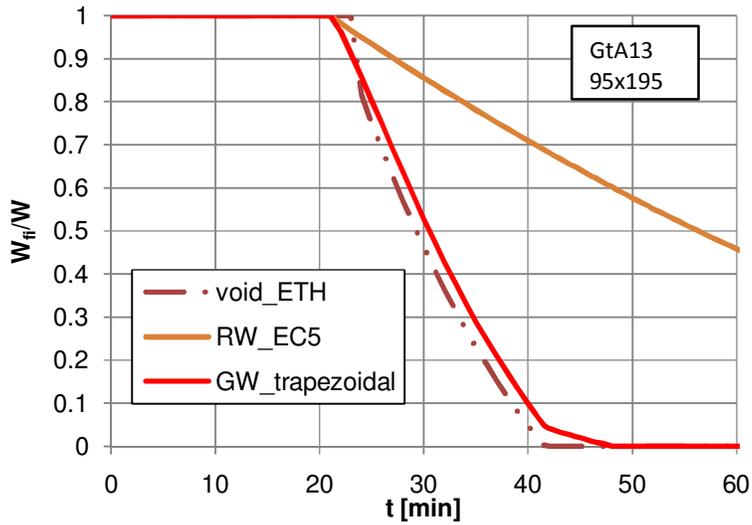


Figure 12 - Example of new design model for structure with Type A gypsum plasterboard and timber studs 95x195

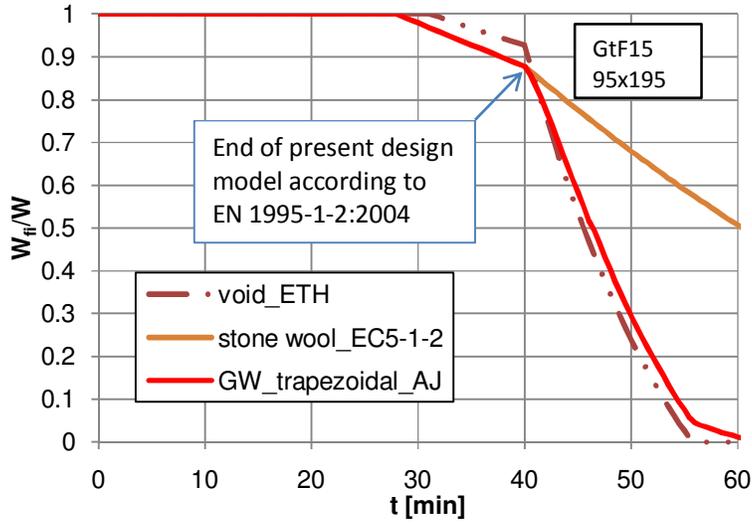


Figure 13 - Example of new design model for structure with Type F gypsum plasterboard and timber studs 95x195.

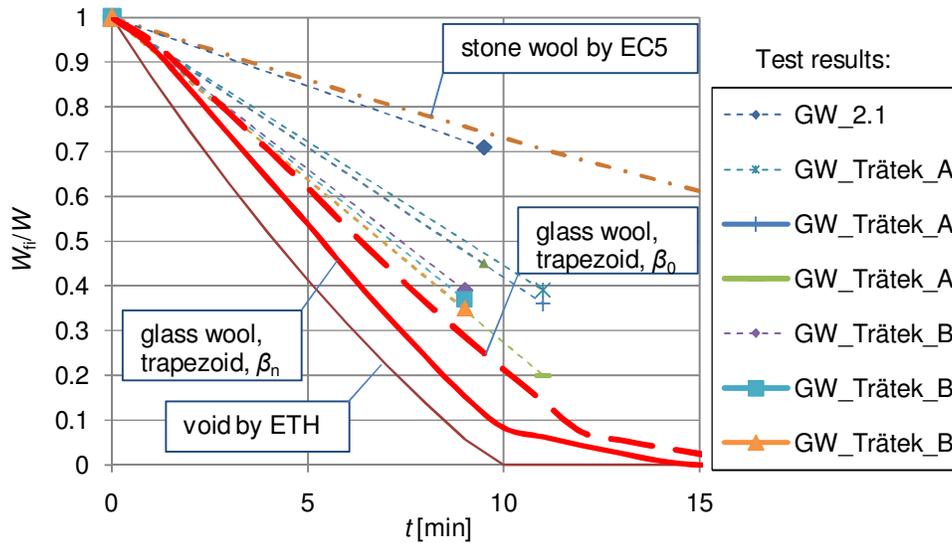


Figure 14 - Comparison of calculation method with the test results.

The charring at corners is taken into account by using β_n on the narrow side of the cross section. Charring on the wide side could be calculated by using one-dimensional charring rate β_0 . Alternatively, the curve with charring rate β_n on wide side is shown in Figure 14. Test results show that β_0 gives the appropriate result.

6 Conclusions

Fire resistance of glass wool-insulated walls and floors should be calculated in the same way as for stone wool-insulated walls and floors when protected from direct fire by cladding (protection Phase 2 according to EN 1995-1-2).

Post-protection Phase 3a begins with delay of the start of charring on the wide side of studs caused by recession of glass wool. After the delay, the method proposed by Frangi et al [4], for timber-frame floors with void cavities, should be used for Phase 3a. The residual cross-section is treated as trapezoidal.

Recession of glass wool insulation, with densities from 14 kg/m^3 , could be counted as 30 mm/min of the insulation thickness.

Post-protection Phase 3b should be used only for cross-sections greater than 60 mm wide.

It should be ensured that the insulation does not fall off during the fire.

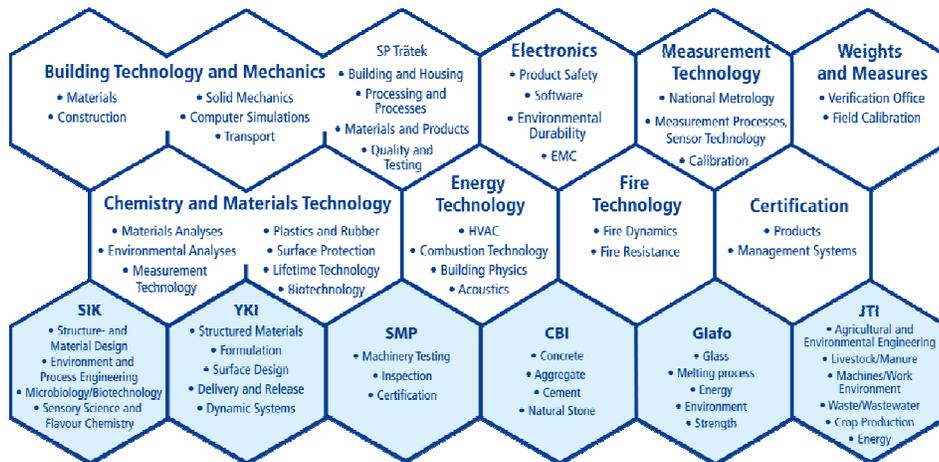
The reduced properties method, or the reduced cross-section method, should be used for structural design.

7 References

1. EN 1995-1-2:2004, Eurocode 5: Design of timber structures - Part 1-2: General rules-structural fire design. European Standard. European Committee for Standardization. Brussels, 2004.
2. CEN/TC88. prEN ISO 9229 Thermal insulation - Definitions of terms. European Standard. European Committee for Standardization. Brussels, 2006.
3. EN 520:2004. Gypsum plasterboards - Definitions, requirements and test methods. European Standard. European Committee for Standardization. Brussels, 2004.
4. Frangi, A., Erchinger, C., Fontana, M. Charring model for timber frame floor assemblies with void cavities. *Fire Safety Journal*, 43, Elsevier Ltd, 2008.
5. SP Trätekt. Test report P705487A. Stockholm, 2009.
6. SP Trätekt. Test report P705487B. Stockholm, 2009.
7. Just, A. Full scale wall tests of timber frame assemblies. Test report. Tallinn University of Technology, 2009.
8. EN 1363-1, ISO 834. Fire resistance tests - Part 1: General requirements. European Standard. European Committee for Standardization, Brussels, 1999.
9. Östman, B., König, J., Mikkola, E., Stenstad, V., Carlsson, J., and Karlsson, B., Brandsäkra trähus. Version 2. Trätekt, Swedish Institute for Wood Technology Research, Publ. No. 0210034, Stockholm, 2002.

SP Technical Research Institute of Sweden develops and transfers technology for improving competitiveness and quality in industry, and for safety, conservation of resources and good environment in society as a whole. With Sweden's widest and most sophisticated range of equipment and expertise for technical investigation, measurement, testing and certification, we perform research and development in close liaison with universities, institutes of technology and international partners.

SP is a EU-notified body and accredited test laboratory. Our headquarters are in Borås, in the west part of Sweden.



SP consists of eight technology units and six subsidiary companies. Three of the companies, CBI, Glafo and JTI are each 60 % owned by SP and 40 % by their respective industries.



SP Technical Research Institute of Sweden

SP Trätekt
 Box 5609, SE-114 86 STOCKHOLM
 Telephone: +46 10 516 50 00, Telefax: +46 8 411 83 35
 E-mail: info@sp.se. Internet: www.sp.se

SP Report 2010:28
 ISBN 978-91-86319-66-3
 ISSN 0284-5172